AIR TECHNICAL INTELLIGENCE TRANSLATION

TITLE (UNCLASSIFIED)

THE TECHNOLOGY OF FORGING AND STAMPING FREE FORGING AND VOLUME STAMPING

BY

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Chapter II

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CHAPTER II

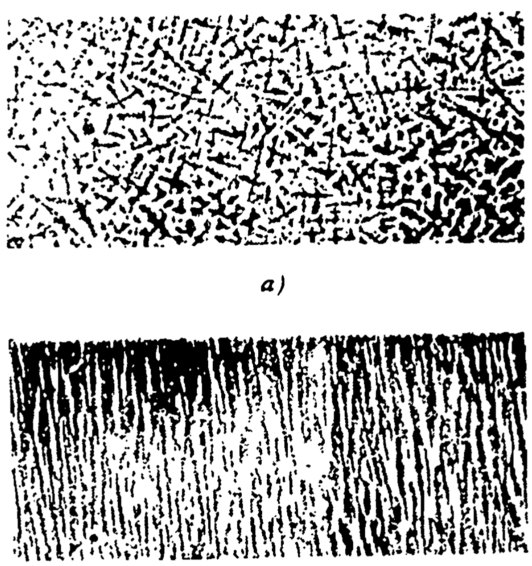
THE TECHNOLOGY OF FORGING AND STAMPING

FREE FORGING AND VOLUME STAMPING

The Quality of Forged and Stamped Products

The Effect of Forging upon the Macrostructure

Hot mechanical treatment (forging or rolling) of a cast ingot will deform and change its original structure (Fig.1a) by drawing out its crystallites in the direction of the flow of the metal. The result will be the formation of a so-called fibrous macrostructure (Fig.1b); first in its central zone, and later, with the increase in the degree of forging*, it will be formed in its peripheral zone.



a) b)

Fig.1 - The Macrostructure of Steel

a) Casting; b) Forging

In the central zone, the fibrous structure is formed when the degree of forging has a value of 2 - 3. At such rate of forging, the column-like dend-

* The degree of forging is the ratio of the area of the original cross section of a cast ingot to the area of the cross section of the forging made from it.

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rites in the peripheral zone will undergo little change in their original direction.

When the degree of forging is raised to 4 - 6, the deformed dendrites of the peripheral zone are still present and they are not in the direction of the flow of the metal. Only when the degree of forging reaches the value of 10 and higher, forged steel will acquire a fibrous macrostructure along its entire cross section (Bibl.15).

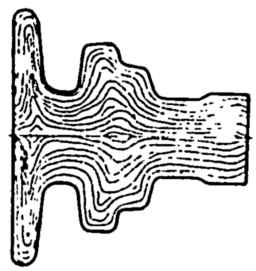

Fig.2

Therefore, when evaluating the mechanical properties of a forging, consideration should be given to the direction, i.e., along and across the fibers of the sample under test.

A fibrous macrostructure of forged (rolled) steel has a fairly stable formation. It cannot be destroyed by heat treatment and the pressure following the heat treatment may possibly only change the straight-line direction of the fibers to curves, (Fig.2).

The Effects of Forging on the Mechanical Properties (Bibl.15)

Hot forging will practically have no residual effect upon such properties as, strength σ_{ar}; fluidity σ_T and proportionality σ_{pts}. It means, the above properties will remain the same for samples subjected to the same heat treatment resulting in the same microstructure, although forged at different degrees of forging.

Forging of a cast ingot will produce a considerable residual effect on such properties as impact viscosity a_n, cross sectional shrinkage (narrowing) ψ, elongation δ and endurance σ_{-1}.

The following should be noted concerning the above properties: increasing the degree of forging to 10 will notably improve these properties in longitudinal (along the fibers) samples and this improvement will remain stable. On the other hand, as a rule, the a_n, δ, ψ, and σ_{-1} in transversal (across the fibers) samples

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by the grade of the steel and the size of the piece (see later in text).

Hot forging of a steel which, as a casting, contains in its microstructure a cementite net or large carbide grains, will favorably affect the quality of the finished product by destroying the net and by pulverizing the carbides.

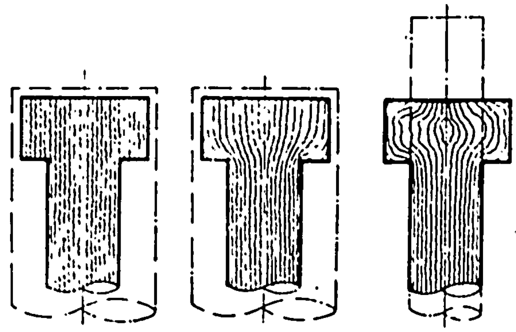

Fig.3

Cold forging will physically solidify (harden) the metal; heat treatment will relieve it (see Chapter XI).

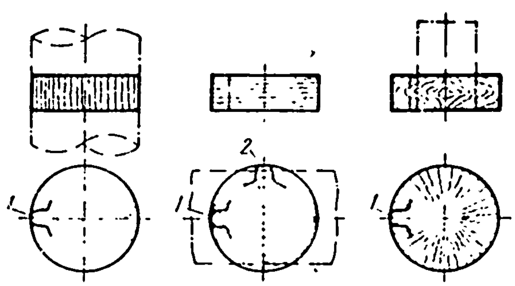

Fig.4

<u>Preparatory Methods and Their Effect on the Finished Product</u>

To obtain the best mechanical properties, the following conditions are to be maintained: 1) a degree of forging best suited for the piece to be forged (see earlier in text); 2) the direction of the fibers should coincide with the direction of the maximum normal stresses to which the finished product will be subjected in performing its duty. If this is impossible adjusting the mandrill, upsetting, or any other means should be used to diminish the discrepency in the mechanical properties along and across the fibers; 3) the direction of the fibers should be coordinated with the contours of the piece, the fibers should not cross each other; 4) the axial zone of the ingot should not be displaced on the surface of the forging; 5) thermomechanical conditions best for

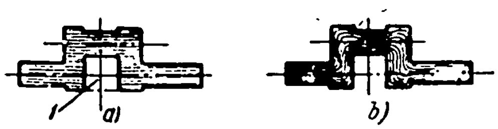

Fig.5

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the forging should be observed (see later in text).

The above requirements may not be strictly adhered to in cases where best mechanical properties are not essential and cost and productivity are more important.

The field, dealing with the effect of technological processes in forging on the quality of the finished product, was tackled and broadly covered by Prof.K.F. K.F.Grachev.

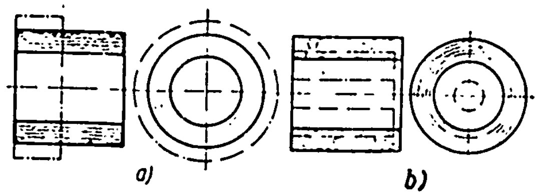

Fig.6

Examples: 1. Figure 3a shows a bolt cut from a rod. The macrostructure of its head is unsatisfactory - the normal stresses are directed across the fibers. Also, the stem of the bolt is formed from the central zone of the rolled rod, a zone having qualities of a lower grade. The bolt in Fig.3b is made by having its stem drawn out. The direction of its fibers is more favorable. Making the bolt (Fig.3c) so that its head is pressed down from a rod of the same diameter as its stem, produces the most favorable direction of its fibers.

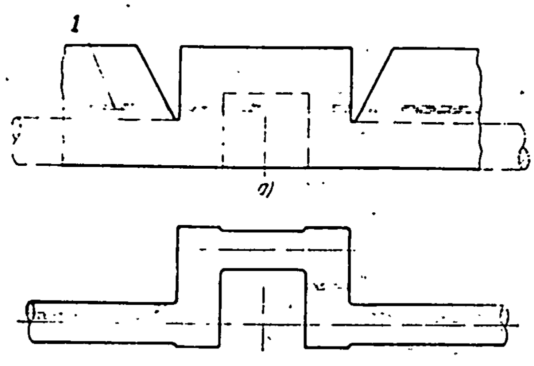

Fig.7

1) Axial zone of stock

Example 2. The gear, shown in Fig.4a is cut out from a rod. The normal stresses in the teeth (1) will be directed unfavorably - across the fibers. In a gear, stamped out from a strip (Fig.4b), the direction of the fibers in relation to the direction of the normal stresses will vary for each tooth. Tooth (1) operates along the fibers, which is correct; while tooth (2) operates across the fibers, which is incorrect. A gear made by the upset method (Fig.4c) will have most favorable directions for its fibers.

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Example 3. The crankshaft in Fig.5a is forged without its wrist; the wrist and the webs are formed by cutting out part I. The result is: the fibers are cut and the webs operate across the fibers. By having a crankshaft made by bending (Fig.5b) the direction of the fibers will correspond to the direction of the normal stresses.

Example 4. When a ring, subject to internal pressures, is made by the method of drawing out with a mandril, (Fig.6a), its fibers will be parallel to the axis of the ring, i.e., perpendicular to the directions of the maximum stresses operating tangentially. On the other hand, the same ring, but with the use of a tube expander during the forging (Fig.6b), will have fibers with a direction corresponding to the operational conditions of the ring.

Example 5. In a crankshaft forged from a plate after the split-cutting of the crankthrow (Fig.7a) and by drawing out the ends, the axial zone will pass through the middle of the webs, but in the crankpin sections of the shaft the axial zone will be displaced in relation to their axis and will appear partially on the surface. This displacement will not be produced in a shaft forged by bending.

TECHNOLOGICAL FUNDAMENTALS IN DESIGNING FORGED AND STAMPED PRODUCTS

General Information

The technological considerations required when designing products to be produced by free forging and hot stamping differ sharply.

The choice between free forging and stamping should be based upon many factors, among which are: the possibility of applying (technically) one method or another, and the advantages of one method over another with due consideration to the quality of the product and the configuration desired.

For instance, free forging may be used in forging pieces of any weight, from the smallest to the largest, for example 200 t. The weight limit for stamping is 1-2t, with the bulk of stampings weighing up to 100 kg. Free forging is good only for pieces with plain configurations, or having excessive parts to be removed

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mechanically in order to simplify the configuration. With stamping, a complicated configuration is feasible. As far as quality and precise surface is concerned, these are low for forging and high for stamping. When machining the piece, more will be taken off when the piece is a forging and less, when it is a stamping. The output by forging is several times less than by stamping.

As a rule, forging of single pieces, or of a few pieces, is more advantageous than stamping. On the other hand, for mass production, stamping has by far greater advantages.

For the average run in quantity, the selection is based upon the final cost of the finished product, thus, in many cases, despite the higher cost of operation, the use of less material and less machining thereafter, make stamping cheaper. Even when the quantity amounts to a few dozens, stamping may prove to be cheaper than forging.

Technological Considerations in Designing Products Fabricated by Free Forging

The design of the stock to be fabricated by free forging should also be coordinated with the technologist. This, to insure maximum mechanical properties, minimum wastage and ease of operation not only in the process of forging but also in the finishing operations thereafter.

The most desirable forms for such products should be simple, symmetrical, straight and smooth and should be bound by plane or cylindrical surfaces. The more the configuration of a forging is complicated, the higher the cost of its fabrication.

Certain portions of a forging may prove to be unforgeable by the method of free forging. In cases of this kind, surplus material must be added to the stock in order to simplify the configuration, with the subsequent removal of the surplus material mechanically, or by torch.

For example, the forging shown in Fig.8 cannot be produced by free forging

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without the use of surplus material. The configuration shown in Fig.9 has to be the basis for the design.

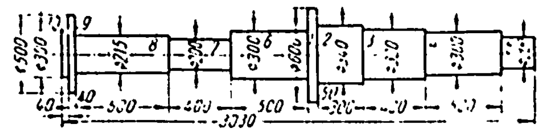

Fig.8

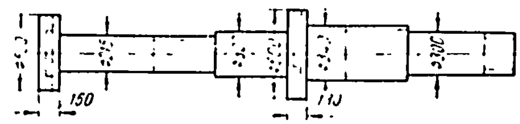

Fig.9

Cones (Fig.10a) and tapered shapes (Fig.10b), especially when sloping only slightly, should be avoided.

Consideration should be given to the difficulty of producing by free forging

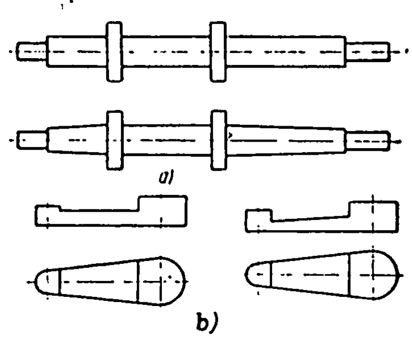

Fig.10

a) Correct; b) Undesirable

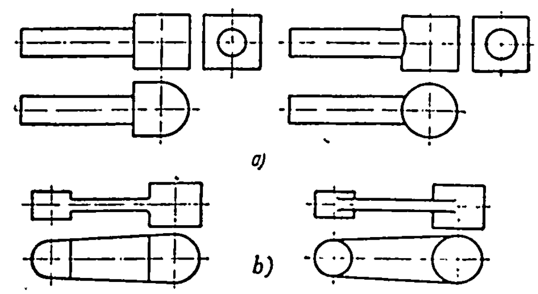

Fig.11

a) Correct; b) Undesirable

portions formed by the intersection of cylindrical surfaces (Fig.11a), or formed by the intersection of cylindrical with prismatic surfaces (Fig.11b).

In the handbook of small pieces, one-sided projections (Fig.10b) are more desirable than two-sided (Fig.11b) projections.

Ribs are to be avoided. In most cases, ribs cannot be made by the method of free forging and the adding of surplus material becomes necessary. So-called "ribs of rigidity" in forgings are not permissible (Fig.12).

Also to be avoided are "teats", plate-shape and other projections on the main

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body of the forging (Fig.13a), as well as projections inside fork-shaped configurations (Fig.13b).

Wherever the difference in cross-sectional areas is great, or where the configuration is complicated, it becomes necessary to combine several pieces of a simpler design, or weld several pieces together (Fig.14).

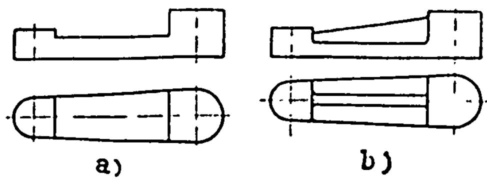


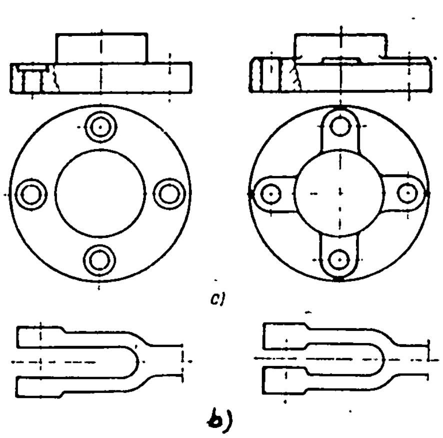
Fig.12

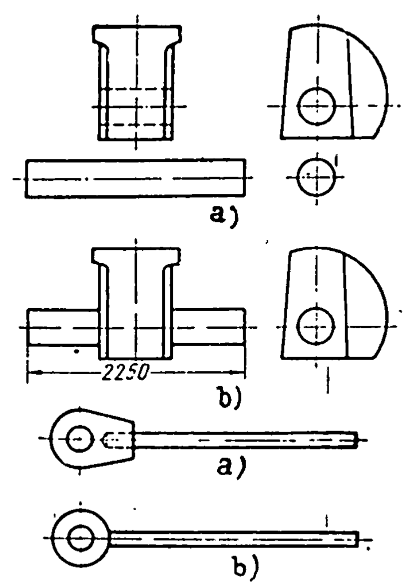
a) Correct; b) Wrong

Another thing to consider is the possibility of getting a forging with a proper direction of the fibers.

Technological Considerations in Designing Stamped Products

General Information: The geometrical shape of the piece should be such as to make its removal from the form easy. The stamping dies consist of two parts (the





Figs.13 and 14

a) Correct; b) Wrong

upper and lower halves). As a rule, they are open. Before the upper and lower dies touch each other, the metal will flow out beyond the dies, thereby forming a ring-shaped burr around the line of separation of the dies (Fig.15).

Stamping presses (crank type for hot stamping, screw-friction type, or hydraulic type) have dies usually consisting of two parts: the dies are either open-type, as in hammer presses, or closed type where a burr can be formed only at the end of the operation. The appearance of a burr is due to a clearance being present between the lower and, the entering into it, upper die. The lower die is known as matrix, counter die, die pot; the upper - as plunger, punching die, etc. (Fig.16).

For complicated configurations, the matrixes are compounded from two or more parts (Fig.17).

In a horizontal stamping press, the die consists of three parts: two matrixes (stationary and movable) and a plunger. The separation of the lower and upper dies is in two mutually perpendicular directions.

If the stock is not to be stamped all around, the problem of the separation of the dies should be worked out by the designer, as it may involve such features as slope of the walls, radius of roundness, etc.

In Table 1 are instructions dealing with design of forgings to be stamped

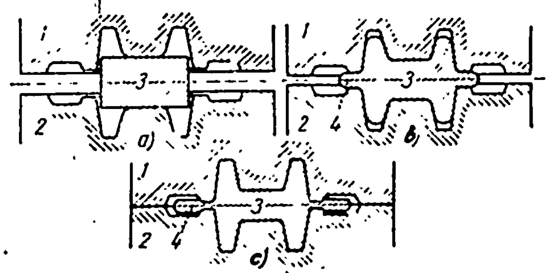


Fig.15 - Formation of a Burr: a - Beginning of stamping; b - Intermediate phase; burr begins to form; c - End of stamping; 1 - Upper die; 2 - Lower die; 3 - Stock; 4 - Burr

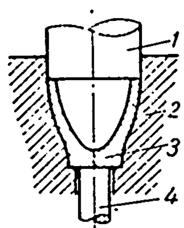


Fig.16 - Closed Type Stamping Die
1 - Plunger; 2 - Matrix; 3 - Stock; 4 - Ejector

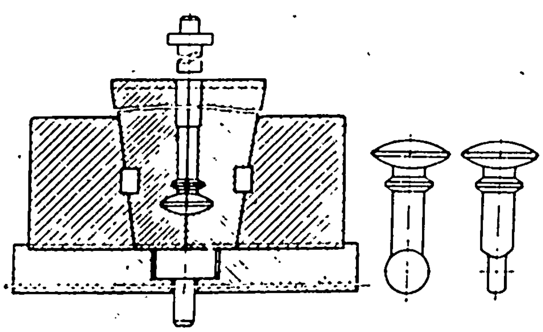


Fig.17 - Die with Movable Matrix

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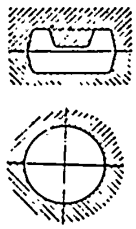
Table 1

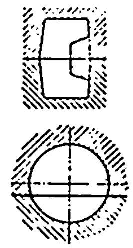
Selection of Correct Separation Surfaces (Bibl.8,36,7,1)

1. Make easy removal of the forging from the dies possible. Deep impressions in the body of the stamping can be obtained only in the direction of impact. All of the stamping's horizontal cross-sectional dimensions, above or below the parting line, should be less than the cross-sectional dimension of this line.

Correct

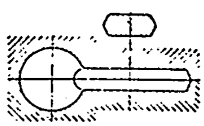


Wrong

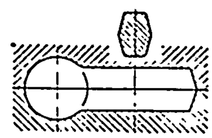


2. The separation should be effected in the plane of the two greatest dimensions of the product, i.e., so as to make the recesses in the die have the least depth and greatest width (to help in filling up the recesses)

Desirable



Undesirable

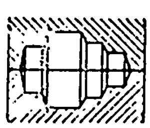


Remarks: In some cases, separation is possible without strict adherence to the requirements, e.g.,

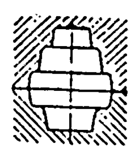
a) if it saves metal, simplifies making of the stamping and cutting dies, or permits use of fewer preliminary passes in the die.

b) if some surface (not to be stamped) should be flat and without a stamping slope.

In line with requirement 2



Is allowed as an exception



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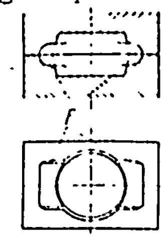
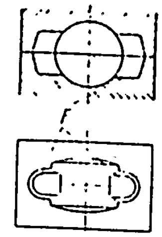
In line with requirement 2 but surface F has stamping slope

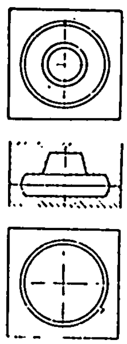


Is not in line with requirement 2



3. The separation of the dies should be so designed that the recesses in the upper and lower dies should have the same contour (it will make it easier to detect if any of the dies move)

Correct



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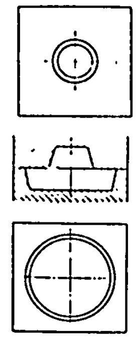
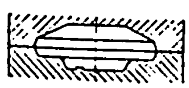


4. The separation should be so designed that close contact with the surface is made only by the vertical walls (having a stamping slope), but not by sloping walls (it makes it easier to detect movements of the die)

Correct



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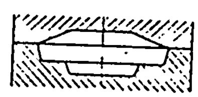
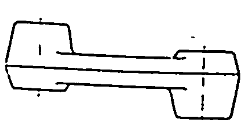


5. Inasmuch as possible, the design should be such, that the separation takes place in a plane surface, and complicated surfaces are to be avoided (easier to make the die)

Correct



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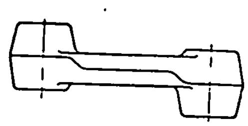

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by open-type dies (forming ring-shaped burrs) of hammers and presses. Other instructions in Table 1, deal with the selection of the separation of the die surface.

The side surfaces of the stock should be sloping (stamping slope) in the vertical direction, i.e., in the direction of the impact. This will insure an easy removal of the stamping from the dies. A true verticality of the walls may be secured by mechanical treatment of the piece after.

Normal slope values for outer walls (that move away from the walls of the die) and for inner walls (which, during the cooling , hug the protuberances in the recesses of the die) are shown in Table 2.

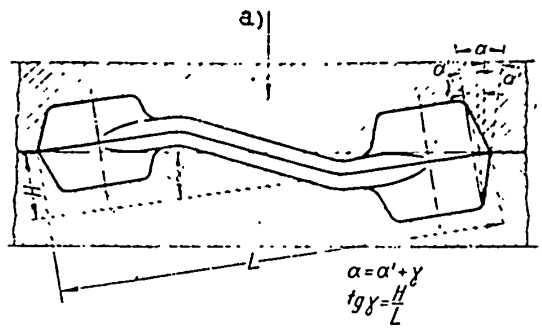


Fig.18 - Method of Counterbalancing the Shearing Forces

'α- Normal stamping slope; α - Increased stamping slope

a) Direction of the impact by the hammer

For certain pieces, whose axis is bent, larger slopes are desirable, as this will allow the recessed portion of a die to have a location favoring the counterbalancing the shearing forces, which arise during the stamping operation (see Fig.18).

With angles $\gamma > 7^{\circ}$, the above method (see Fig.18) will greatly distort the stamping. Therefore γ should not exceed 7°.

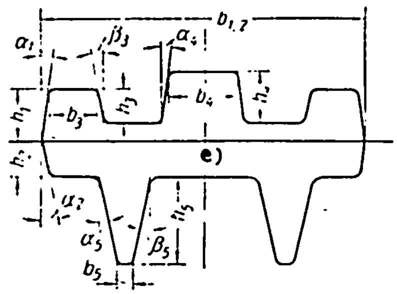
All surface ends should be rounded and sharp angles to be avoided.

Surfaces to be joined should be rounded, using as large a radius as practical. The purpose is to avoid the necessity of having to use a greater than normal surplus of material over the entire surface, which would be necessary to insure a correct

Table 2

Stamping Slopes for Steel Stampings

(Bibl.8, 36, 1)



h/b	c) α	c) β	d) α	d) β
b) 1	5	7	2	3
1—3	7	10	3	5
3—4,5	10	12	5	7
4,5—6,5	12	15	7	10
a) 6,5	15	15	10	12

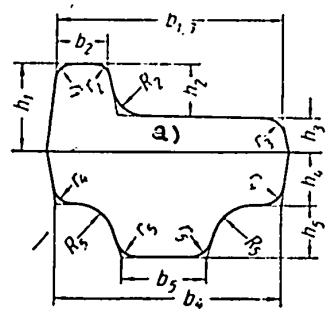
f)

a) Over; b) Up to; c) Stamping without an ejector by hammer and mechanical presses; d) Stamping with an ejector by mechanical presses; e) Line of separation; f) Legend: β –Slope of inner walls; α –Slope of outer walls

Table 3

Radii for Rounded Ends of Surfaces

(Bibl.36, 1)



h in mm	r in mm at h/b ⩽ 2	r 2 — 4	r > 4	R in mm at h/b ⩽ 2	R 2 — 4	R > 4
b) 15	1,5	1,5	2,0	4,0	5,0	8,0
15—25	1,5	2,0	2,5	4,0	6,0	8,0
25—35	2,0	2,5	3,0	5,0	8,0	10,0
35—45	2,5	3,0	4,0	6,0	10,0	15,0
45—60	3,0	4,0	5,0	8,0	12,5	20,0
60 80	4,0	5,0	6,0	10,0	15,0	25,0
80—100	5,0	6,0	8,0	12,5	20,0	35,0
100—130	6,0	8,0	10,0	15,0	25,0	40,0
130 170	8,0	10,0	12,5	20,0	30,0	45,0

c)

a) Line of separation; b) Up to; c) Remarks: Radii R of the internal (entering) angles should be greater than radii r of the external angles (emerging), thereby avoiding spoilage (of clamps) and helping the dies to remain firmly in place

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angle (Fig.19).

Besides this, the design of a piece to be stamped in open-type dies, should be in conformity with the instructions given in Table 4.

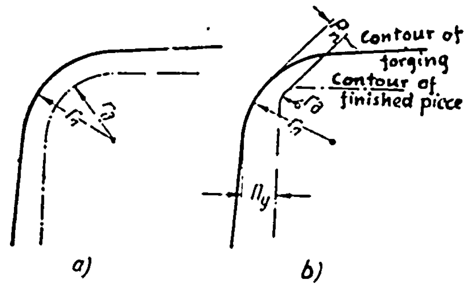


Fig.19 – The Relation between the Amount of Added Material to the Radius of Roundness: a – Optimum relationship: $r_d \geqslant r_p - p_n$; b – Worst relationship: $r_d < r_p - p_n$; where, r_d is the radius of roundness of the finished piece; r_p is the radius of roundness of the forging; P_n is the normal amount of material to be added; P_y is the increased amount to be added

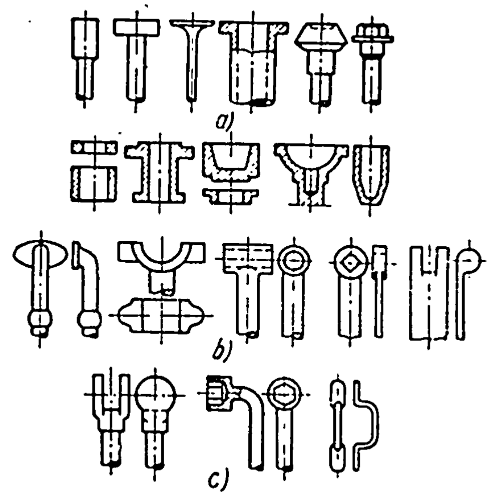


Fig.20

Instructions for Designing Pieces to be Stamped in Horizontal Forging Machines

Pieces with a great variety of shapes can be stamped in horizontal forging machines (Fig. 20a, b, c). For best results, however, the stamping of pieces having a regular form (Fig. 20a), or rotating bodies with projections and cavities should be performed in a horizontal forging press. Such pieces can be fabricated by a horizontal forging press with more advantages than the hammer or press. In designing pieces to be fabricated in horizontal machines – follow instructions given in Table 5.

Table 4

Instructions for Designing Pieces to be Forged by Hammers with Open-Type Dies

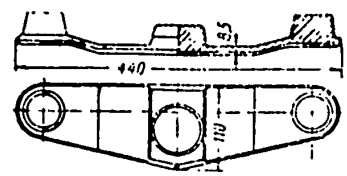
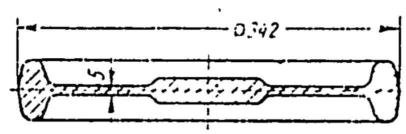
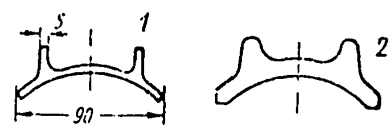
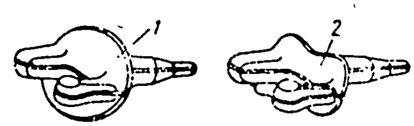
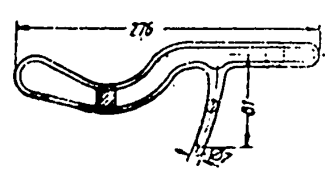
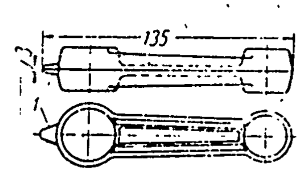
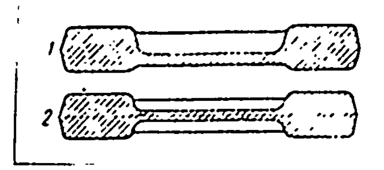
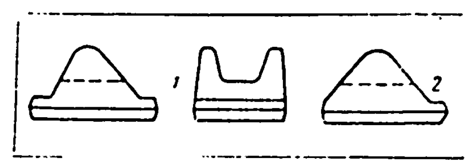
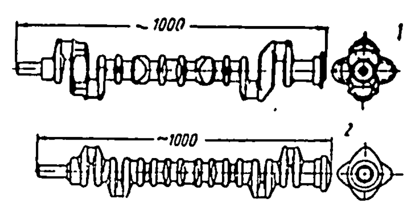
1. Design with the object to obtain a minimum difference in cross-sectional areas of different portions spread along the length of the piece; avoid thin walls, high ribs, flanges, projections, teats, long branches, and thin influxes in contact with the plane of separation (ease of operation, less spoilage and saving of material).	
a) Sharp difference in cross-sectional areas and small thickness of the shelf will hamper the work, will increase the wastage and will not fill the figure.	
b) A thin disc will cause a low firmness of the dies, due to rapid cooling and high deformation resistance. Repeated heatings become necessary to prevent the stamping being unfinished. Will increase the amount of rejects.	
c) Piece 1, due to presence of thin and tall ribs, cannot be obtained by stamping without a subsequent mechanical treatment. The raw piece assumes shape 2.	
d) In shape 1, the flange has a large diameter which hampers the stamping. Designing according to shape 2 will increase the ease of operation 1½ times.	
e) A long and thin branch brings a large wastage of metal (75% of the weight of the forging) and an increase in rejects due to figure being unfilled.	
f) The thin influx 1, in contact with the plane of separation, is subject to breakage, to being torn-off and to cleaving with the cold cutting-off the burrs; also to being dragged-in inside the matrix with the hot cutting of the burrs.	

Table 4 (cont'd)

<table>
<tr><td colspan="2">2. Try to design with the object to obtain symmetrical forms in the plane of separation and symmetrical slopes for the projecting walls (simplifies the making of the dies, eases the stamping operation and lowers the amount of rejects).</td></tr>
<tr><td>a) Shape 2 is desirable; the hollowness is the same in the upper and lower dies; it can be turned over during the operation to remove the scale and for better formation of the shape. All this is not obtainable with shape 1, which is undesirable.</td><td></td></tr>
<tr><td>b) The walls in shape 1 have different slopes in relation to the plane of separation. During the stamping it will cause the appearance of stresses tending to displace one die from another. This defect is absent in shape 2.</td><td></td></tr>
<tr><td colspan="2">3. Try to design the configuration with the object of avoiding additional operations such as twisting and bending. The design should strive to reduce the number of stage operations (ease of operation).</td></tr>
<tr><td>a) Crankshaft (1) having eight throws cannot be so stamped, as to have its throws at an angle of 90°. This is due to the poor configuration of the webs which prevents the setup of the separation. The throws are stamped in one plane and, by a special machine, are twisted thereafter by an additional operation. The eight-throw shaft (2), with a similar elliptical form of the webs, makes the separation of the dies possible and allows the stamping (in one operation) of the shaft with the webs at an angle of 90° without twisting.</td><td></td></tr>
</table>

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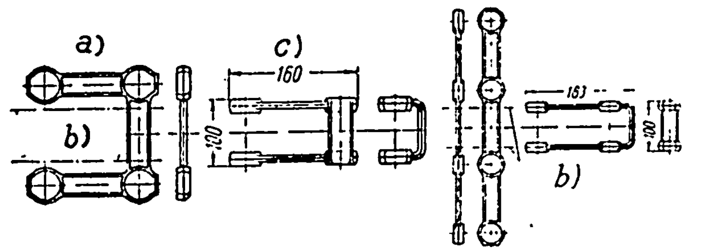
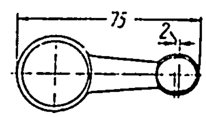
b) The piece shown at left end is stamped with its form developed, the bending is done after. The piece shown at the right end is stamped also in developed form. But in this case, bending passes are not required, therefore, the stamping has a simple configuration. In the first case, the excess of metal is 87% of the weight of the stamping; in the second case it is 33%.



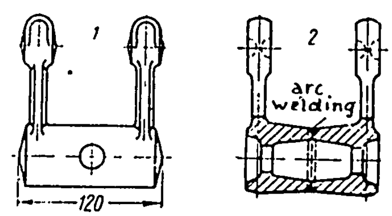
a) After stamping; b) Lines of bending to follow; c) After bending

4. When the minimum thickness of the walls after the drilling of holes is to be guaranteed, the lugs (teats) should be made oval in shape and in the direction of a possible displacement.



5. In each separate case, determine the advantage of fabricating the product from two or more parts to be welded together after the stamping, and vice versa, the advantage of first welding or fastening by any other means, several pieces to be stamped as one piece.

a) Piece (1), as a single piece, is too complicated to be stamped, requiring excess material equal to 65% of the weight of the stamping. The same piece (2) when welded, is simpler to be stamped in parts (there are no branching) with an excess of material reduced to 40%. Markings of the holes is possible.



b) The stamping of a one-piece connecting rod is not easy; it is hard to obtain a clean cut of the burrs in the fork of the rod; also an oval shape for the stem, and the excess material is 93%. These defects can be eliminated by welding with a reduction of excess material to 48%.

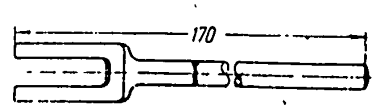


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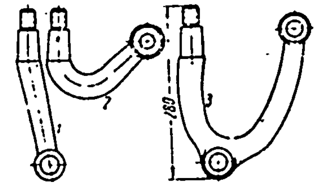
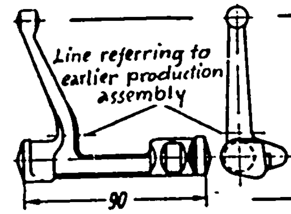
Table 4 (cont'd)

c) Two levers (1) and (2), to be fastened to a third piece, can be designed as one piece (3). Although the stamping will be more complicated, this method, by economizing about 1 kg of metal, is more advantageous	
d) The stamping of the lever as one piece is more economical than stamping two parts to be welded together after.	

6. Always look for the possibility and advantages of cutting by coining (calibrating) as a substitute for the mechanical treatment of the surfaces after the stamping is finished.

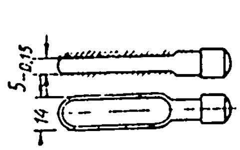
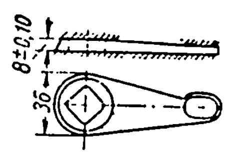
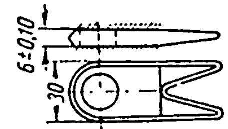
		
a) Reduction of Working Time by Coining: 25.8 min	b) Reduction of Working Time by Coining: 19.4 min	c) Reduction of Working Time by Coining: 10.0 min

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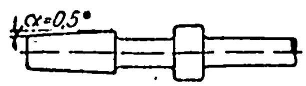
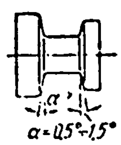
Table 5

Instructions for Designing Products to be Stamped in a Horizontal Forging Machine (Bibl.4, 5, 8, 1)

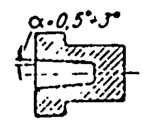
1. The following stamping slopes must be used as a minimum: a) Not less than 0.5° on each side for cylindrical portions which are to be shaped in the recess of the upper die, if their length is more than 0.5 of their diameter.



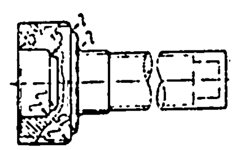
b) Not less than 0.5-1.5° on a side for shoulders which are to be formed in the deep recesses of the matrix



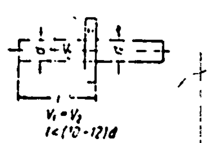
c) For walls of deep impressions punched by the upper die (plunger) the limit is 0.5 - 3°



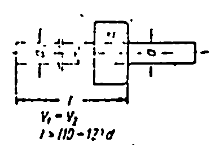
2. Transitions should be made with radii of not less than 1.5 - 2.0 mm



3. When forming a piece having the shape of a rod with a flange (by pressing down) on the end or in the middle, the volume of the flange V_1 should not exceed the rod volume V_2 of a given diameter by a length $l = (10 \div 12)d$.



a) Correct



b) Wrong

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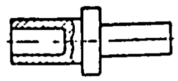
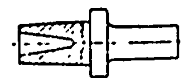
Table 5 (cont'd)

4. Avoid narrowing of the longitudinal cross section of the forging which constricts the fluidity of the metal when meeting the plunger.

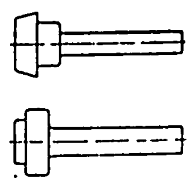


a) Correct

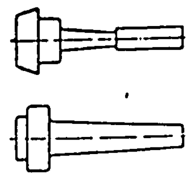


b) Wrong

5. Avoid conical shapes for the removable parts and tail ends.

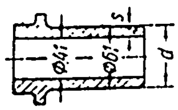


a) Correct

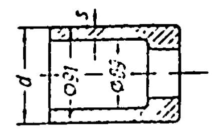


b) Wrong

6. Wall thickness of pieces with deep openings (open or closed) should not be less than 0.15 times the external diameter of the piece.



a) Correct



b) Wrong

Thermal Conditions for Forging and Hot Stamping

Forging and hot stamping should be effected at temperatures which will insure the recrystallization of the metal during the process. A complete recrystallization usually takes place at temperatures above $(0.65 - 0.75)T_{pl}$, where T_{pl} is the absolute temperature at beginning of the melting (Bibl.10). Forging and stamping accompanied

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only by a partial recrystallization, in most cases, will bring a nonuniform structure, which works against the process of deformation.

Complete recrystallization depends not only upon the temperature, but also upon the rate of deformation. Increasing the rate of deformation hampers the recrystallization.

The maximum permissible warming temperature and the optimum temperature at the end of forging are set for different alloys differently.

Heating to a higher temperature than necessary will be responsible for a coarse-grain structure of the forging. Also, heating to a temperature near the melting point brings an "overburn" which is responsible for the complete loss of plasticity and the product becomes an irrecoverable loss.

Continuing the forging at temperatures below the optimum for the end stage of forging will bring hardening of soft metal and cracks in a hard metal. Ending the forging at temperatures above the optimum will make the grains grow.

Temperature intervals for forging and stamping are shown in Table 6.

The process of heating the raw piece is realized in forges, furnaces and by an electric current.

The heating should provide: a) a temperature required by the raw piece at a uniform rate of warming-up, along the length and the cross section of the piece; b) the metal should remain as a single solid piece; c) minimum decarbonization of surface layer and minimum loss of metal in scale formation.

The rate of warming-up the raw piece to a given temperature depends upon the furnace temperature, method of placing the raw piece at the bottom of the furnace (singly, in close contact, on a shelf, etc.), the size and configuration of the piece and upon the physical properties of the metal (heat conductivity $a = \frac{\lambda}{c\gamma}$, where λ is the heat conductivity, c is the heat capacity and γ is the specific weight.

The basic factor, other conditions being equal, controlling the rate of warming-

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up the metal in the furnace is the temperature of the effective space of the furnace. However, the higher the difference between the temperatures of the effective space

Table 6

Temperature Intervals for Forging and Hot Stamping (Bibl.2, 15)

Alloy by Chemical Analysis in %, or by Trade Mark	Temperature in 0°C	
	Beginning of Melting	End of Melting
Carbon Steel		
Carbon up to 0.3	1200-1150	800-850
" " 0.3-0.5	1150-1100	800-850
" " 0.5-0.9	1100-1050	800-850
" " 0.9-1.5	1050-1000	800-850
Alloyed steel		
Low alloyed steel	1100	825-850
Medium alloyed steel	1100-1150	850-875
High alloy content	1150	875-900
Aluminum alloys		
D1	470	350
AK2, AK4, AK5, AK6	490	380
AK8	470	400
Magnesium alloys		
MA1, MA2	430	350
MA3	400	300
MA5	370	300
Copper alloys		
Br. AZh 9-4; Br. AZh Mts 10-3-1.5; Br. AZhN 10-4-4	850	700
LS 59	750	600
Nickel alloys		
Monel	1180	1000 (870*)
Nickel	1250	1000 (870*)

* Forging by means of light impacts

of the furnace and the surface of the raw piece, the higher will be the temperature gradient across the raw piece. This gradient increases with the decrease in the conductivity of the metal and with the increase of the cross-sectional area of the raw piece.

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The temperature gradient is the source of thermal stresses. These stresses, especially in the presence of residual stresses in a cold raw piece, in the first period of heating (i.e., before passing through the interval of structural conversion $A_{c1} - A_{c3}$) can bring the disruption of the solid state of the metal and the appearance of macro and micro cracks.

In small forgings made of structural steel with a diameter of 100 to 150 mm and heated rapidly, the above-mentioned effects are not observed. Such forgings may be placed in a furnace with an effective space temperature higher by 100 - 150°C than the required end temperature.

Cold alloyed steel pieces of low heat conductivity, also large cold pieces and castings of all trade marks, for such metals, only a permissible rate of heating should be maintained. The furnace temperature, at the time of placing the raw pieces in the furnace, should be considerably lower than the temperature during the forging: for carbon-steel castings weighing 1 - 2 t ~ 900°C, for steels with high alloy content ~ 500 - 600°C, for large castings of all trade marks, weighing ~ 60 m and over ~ 200°C.

Further heating is accomplished by gradual raising the furnace temperature or by shifting the raw pieces to zones of higher temperatures (methodical furnaces); the first period of heating should amount to 60-70% of the entire duration of the heating.

The second heating period, i.e., from the critical to the temperature of the forging process, should be carried out with an high rate, to avoid intensive growth of the grains, decarbonization of the surface and formation of scale.

The duration of the heating of small steel pieces is shown in Table 7. The duration of the heating of castings, and of pieces the dimensions of which are not shown in the table, can be found by the equation worked out by Dobroktov:

$$t = kD\sqrt{D}$$

where t is the full time duration of the heating per hour; D is the diameter of the

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piece in m; k is a coefficient equal to ~ 12.5 for carbon steel and for steel with low alloy content, and is equal to ~ 25 for steel of high alloy content (Bibl.18).

Table 7

The Rate of Heating of Structural Carbon Steel from 15 to 1200°C (in min)

(The Effective Space Temperature of the Furnace is 1300°C)

Diameter d, or Side of Square in mm	Shape of the Raw Piece — Round — Methods of Placing of Raw Pieces in the Furnace: Singly	Round: At a Distance Equal to d	Round: At a Distance Equal to 0.5 d	Round: In Close Contact	Square: Singly	Square: At a Distance Equal to d	Square: At a Distance Equal to 0.5 d	Square: In Close Contact	
10	2.0	2.0	3.0	4.0	2.5	3.5	4.5	8.0	
20	3.0	3.5	5.0	7.0	4.5	6.0	8.0	13.0	
30	5.0	5.5	7.0	10.0	6.0	8.5	11.0	19.0	
40	6.5	8.0	9.5	13.0	8.0	11.0	14.0	25.0	
50	8.0	9.5	12.0	16.0	10.5	11.5	17.5	32.0	
60	9.5	11.5	14.0	19.5	12.5	17.5	21.0	38.0	
70	11.0	13.5	16.5	22.5	14.5	20.5	25.0	44.0	
80	13.0	15.5	19.5	26.0	17.0	23.5	28.5	52.0	
90	15.0	18.0	23.5	31.0	19.5	27.0	33.5	62.0	
100	18.0	21.5	27.0	36.0	23.0	32.5	40.0	72.0	

Remarks:
1. The time-rate of heating short pieces, as compared with values shown in the Table is: 0.98 when the length is $l \leq 2d$; 0.92 with $l \leq 1.5d$; and 0.71 when $l = d$.
2. For instrument carbon steel with a medium alloy content, the time-rate of heating is increased by 25 - 50%. For structural and instrument steels with a high alloy content, the time-rate of heating is increased from 50 to 100%

When hot ingots are placed in the furnace, the values of k as shown above, may be cut in two.

Heating by electricity (induction method and contact) offers substantial ad-

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vantages over heating in a furnace. These advantages are: a) high rate of heating; b) easy control of the temperature; c) absence of scaling; d) possibility for automatization which allows the adjustment of the time for placing and removal of the pieces into and from the furnace; e) possibility of raising the initial forging temperature without of overheating; f) makes for better working conditions; g) ever present readiness to start operations.

For heating by the induction method, currents of any frequency may be used (usually in industry, or high frequency). The cost of electricity can be reduced to a minimum by coordinating the frequency with the diameter of the piece to be heated.

The following frequencies are recommended: 8000 cycles for pieces having a diameter of 20-45 mm; 2500 cycles for pieces with 30-80 mm in diameter; 1000 cycles for pieces with 50-140 mm in diameter; 50 cycles when the diameter of the piece is 130 mm and longer.

For heating of a large number of pieces, or in mass-production, it is best to use a metallic type induction heater and to heat several pieces in one time. The pieces to be laid out one after another along the axis of the induction coil. The number of pieces n to be placed at one time in the heater is:

$$n = \frac{T}{t}$$

where T is the heating time in minutes and t is the desirable rate of removing heated pieces from the furnace. If D_i is the diameter of the inductor and D_z is the diameter of the piece, then with the increase in the ratio $\frac{D_i}{D_z}$ the heater efficiency falls of sharply. It is therefore desirable to maintain the following ratios. For pieces with a diameter up to 50 mm the ratio should be $\frac{D_i}{D_z} \leq 1.6 - 1.8$ and $\frac{D_i}{D_z} \leq 1.2 - 1.4$ for pieces whose diameter is over 50 mm (Bibl.11). Information on duration of heating and the necessary power is given in Table 8.

Electric heating by the contact method (due to the heat of ohmic resistance

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Table 8

Time Necessary for Induction Heater to Heat Raw Pieces to

Final Forging Temperature

Diameter of the Pieces in mm	Assumed Consumption of Electrical energy in kw per 1 kg	Technologically Minimum Permissible Time of Induction Heating, in min	Length of the Pieces in mm								
			80	100	125	160	200	250	320	400	500
			Heating Time in min per 1 Piece								
Frequency 8000 cycles, Power of Installation 100 kw											
20	0.5	0.03	0.07	0.08	0.1	0.13	0.16	0.2	-	-	-
30	0.49	0.1	0.14	0.18	0.22	0.29	0.36	0.45	0.58	-	-
40	0.48	0.2	0.25	0.31	0.39	0.45	0.62	0.78	1	1.25	-
50	0.46	0.5	-	0.47	0.58	0.75	0.94	1.17	1.5	1.87	2.34
Frequency 1000 - 2500 cycles, Power of Installation 100 kw											
60	0.49	1	-	-	-	1.04	1.3	1.47	2.09	2.58	3.24
80	0.47	2	-	-	-	1.78	2.25	2.8	3.55	4.5	5.6
100	0.45	3	-	-	-	2.65	3.35	4.15	5.3	6.64	8.3
120	0.43	4	-	-	-	3.65	4.6	5.7	7.3	9.2	-
140	0.4	5.8	-	-	-	-	5.8	7.3	9.3	-	-
Usual Industrial Frequency, Power of Installation 200 kw											
160	0.48	6.2	-	-	-	-	-	-	7.3	9.1	11.4
180	0.46	6.6	-	-	-	-	-	6.9	8.8	11	13.8
200	0.44	7	-	-	-	-	6.5	8.2	10.3	13	-
250	0.41	9	-	-	-	-	9.5	11.8	15.2	-	-
300	0.38	11	-	-	-	10.1	12.6	15.8	-	-	-

Remarks:

1. The values shown in the Table should be multiplied by 1.15 when heating alloyed steels; by 1.2 - 1.3 for nonmagnetic steels; and by 1.25 for pieces with a square shape.
2. If the power of the installation is increased or decreased, the time shown in the Table is also increased or decreased proportionally

of the forging being a part of the electrical circuit) is very convenient for long pieces whose profiles are small. Installations of this nature are much simpler and

Table 9

Secondary Voltage and Power Required for Heating a Piece 100 mm Long by the Electric Contact Method (Bibl.11)

Diameter of the piece in mm	Heating time t, in min				
	0.15	0.3	0.6	1.2	2.4
	Secondary voltage v, in volts				
	2.36	1.67	1.18	0.84	0.59
	Power P in kw				
20	19.3	9.7	4.8	2.4	1.2
30	58	29	14.5	7.25	3.6
40	97	48.5	24	12.1	6.1
50	145	73	36.2	18.1	9.1
60		106	53.2	26.6	13.3

The required secondary voltage v_2 and the power P for heating pieces with a diameter D_z and length L with a heating duration chosen as t, will be: $v_2 = v_K$; $P = pK$

The length of the piece L, in mm.	Diameter of the piece D_z in mm				
	20	30	40	50	60
	Correction factor K				
200	2.42	2.70	2.9	–	–
300	3.5	3.84	4.1	4.55	–
400	4.68	4.93	5.36	5.65	–
500	5.85	6.1	6.5	6.85	7.25
600	7	7.15	7.6	8.1	8.35

the capital investment is less than for the induction type heaters. There should be

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enough pressure between the clamps and the surface of the forging. The pressures should be as follows: 1000 kg/cm^2 for pieces with a diameter of 20-30 mm; 3000 kg/cm^2 for diameters of 30-50 mm; 5000 kg/cm^2 for diameters of 50-70 mm. Information on heating time, power and secondary voltage and their relation to the size of the piece are shown in Table 9.

After forging, the cooling conditions are just as important as the heating conditions. Too rapid cooling creates thermal stresses resulting in internal and external cracks. The smaller the heat conductivity of the steel and the larger is the size of the raw piece, the slower is to be the rate of cooling.

Technological Processes and Equipment

The basic technological processes and the equipment used in forging are given in Table 10. Prof. A.P.Gavrilenko, was the first to give a detailed report on problems connected with forging under pressure. There are three basic groups of processing methods: free forging, stamping and the finishing group.

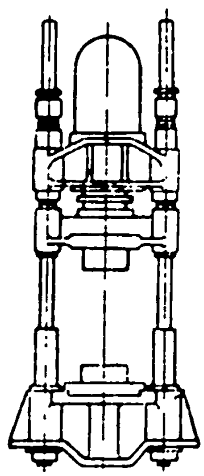

Fig.21

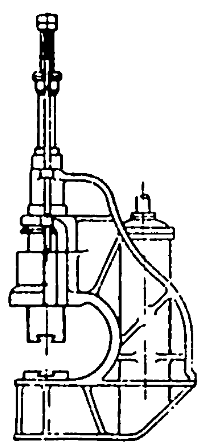

Fig.22

Free Forging. General information. Free forging is effected by hydraulic presses, by steam, pneumatic and spring-operated hammers.

Heavy and very heavy forgings to be made from cast ingots are being forged exclusively by hydraulic presses with power over 800 t.

Medium-weight forgings, originally from rolled material (stripped ingots, forge-shop ingots, etc.) are made by steam hammers with falling parts weighing 1-3 m, and are also made by hydraulic presses with a power of 400-800 m, and seldom by

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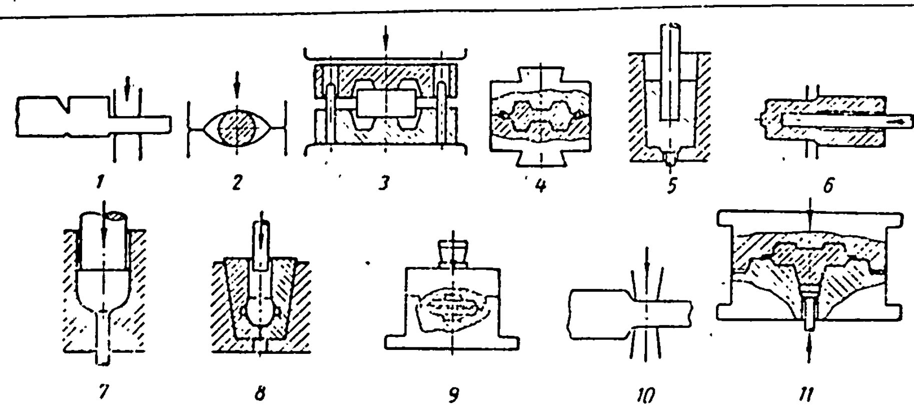
Table 10

Basic Technological Processes and Equipment used in Forging and Stamping

a)	b)					c)					d)							
	e)							f)										
	g)	h)	i)	j)	k)	l)	m)	n)	o)	p)	q)	r)	s)	t)	u)	v)	w)	x)
y)	1	—	1	—	10	1	—	—	—	—	—	—		—	—	—	—	—
z)	2	—	2	—	2	2	—	—	—	—	—	23	24			—	—	
aa)	3	—	3	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—
bb)	—	4	—	4	—	11	9	14	—	—	—	—	—	—	—	—	—	—
cc)	—	—	—	—	—	12	12	—	—	—	—	—	—	—	—	28	—	—
dd)	—	—	—	—	—	5	13	15	—	—	—		—	—	—	—	—	—
ee)	—	—	—	—	—	7	—	7	—	—	—	—	—	—	—	—	—	—
ff)	—	—	—	—	—	8	8	—	—	—	22	—	—	—	—	29	—	—
gg)	—	—	—	—	—	—	—	—	25	—	—	—	—	25	—	30	—	—
hh)	—	—	—	—	—	6	—	16	—	—	—	—	—	—	—	—	—	—
ii)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	26	—	—	—
jj)	—	—	—	—	—	—	—	—	20	—	—	—	—	—	—	—	—	—
kk)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	27	27
ll): mm)	—	—	—	—	—	—	—	17	—	17	—	—	—	—	—	—	—	—
nn)	—	—	—	—	—	—	—	—	—	18	—	—	—	—	—	—	—	—
oo)	—	19	—	19	—	—	19	—	21	—	—	—	—	—	—	—	—	—

pp)



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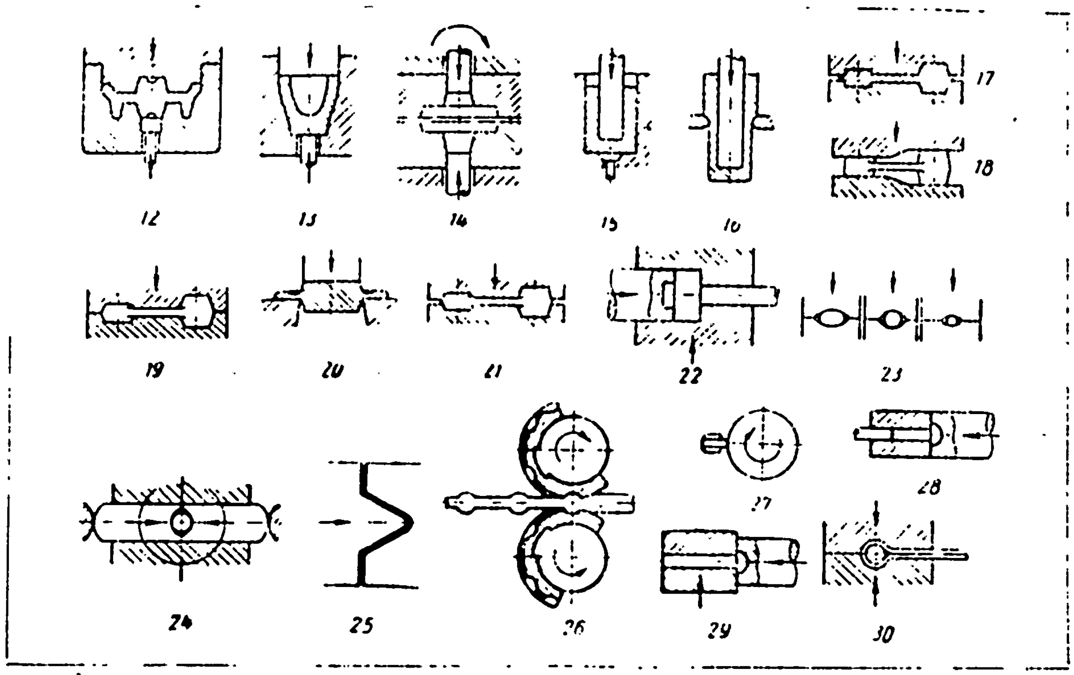

a) Type of processes; b) Hammers; c) Presses; d) Forging machines; e) Steam air; f) Crank type; g) Forging; h) Stamping; i) Pneumatic; j) Friction; k) Spring lever; l) Hydraulic; m) Screw friction; n) Hot stamping; o) Cutting; p) Crankthrow; q) Horizontal forging; r) Vertical forging; s) Rotary forging; t) Horizontal bending machines; u) Forging rolls; v) Smith stamping automatic; w) Hot milling cutters; x) Abrasive machines; y) Forging, in particular; z) With shaped strikers; aa) With backing open dies; bb) Stamping in tightly held open dies; cc) Stamping by plungers in closed dies with one-piece matrix, in particular; dd) By piercing; ee) By upsetting; ff) Stamping by plungers in movable matrixes; gg) Stamping by bending; hh) Drawing through a ring; ii) Fluting; jj) Cutting off burrs; kk) Cleaning away burrs; ll) Calibrating coining; mm) Voluminal; nn) Surface; oo) Trueing; pp) Remarks: In Table 10, the numerals correspond with the numbers of the sketches below and indicate how wide is the application of the machine for a given process. The sign (-) indicates limited or absence of application

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pneumatic hammers.

Small forgings from rolled material (square, round or strip) are made, in most cases, by pneumatic hammers and occasionally, by steam and compressed-air hammers with falling parts weighing less than 1 ton. For very simple and very small forgings bumper-spring operated hammers are used sometimes.

Two types of hydraulic presses are used: (a) four-column frame type (Fig.21) with 1 to 4 cylinders, depending upon the tonnage and design of the press, (b) open front type shown in Fig.22. Specifications of a four-column press are given in Table 11.

Table 11

Specifications of Four-Column Hydraulic Forging Presses

(Taken from GOST 7284-54)

a)	b)	c)	d)	e)
500	800	1600	1180	55
800	1000	2000	1500	90
1250	1250	2500	1900	140
2000	1600	3200	2480	250
3200	2000	4000	3000	400
5000	2500	5000	3750	

a) Rated power in m; b) Maximum length of stroke in mm; c) Maximum distance between the stand and movable cross-piece in mm; d) Inner distance between columns in mm; e) Approximate weight in m

Table 12

Guide for Selecting Hydraulic Forging Presses for Ingots of Various Weights

(Bibl.45)

a)	b)		a)	b)	
	c)	d)		c)	d)
600	1	3	2 000	14	28
800	2	5,5	3 000	30	55
1000	3,5	8	6 000	80	120
1200	5	11	10 000	160	240
1500	8	17			

a) Power of press in m; b) Weight of the ingot in m; c) Average; d) Maximum

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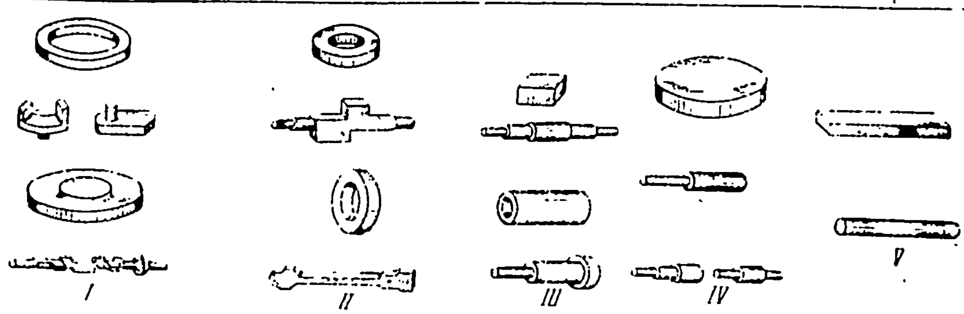
As to the type of the drive used, there are: purely hydraulic presses deriving the power from a pump and a hydraulic accumulator, and steam-hydraulic presses deriving the power from a steam-hydraulic manifold. In this type of press, compressed air may be used instead of steam. The tonnage required for ingots of different weights is shown in Table 12. The relationship between the capacity of hydraulic forging presses and the complexity of the configuration is shown in Table 13, where the capacity is shown for forging without the use of a manipulator; the use of an manipulator increases the capacity 1.5 - 2.0 times (the less complex is the configuration - the larger is the capacity).

Table 13

Complexity of the Configuration of a Forging and its Effect on the Capacity of Hydraulic Forging Presses (Bibl.45) (When a Manipulator is not Used)

a)	b)						
	600	800	1000	1200	1500	2000	3000
	270	320	370	430	480	570	680
II	510	600	700	790	890	1000	1150
III	650	850	1040	1250	1430	1750	2100
IV	930	1150	1400	1640	1920	2250	2630
V	1550	1830	2100	2400	2750	3250	4400



a) The complexity group; b) Capacity per hour, in kg, with the power of the press measured in m

Forge Hammers. Two types of air and steam operated forge hammers are commonly used; these are: open-front single-side frame type (Fig.23) and two-sided frame type which are divided into arch type (Fig.24) and bridge type (Fig.25).

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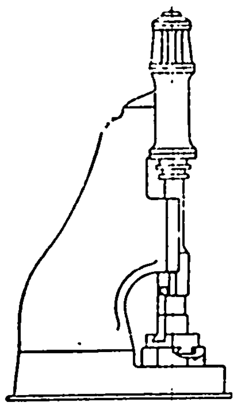

Fig.23 - Open-Front Air and Steam Operated Forge Hammer

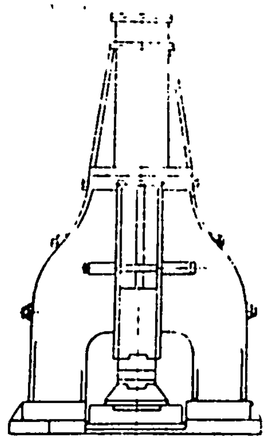

Fig.24 - Arch-Type Two-Sided Frame Air and Steam Operated Forge Hammer

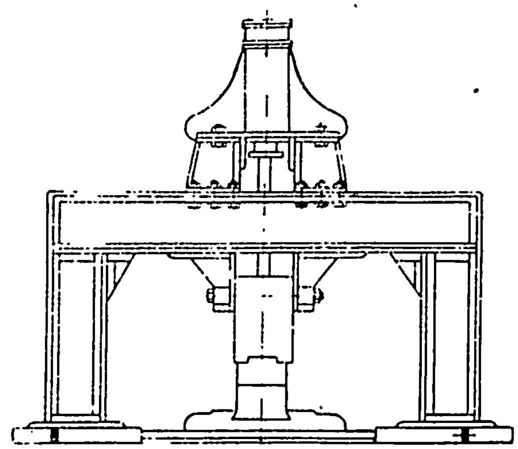

Fig.25 - Bridge-Type, Two-Sided Frame, Air and Steam Operated Forge Hammer

Table 14

Specifications of Arch-Type Air and Steam Operated Forge Hammers (Taken from GOST 4730-49)

a)	b)	c)	d)
1000	1000	1800	410×230
1500	1150	2100	470×260
2000	1260	2300	520×290
3000	1450	2700	590×330
4000	1600	3000	650×370
5000	1700	3200	710×400

a) Weight of falling parts in m; b) Length of stroke of the ram in mm; c) Clearance between sides in mm; d) Size of striker in mm

Table 15

Specifications of Pneumatic Forge Hammers (Taken from GOST 712-52)

a)	b)	c)	d)	e)
75	210	300	145×65	2 656
150	190	350	200×85	4 000
250	150	420	225×90	5 756
400	130	520	265×100	9 000
560	115	620	300×110	12 000
750	105	750	345×130	17 900
1000	95	800	390×150	—

a) Weight of falling part in kg; b) Number of strokes per min; c) Length of "flying-out" in mm; d) Size of striker in mm; e) Weight of hammer without its anvil-block in kg

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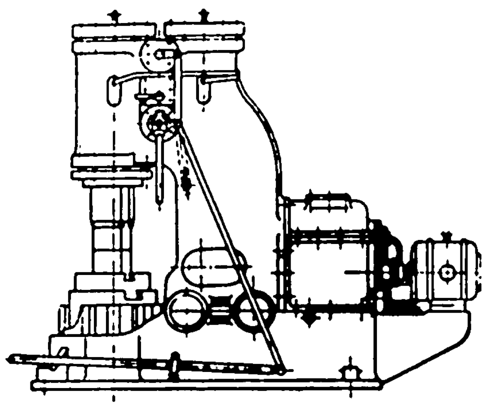
Pneumatic forge hammers (Fig.26) are made with a single open front, without guides, and with the piston, rod and ram as one piece.



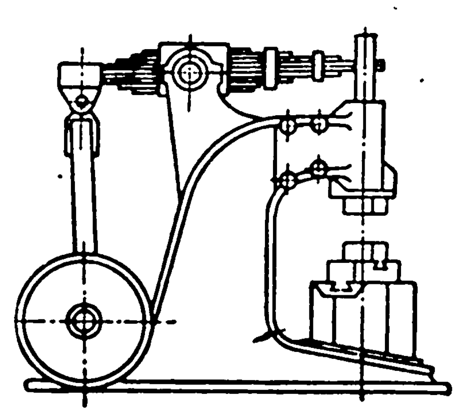


Fig.26 - Pneumatic Forge Hammer

Fig.27 - Bumper-Spring Operated Hammer

Specifications for air and steam operated forge hammers are given in Table 14, and for pneumatic forge hammers in Table 15.

Hammers operated by bumper springs are made in small sizes and their use is limited. A hammer of this type, with the weight of the falling part equal to 30 kg, is shown in Fig.27.

Table 16 shows the relationship between the hammer capacity and the complexity of the forging configuration. The required weights of the falling parts of the forge hammer in relation to the ingot weights may be determined by using Table 17.

Manipulators. In free forging by hydraulic presses, the use of a manipulator is necessary. Its use increases the capacity by more than 1.5 times by the mechanization of the shifting movements of the forging. The lifting capacity of a manipulator, depending upon the power of the press is:(Bibl.45):

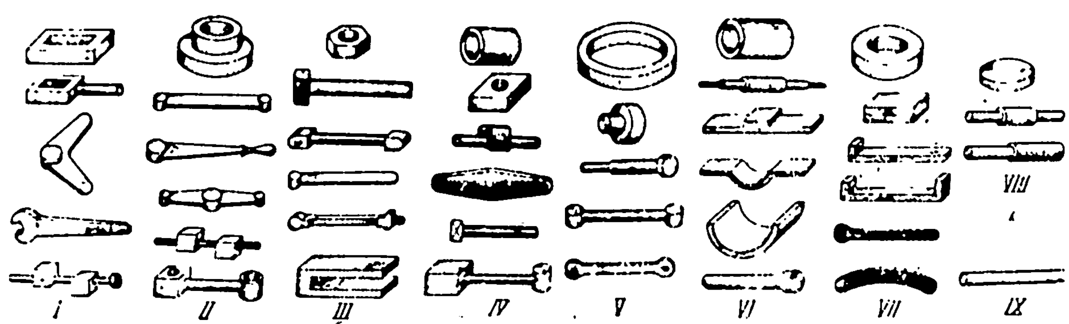
Power of the Press in m	Lifting power of manipulator in m
600	2 - 3
800	3 - 5
1000-1200	5 - 10

Power of the Press in m	Lifting Power of the manipulator in m
1500	10 - 15
2000	15 - 20
2500-3000	30 - 50
5000-6000	75 - 100

Table 16

Guide to the Relationship between Capacities of Forge Hammmers and Complexity of Configuration in Forgings (Bibl.45)

a)	b)										
	0,1	0,15	0,2	0,3	0,4	0,5	0,75	1	2	3	5
I	3,5	4,5	6	9	13	17	26	37	83	115	155
II	6	7,5	9	15	25	38	65	97	160	210	250
III	7	9	12	19	30	45	80	115	220	295	380
IV	9	11	14	26	40	60	105	145	235	310	410
V	12	15	18	32	52	75	133	165	265	350	500
VI	14	19	25	42	68	98	155	200	320	430	580
VII	20	25	32	50	75	105	170	225	370	500	650
VIII	28	32	40	60	90	120	210	300	535	715	920
IX	85	95	115	155	200	250	370	465	915	1200	1500



a) Complexity group; b) Capacity per hour, in kg, with weight of falling part in m

Even with the use of a manipulator, the use of a bridge crane is also necessary. The over-all weight of material in free forging is determined from the following equation:

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$$G_{is} = G_{pk} + G_{pr} + G_{dn} + G_{ug} + G_{ob}$$

where G_{is} is the overall weight of material; G_{pk} is the weight of the forging; G_{pr} is the weight lost by the added part of the ingot; G_{dn} is the loss by the ingot; G_{ug} is the loss by burning; G_{ob} is the loss by chipping.

Table 17

Guide for Selecting Proper Weight of Falling Parts of Forge Hammers for Forgings of Various Weights (Bibl. 45)

Weight of Falling Parts in m	Weight of Forging in kg			Maximum Cross-Sectional Area of Raw Forging (Side of Square) in mm
	Shaped Forgings			
	Average Weight	Maximum Weight	Maximum Weight for Smooth Rolls	
0.1	0.5	2	10	50
0.15	1.5	4	15	60
0.2	2	6	25	70
0.3	3	10	45	85
0.4	6	18	60	200
0.5	8	25	100	115
0.75	12	40	140	135
1.0	20	70	250	160
2.0	60	180	500	225
3.0	100	320	750	275
5.0	200	700	1500	350

The loss in weight from the added surplus part of ingots, made from structural carbon steel and cast from above, is usually 15-25% of the ingot weight. For structural alloy steel; 25 - 35%. Ingots cast without the use of a warming ekepiece will lose up to 35-40%. For instrument alloy steel, the surplus material may go up to 50%.

The lost weight by the ingot G_{dn} is assumed to be at 4-7% for carbon steels and 7-10% for alloyed steels. In percentage of the over-all material, the loss by burning can go up to 2% of the material being heated for each heat, and to 1½% for each preheat. The loss by chipping depends upon the complexity of the forging and also upon the technological process used. For forgings having the same configuration, the smaller pieces will have a greater loss.

The percentage of total loss due to burning and chipping for different forgings, forged by hammers from measured stock is as follows:

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Forgings by Group	Loss in % of Weight of Forging
End flanges - round, oval, flat, square, strips, cubic, blocked	1.5-2.5
Open flanges, collars, nuts	2*
End gears	8-10
Expander rings, bushings, shells	2.5*
Welded rings, bushings, shells, couplings	3--5
Smooth shafts, rollers, square, straight, and hexagonal blocks	5-7
Shafts and rollers with projections or flanges, keys, shoes, traverses	7-10
Shafts, rollers with recesses on two sides, or with shoulders, spindles, rods, yokes	10-12
Levers for tightening nuts, forgings of the connecting rod type, levers, compounded connecting rods	15-18
Cranks	18-25
Crankshafts, curved and two-shouldered levers	25-30

* Does not include losses due to waste of punched-out material. These loses have to be calculated and added additionally. When a backing ring is used, the volume V_v of the wasted punched-out material is:

$$V_s \approx (0.70 + 0.75)\frac{\pi d^2}{4} h = (0.55 + 0.60)\, d^2 h$$

When punching without the use of a backing ring, the volume of the punched-out material is:

$$V_s \approx (0.20 + 0.25)\frac{\pi d^2}{4} h = (0.15 + 0.20)\, d^2 h$$

When the punching is done with a hollow punch (when forging in a press), the volume

$$V_s \approx (1.1 + 1.15)\frac{\pi d_s^2}{4} h$$

where d is the diameter of the punch; h is the height of the stock; d_s is the diameter of the hole.

The approximate weight after deducting losses and waste of the cast-iron ingot suitable for forging is shown below:

Forging by Group	Remainder in % of Weight of Ingot
Straight shafts and rods	60-70
Shafts with long wristpins	58-64
Shafts with short wristpins and shafts with flanges on both ends	54-60
Single throw crankshafts	50-58
Multithrow crankshafts	40-50
Plates and stri material	50-65
Cubic shapes	52-60
Rings and bandage	55-56
Discs	50-60
Drums, hollow cylinders	60-65

Sizes of Ingots to be Forged (Stock). When the forging is to be done by the method of upsetting, consideration should be given to the weight of the stock and its volume (V_{is}). The sizes are to be so selected that the height h_{is} does not exceed the diameter d_{is}, or the side of the square, by more than 2.5 times (to avoid bends by the upsetting). Nevertheless, the height must be 1.25 times larger than the diameter (to make the chipping and the cutting by shears easy). In other words,

$$1.25d_{is} < h_{is} \leq 2.5d_{is}$$

With this relationship we have: $d_{is} = (0.8 - 1.0) \sqrt[3]{V_{is}}$ for round stock, and $d_{is} = (0.75 - 0.90) \sqrt[3]{V_{is}}$ for square pieces.

The length of the stock is found by dividing the volume by its cross-sectional area, in accordance with the precisely determined diameter, or the side of the square of the stock, corresponding exactly to the grade of the stock, as specified by GOST.

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The length of the stock is found by dividing the volume by its cross-sectional area, in accordance with the precisely determined diameter, or the side of the square of the stock, corresponding exactly to the grade of the stock, as specified by GOST.

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When selecting stock of great height to be formed under the hammer, it is necessary to verify the possibility to do it technically by upsetting, using the equation

$$H - h_{is} \quad 0.25 \; H$$

where H is the length of stroke of the hammer. For forging of a cast ingot by upsetting, the specifications of the ingot should be in line with the over-all weight, which is to be calculated, as shown above.

When forging by drawing-out: forgings with round, square, or nearly round or square shapes of their cross section, should follow the following relationship:

$$F_{is} \geq y F_{max}$$

where F_{is} is the cross-sectional area of the over-all stock; F_{max} is the area of the maximum cross section of the forging; y is the degree of forging (see earlier in text).

Basic Operations of the Technological Processes in Free Forging. These are: 1) Upsetting, 2) drawing out, 3) punching, 4) cutting, 5) bending, 6) twisting and 7) forge welding.

Upsetting. With upsetting, the height of the original stock is reduced at the expense of the increase in the area of its cross section. Upsettnng, when done only for a portion of the stock is called partial upsetting. Upsetting is Used: a) to obtain forgings (or portions of forgings) having greater cross-sectional areas and relatively small heights (flanges, gears, discs) from stock whose cross-sectional area is smaller; b) as a preliminary step before punching of hollow forgings (rings, drums); c) as a preliminary operation aimed to destroy the dendrite structure of the casting and to improve the quality of the stock having a transveral structure; d) to increase the degree of forging for the subsequent drawing-out operation.

The upsetting of a cylindrical stock from a tailless casting (pins, shanks, etc) is done: 1) under hammer, and 2) by a press, when the next operation is punching

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(see Fig.28).

The upsetting of a stock having a tail (Fig.29) is done by a press, if drawing out is to follow. In such cases, backing plates are used, with the lower plate containing a hole under the tail.

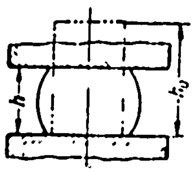

Fig.28

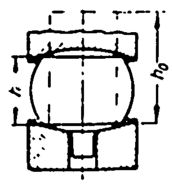

Fig.29

The upsetting on plates with holes (backing rings) is peculiar in that respect, that simultaneously with the upsetting process, metal will flow in the holes of the backing rings A and B (Fig.30). This method is used to obtain products of the type of end gears, flanges and discs with lugs or teats. It is also used in cases where the volume of the product is unusually large in relation to the diameters of the lugs and, for some reason it is undesirable, or impossible to extend the ends of the product (for example, if the height of the teats is very small).

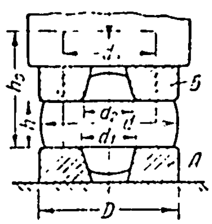

Fig.30

Partial upsetting in a ring (Fig.31) is used to obtain products of the type of end gears, flanges and disks with teats, or lugs. It is used in cases, when the diameter of the lugs (Fig.31a), or if the end of the stock can be preliminary extended to the same extent (Fig.31b).

Partial upsetting in the counter-die (the lower die) is used to obtain flanges and heads on long rods (Fig.32). The stock may have a diameter equal to the opening (to the diameter of the rod), or if it is possible to have the end of the stock extended to the same extent. A cavity, having the shape of the head, can be made in the upper portion of the lower die (a backing die, Fig.33).

Upsetting by enlarging is used for decreasing the height and enlarging the diameter of a product already upset when, due to the high resistance to deformation,

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further upsetting by direct strikes of the hammer (or by pressure of the press) over the entire surface is impossible. The enlarging is effected by means of a roller

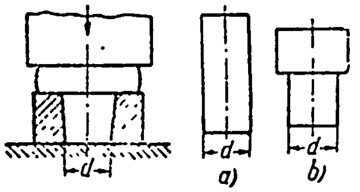

Fig.31

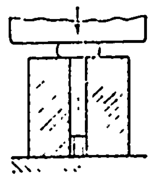

Fig.32

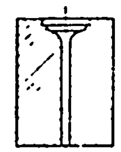

Fig.33

(Fig.34), or for forgings with large diameters, (for instance, turbine disks), directly by means of strikers (Fig.35).

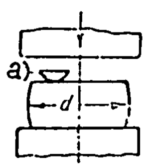

Fig.34

a) Enlarging roller

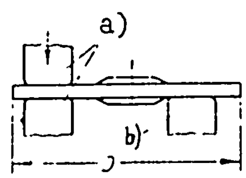

Fig.35

a) Strikers; b) Prop

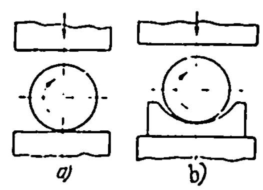

Fig.36

The finishing operation after upsetting, is the rolling along the diameter. It is used to eliminate the barrel-shape to impart a cylindrical form and a smooth surface (Fig.36a). This operation is made easier by using an underlayer or squeezers (Fig.36b).

Drawing-Out Operations (Extrusion). In drawing-out operations, the length of the original stock increases at the expense of the reduction of its cross-sectional area (shafts, draught-bars, connecting rods, etc). The tools used (Fig.37) are: a) flat strikers, b) cut-out strikers, c) seldom used rounded strikers, d) squeezers, e) rollers, f) knuckles, g) mandrils, h) chucks, etc. The drawing out is effected

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by consecutive squeezings (by the squeezers) (Fig.38) while the stock is fed along the axis of the drawing-out direction. It is also accomplished by turning the stock around (edging). The varieties of this process are:

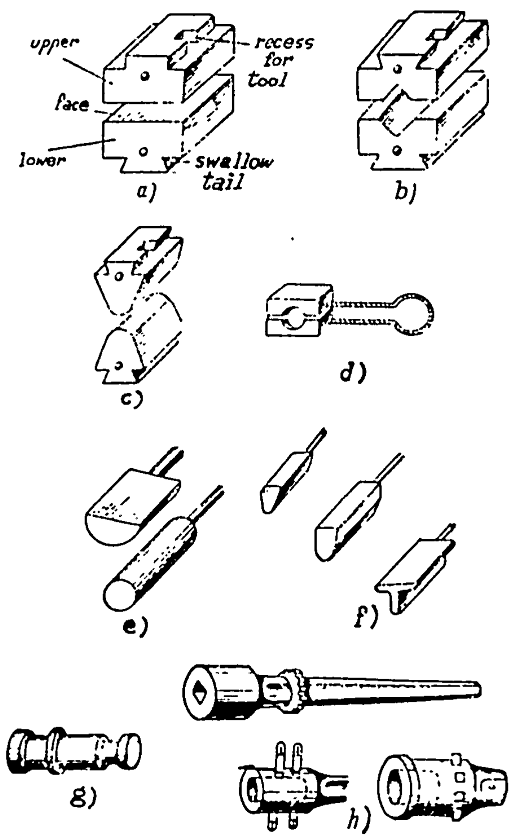

Fig.37 - Tools used for Drawing-out Operations

a) Flattening (widening, enlarging), the increase in width of the original stock at the expense of its height. It is used to obtain forgings or portions of forging having a flat shape, of the type of flat thin plate.

b) Drawing out on a mandril (Fig.39), which is increasing the length of a hollow forging at the expense of reducing the thickness of its walls (forging of gun-barrels, boiler-drums, turbine rotors, etc). The tools used are: cut-out strikers (or a cut-out lower striker and a flat upper one), and mandrils with slightly conical surfaces.

c) Enlarging on a mandril, which is the simultaneous increase of the external and internal diameters of a hollow piece at the expense of the thickness of its walls (rings, shells, drums). The tools used are: a narrow long upper striker (preferably to be as long as the forging), a cylindrical mandril and supports under the mandril. The method (Fig.40) is as follows: the internal surface of the stock rests on the mandril, which is supported at its ends, and the forging is carried out by rotating the stock while feeding it, with the long side of the striker being

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parallel to the axis of the forging.

d) A combination of drawing out with a mandril and enlarging on a mandril. The enlarging will correct the barrel-shapedness of the stock, which before that was

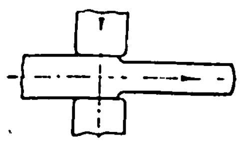

Fig.38

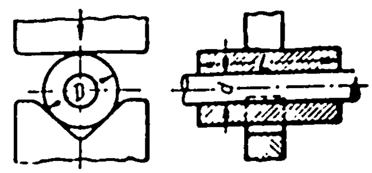

Fig.39

upset and punched, and will increase the internal diameter to the required size; the drawing out with a mandril will reduce the wall thickness and will increase the

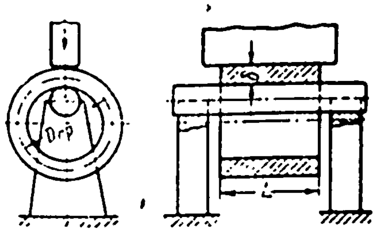

Fig.40

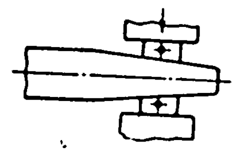

Fig.41

length to the required size, while calibrating on the mandril the inner surface of the forging at the same time.

e) When the forging is to be tapered or conical,the drawing out is effected by wedge-like rollers (Fig.41).

Punching is used to obtain a thorough opening in the forging (piercing), or a very deep impression in the forging. When the punching is done by hand, the tools used are: punches (round, flat, square, or shaped) and forms with corresponding openings. When done by machine, the tools are: punch dies (solid with round or shaped cross sections, also hollow dies), ckepieces (solid and hollow), calibrating

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mandrils, backing pieces with openings (backing rings). Punching will distort the shape of the forged piece; the through punching (producing a hole) will produce a loss or waste of material in the form of the punched-out pieces.

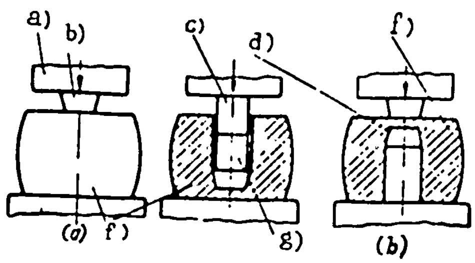

Fig.42 - Method of Punching without the use of a Backing Ring

(a)- Start of operation;(b)- End of 1st stage; c - Start of 2nd stage

a) Striker; b) Punch die; c) 2nd ekepiece; d) 1st punch die; f) Surplus side of stock; g) 1st ekepiece

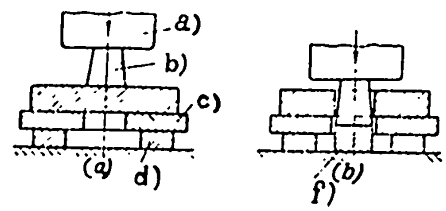

Fig.43 - Method of Punching by Using a Backing Ring

(a)- Start of operation;(b)- End of operation

a) Striker; b) Punch die; c) Backing ring; d) A prop; f) Punched-out piece

The consecutive operations for punching from both sides without the use of a backing ring is shown in Fig.42. The punching of one side with the use of a backing ring is shown in Fig.43.

For large openings (over 500 mm), a hollow punch die is used (see Fig.44).

Cutting is done to obtain several smaller pieces from a single large piece, to remove surpluses at the forging ends, to remove the added parts of the stock and of the forging, and to obtain shaped forgings (crankshafts with throws cut out, draught bars, forks, etc). Various methods of cutting out are shown in Fig.45.

The tools used for cutting are shown in Fig.46. For operations by hand, a chisel (Fig.46a) is commonly used, also, ship hammers (Fig.46b). Tools used in machine cutting are: axes (Fig.46c - two sides; 46d - one sided), angular axes (Fig.46e), semi-circular axes (Fig.46f) and several other shapes. In cutting, part of the metal is lost in forms of chips.

Bending is used to obtain (directly, or in combination with other operations)

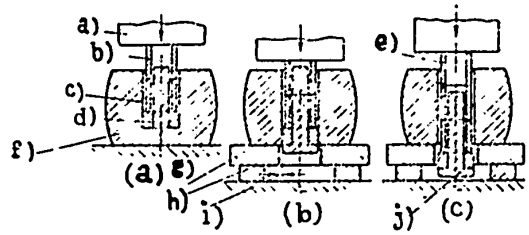

Fig.44 - Method of Punching with a Hollow Punch Die

(a)- 1st stage;(b)- 2nd stage;(c)- End of operation

a) Striker; b) 2rd ekepiece: c) 1st ekepiece; d) Punch die; e) 3rd ekepiece; f) Surplus side of stock; g) Backing ring: h) A prop; i) Clearance 15-20 mm; j) Pushed-out rod

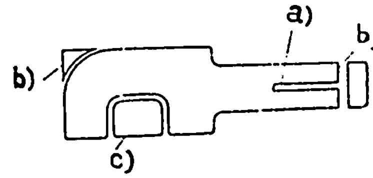

Fig.45 - Methods of Cutting

a) Cut asunder; b) Cut-off

c) Cut-out

products of various bent shapes (angles, braces, hooks, brackets, etc). Bending distorts the original shape of the cross section, and decreases the area in the zone of the bend (Fig.47). In addition, bending may produce folds in the inner contour and cracks in the outer. The probability of such defects is greater when the radius of the roundness is small and the angle of the bend is large. To prevent distortions various tools are used: "smootheners" in hand operations and rolls and strikers in machine work. These are of no help for correcting unfilled forms (reduced area in the zone of the bend). To obtain the desired area in the zone of the bend, it is made larger at this place before the operation. Several methods of bending are shown in Fig.48.

Twisting is used to obtain forgings of a special shape (crankshafts with their throws in different planes, wall bolts, stands, spiral drills, etc). The tools used are: twisters (Fig.49), forks, plain (Fig.50) and hinged (Fig.51). To avoid bending the wristpin during the twisting, the following method is used: a) a striker is placed under the end of the shaft and the stock is drawn to it by a chain, (Fig.52), b) by a lunet (Fig.53).

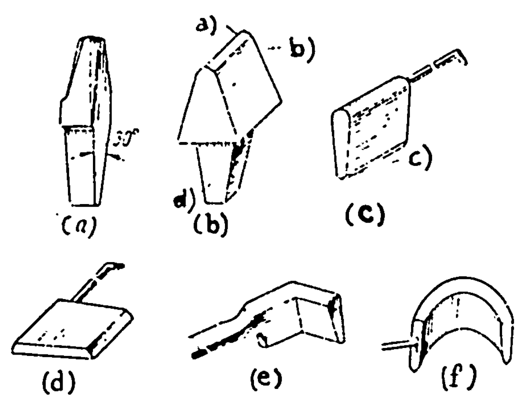

Fig.46 - Tools Used in Cutting

a) Blade; b) Face: c) Sharpening angle; d)The tail

Blacksmith welding is mainly used in hand and machine forging of small pieces to be repaired. Soft steel containing 0.15 - 0.25% of carbon is very good for blacksmith welding, whereas steel containing more than 0.45% of carbon is not good for it. The welding ability of a steel by this method is lowered by the

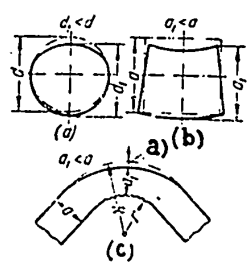

Fig.47 - Distortions by Bending

(a)- Of a round cross section;(b)- Of a rectangular;(c)- Reduced area

a) Reduction of area

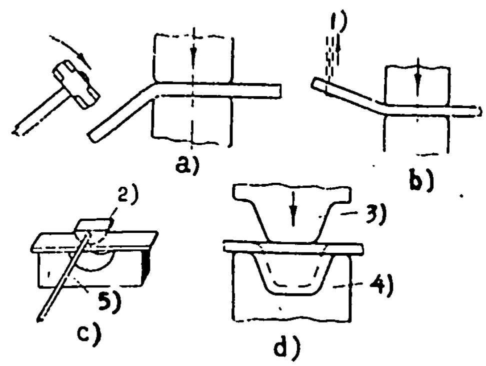

Fig.48 - Bending Methods

a - By hammer; b - By crane; c - With lower die and rolling; d - In the dies

1) Crane; 2) Rolling; 3) Upper die; 4) Lower die; 5) Die

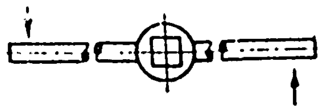

Fig.49 - Twister

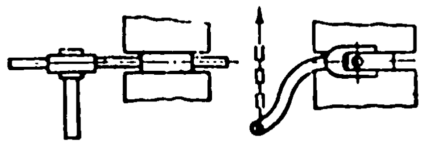

Fig.50 - Bending with Plain Fork

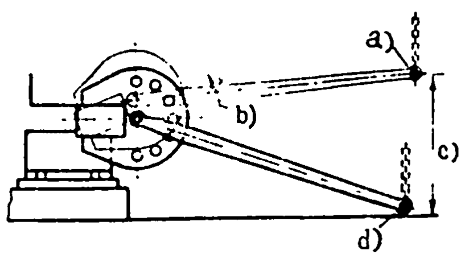

Fig.51 - Bending with Hinged Fork

a) Top position; b) Direction of twisting roll; c) Movement of lever d) Bottom position

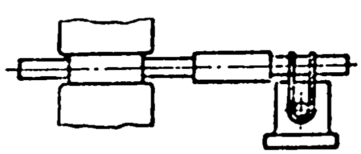

Fig.52 - Avoiding Bends Caused by Weights

presence of impurities.

The basic methods of blacksmith welding are: lap-welding (Fig.54), split-end welding (Fig.55), butt-welding (Fig.56) and splint-welding (Fig.57) for thin strips.

Lately, besides forging with hammers and hydraulic presses, there is a widely developed use of combined process of forging and stamping with crank-type presses offered by A.V.Potekhin. The basis of this combined forging-stamping process is the principle of dividing the technologically complicated method of preparing the forging into separate simple operations, carried out in a definite consecutive order in passes of forging attachments, or in dies installed in the crank-type presses.

Hammer Stamping. General information. Hammer stamping is mainly done with open dies and is accompanied with the formation of burrs along the line of separation. Lately, however, there is a tendency to use special closed hammer dies which make forging without burrs, making it possible to reduce the consumption of metal.

In use are backed dies and firmly

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secured dies. Stamping with backed dies is done by forging hammers and is used when a small quantity is to be fabricated. The firmly attached dies are used in special

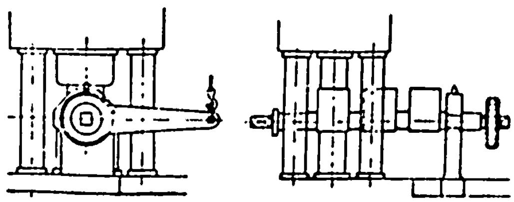

Fig.53 - Twisting by Using a Lunet

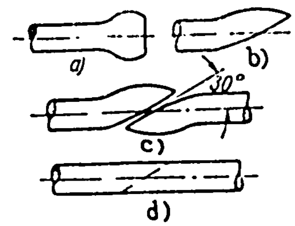

Fig.54 - Lap Welding

a) Upset end; b) Forging the facing; c) Welding; d) Smoothening

stamping hammers for mass production, or when handling large quantities. The final configuration can be imparted only to simple forgings to be made from bar stock (such as square, round pieces, and rarely - strips). In most cases, it is necessary to impart to the stock a shape very near to the configuration of the finished forging.

Fig.55 - Welding of Split End

When handling small quantities, these preparatory operations can be effected by free forging. In mass production, however, or when handling large quantities, they are effected with the aid of preparatory dies. For this purpose, all recesses and all changes in the shape of the stock can be effected by a single stamping block (cube) by means of a so-called multipass design. It is the most widely used method.

Lately, however, with mass production in view, the practice is for a transition, or for a group of transitions, from one device to another. In this manner, the forging may be effected with two or more hammers, or on with a combination of several devices, such as a hammer and forging rollers, horizontal forging machine and a hammer, etc.

Considerable simplification of the stamping process, and at the same time, an increase in productivity, saving of metal and improvement in the quality can be achieved by the application of periodic rolling of a stock, the cross section of

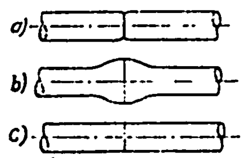

Fig.56 – Butt Welding

a – Before welding; b – After welding; c – After smoothening

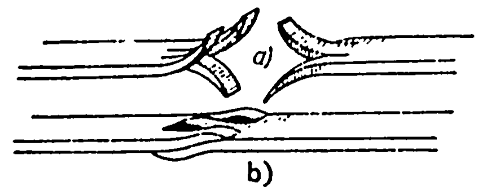

Fig.57 – Splint Welding

a – Ends ready for welding;

b – Welding

which, along its length, is not uniform (Fig.58).

In many cases, the application of the rolling process for special profiles (Fig.59) offers advantages. The stock is cut, preferably by shears, into pieces, It can be cut for one forging, or for two, i.e., one forging to be followed by another by turning the piece. It can also be cut for several forgings (forgings from a bar), in this case, the finished forging is cut by the "knife" of the die (Bibl.36, 1).

Fig.58

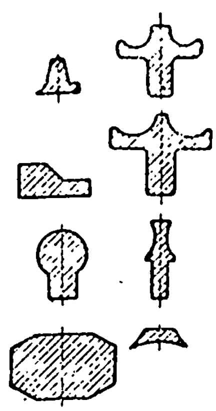

Fig.59

Lately, the use of stock in form of "twins" is widespread, as in this form it saves metal due to the fact that there are no smithtongs to be used on any portion of the stock. Stock, in the form of several forgings-to-be, is prepared for forgings of less than 300 mm long and weights of less than 2.5 kg. Stock, in the form of "twins" is used for forgings up to 400 mm in length and 3 kg in weight.

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Larger forgings are forged singly (Bibl.1).

Stamping Hammers. Stamping with firmly attached dies is done, in most cases, by steam and air operated hammers in a two-column frame. These are double-acting

Table 18

Specifications for Steam and Air Operated Stamping Hammers (from GOST 7021-54)

a)	b)	c)	d)	e)	f)	g)
0,63	1000	180	400	380	600	7,5
1	1200	220	500	450	660	11
1,6	1200	260	550	600	800	15
2	1200	260	600	700	900	18
2,5	1250	300	650	700	900	21
3,15	1250	350	700	800	1000	25
4	1250	400	700	900	1100	31
5	1300	400	700	1000	1200	37
6,3	1300	400	750	1000	1200	42
8	1400	450	900	1100	1300	—
10	1400	450	1000	1200	1400	—
12,5	1300	500	1100	1400	1500	—
16	1500	500	1200	1500	1600	—

a) Weight of falling part in m; b) Length of stroke in mm; c) Least height of dies without tails in mm; d) Clearance between guides in mm; e) Size of ram, from front to back, in mm; f) Size of die holder, from front to back in mm; g) Weight of hammer, without anvil block in m

Table 19

Specifications for Friction-Tppe Hammers with Board (from GOST 957-41)

a)	b)		c)	d)	e)	f)
	from	to				
500	900	1400	180	450	350	600
750	900	1450	220	500	400	650
1000	900	1450	220	550	450	700
1500	900	1500	260	650	600	800

a) Weight of falling part in kg; b) Length of stroke in mm; c) Least height of dies in mm; d) Distance between guides in mm; e) Size of ram, from front to back in mm; f) Size of die holder from front to back in mm

hammers with an upper cylinder (Fig.60). Also, by friction-type hammers with a board (Fig.61). Considerably less in use are steam and air operated hammers with

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lower cylinders and friction-type hammers with belts or ropes. Lately, hammers with two rams are extensively used for large forgings; the movement of the rams is opposite to each other (Fig. 62).

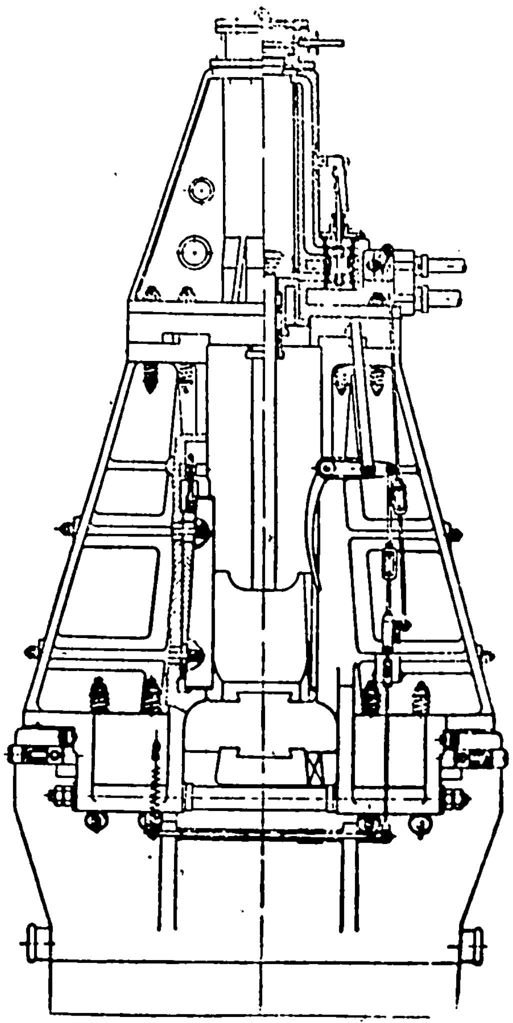

Fig. 60 - Steam and Air Operated Hammer

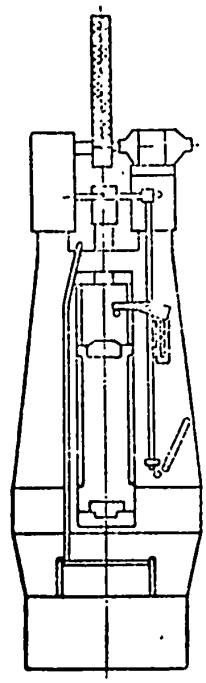

Fig. 61 - Friction-Type Hammer with Board

Specifications for steam and air operated hammers are shown in Table 18, and for friction-type Hammers - in Table 19.

As a guide, the following data may be used to determine the productivity of stamping hammers:

Weight of falling part in mm	0.5	1	2	3
Productivity per hr in kg	120	250	550	750
Weight of falling part in m	4	5	6	9
Productivity per hr in kg	1200	1500	1800	2500

The relationship between the weight of falling parts and the weight of forgings is shown in Table 20.

Table 20

Orientation Data on the Relation between the Required Weight of the Falling Parts of the Hammer, the Area of the Groove for Burrs and the Weight of the Forging (Bibl.7)

a)	.3–0,5	0,5–2	2–3	3–12	12–25	25–40
b)	500	1000	1500	2000	3000	7000–10 000
c)	0,9–1,2	1,2–1,7	1,7–2,4	2,4–4,2	4,2–5,3	5,3–11,2

a) Weight of forging in kg; b) Weight of falling parts of hammer in kg; c) Area of cross section of the groove for the burrs in cm^2

Weight of Stock for Hammer Stamping. The weight of stock G_{is} is represented approximately by the following equation: $G_{is} = G_{pk} + G_z + G_{ug}$, where G_{pk} is the weight of the forging; Gz is the loss due to burrs; G_{ug} is the loss due to burning during the heating.

The lost weight due to burrs can approximately be found from the equation:

$$G_z = (0.5 - 0.8)\,\gamma\, S f_z$$

where γ is the specific weight of the metal; S is the perimeter of the forging measured along the line of separation of the dies; f_z is the area of the cross section of the groove for the burrs. For forgings with complex configurations, the value of the coefficient should be large. Values for the area f_z are given in Table 20.

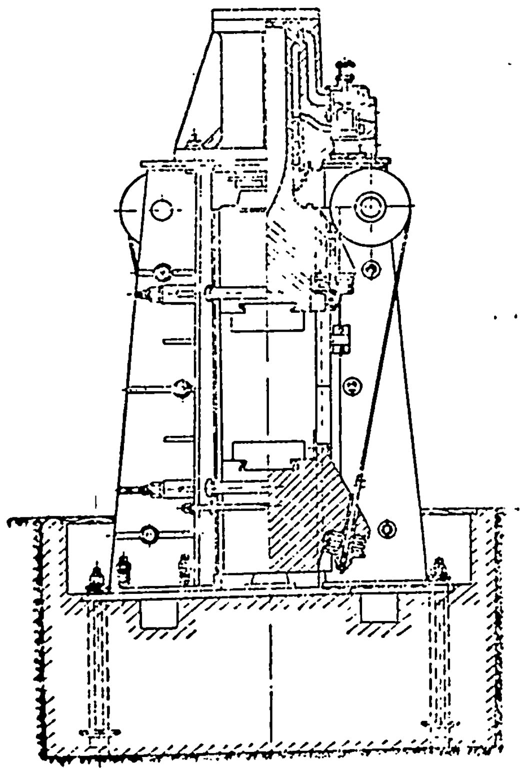

Fig. 62 – Hammer without Anvil Block

The loss due to burring during the heating G_{ug} is assumed to equal 2% of the forging weight.

Losses of metal due to handling by tongs and to cutting of the stock are not included in the G_{is}, shown above.

Sizes of Stock: a) For forging by upsetting, the butt end, the length and the cross section of the stock have the same values as in free forgings operations (see earlier in text).

b) The cross section of the stock F_{is} for all other shapes, where the cross-sectional areas of the portions of the stock do not differ much, may be found by using the following equation:

$$F'_{is} = \frac{(1.05 \div 1.3)\ V_{is}}{L_{pk}},$$

where V_{is} is the volume of the stock; L_{pk} is the length of the forging.

Where, along the length of the forging, cross-sectional areas of different portions differ sharply, some of these portions have to be drawn out. In such a case, for the purpose of orientation, the cross section of the stock may be assumed as equal to:

$$F''_{is} = (0{,}7 \div 1)\, F_{max}.$$

where F_{max} is the maximum cross section of the forging, including the cross section of the burrs, equal to $2.(0.5 - 0.8)f_z$.

The second equation is used in cases when calculations show that the cross section of the stock calculated by using the first equation turns out to be:

$$F'_{is} < (0{,}6 \div 0{,}7)F_{max}.$$

Stamping Dies (Bibl.36, 1). To obtain stamped forgings by means of multipass dies, the following types of passes are used: Preparatory (forming, squeezing, rolling, drawing, bending, also a backing platform), stamping passes (preliminary or rough; and final or clear) and cutting passes (front and back).

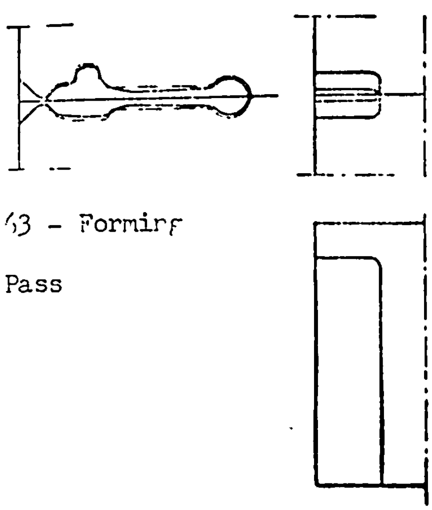

Fig.63 - Forming Pass

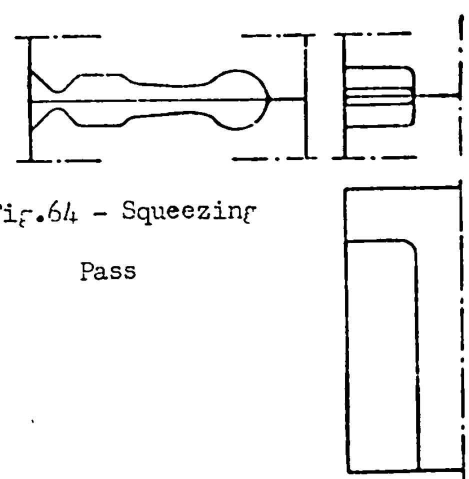

Fig.64 - Squeezing Pass

Forming Passes (Fig.63) are used to impart to the stock a shape similar to the shape of the forging at the plane of separation of the upper and lower dies*.

* Provided no great changes in cross-sectional areas of the stock are required and no displacement of metal along its axis is taking place.

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Squeezing Passes (Fig.64) are used to widen the stock across its axis, also to impart in its longitudinal section a shape which makes it easier to fill up the recesses of the next pass*.

Rolling Passes (Fig.65) increase considerably the cross sections of certain portions of the stock at the expense of decreased cross sections of other portions,

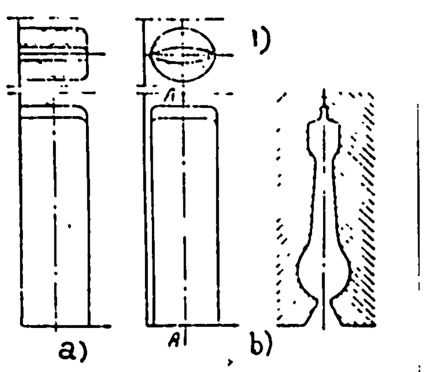

Fig.65 - Rolling Pass

a - Open type; b - Closed type

1) Section along AA

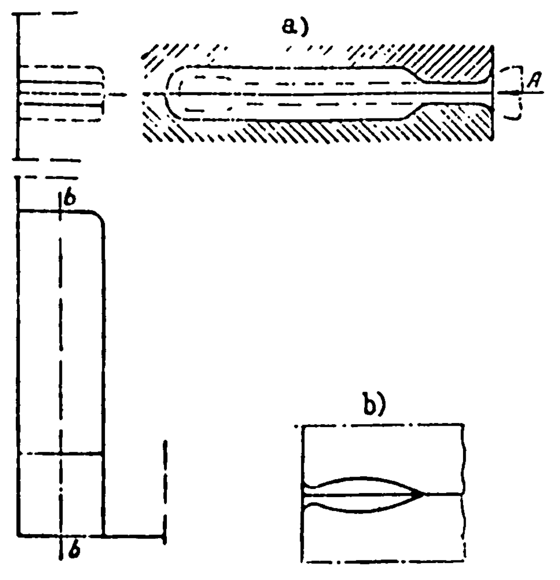

Fig.66

a) Section along BB; b) View along A

(for closed pass)

i.e., they distribute the volume of the stock along its axis so as to make it correspond to the distribution of the volume of the finished forging. There are two types of rolling passes: open type and closed type. The closed type rolls more intensively.

Drawing Passes (Fig.66) are used for decreasing the cross-sectional areas of individual portions of the stock with a simultaneous increase in their lengths. These passes may be located in an upright position, or at an angle of 12-18°

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* Provided no great changes in cross-sectional areas of the stock are required and no displacement of metal along its axis is taking place.

(Fig.67). They may be of the open type or closed, depending upon the shape of the cross section (see Fig.66).

Bending Passes (Fig.68) are used for bending the stock and to make its shape to correspond to the shape of the forging at the plane of the separation of the dies.

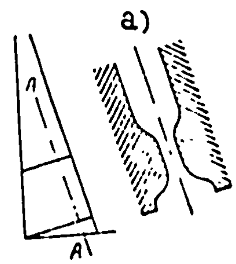

Fig.67

a) Section along AA

Backing Platforms (Fig.69) are used to diminish the height of the stock by upsetting its butt end before the stamping operation.

Final Passes will produce finished forgings with burrs, but the dimension of the forging will be greater than (~ 1.5%) the dimension of the forging after the upsetting operation. In a final pass, there is a groove for the burr. The location of the groove is along the recessed contour in the plane of separation of the dies.

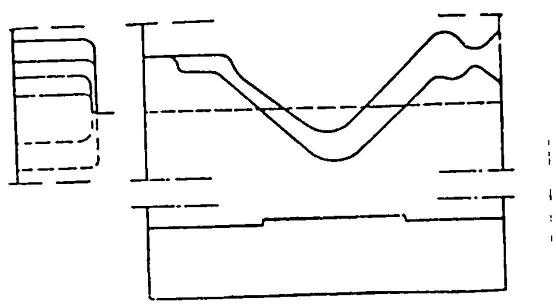

Fig.68 - Bending Pass

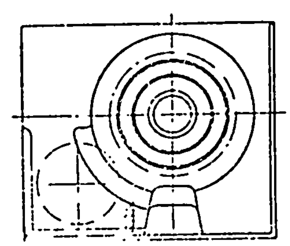

Fig.69 - Backing Platform

The Preliminary Pass is used mainly to prevent the wear of the final pass. Basically, the formation stage is effected in the preliminary pass; the function of the final pass is to give to the forging the exact dimensions required. The preliminary pass is used for forgings with complex configurations. Excepting certain cases, the shapes of the recesses are the same for the preliminary and for final passes, only the radius of roundness in the preliminary pass is larger and it con-

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tains no grooves for the burrs.

Cutting Pass (knife) is used to cut off the finished product from the bar stock, when the bar stock is to produce more than two forgings. Cutting passes may be located in the front, for better productivity (Fig.70a), or in the back, which makes it more durable (Fig.70b). When there is no place in the front the pass is located in the back.

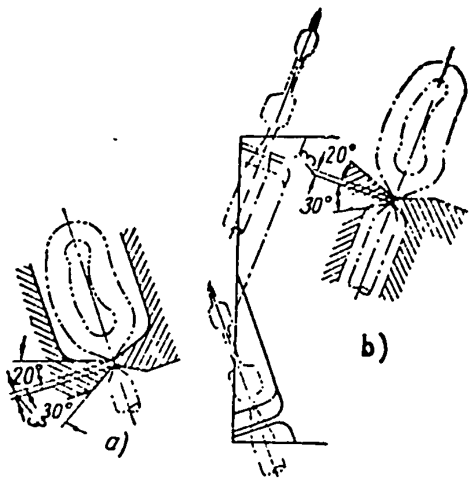

Fig.70 - Cutting Pass (Knife)

a - Front; b - Back

Locating the Passes in the Die. The type of passes and their combination should be chosen at the time of planning the technological processes suitable for the forging. The choice depends upon the configuration, size of forging and upon the required direction of the fibers.

If only one final pass is called for, its center is located in the center of the die, which is the intersection of the tail of the die with the axis of its seat under the key. The axis of the hammer rod passes through the center of the die.

With two passes present, their centers are located on both sides of the center of the die, with the final pass nearer to the die center than the preliminary.

The location of the preparatory and cutting passes depends upon the consecutive order of operations, but as a rule, they are located near the edges of the die.

As an example, a multipass die is shown in Fig.71. After the heating, the stock enters the drawing pass (1) to have its ends drawn out; after that it enters the rolling pass (2) to "gather" material (mostly in the middle portion), and from there, it goes to the bending pass (3). After that, the stock is first stamped in the preliminary pass (4) then in the final pass (5), after which the stamping is cut off from the bar in the cutting pass (6), located in back.

Keeping the Hammer Dies in Place. For the upper die, this is accomplished by swallow-tails placed in the seat of the hammer ram. For the lower die, a bed is

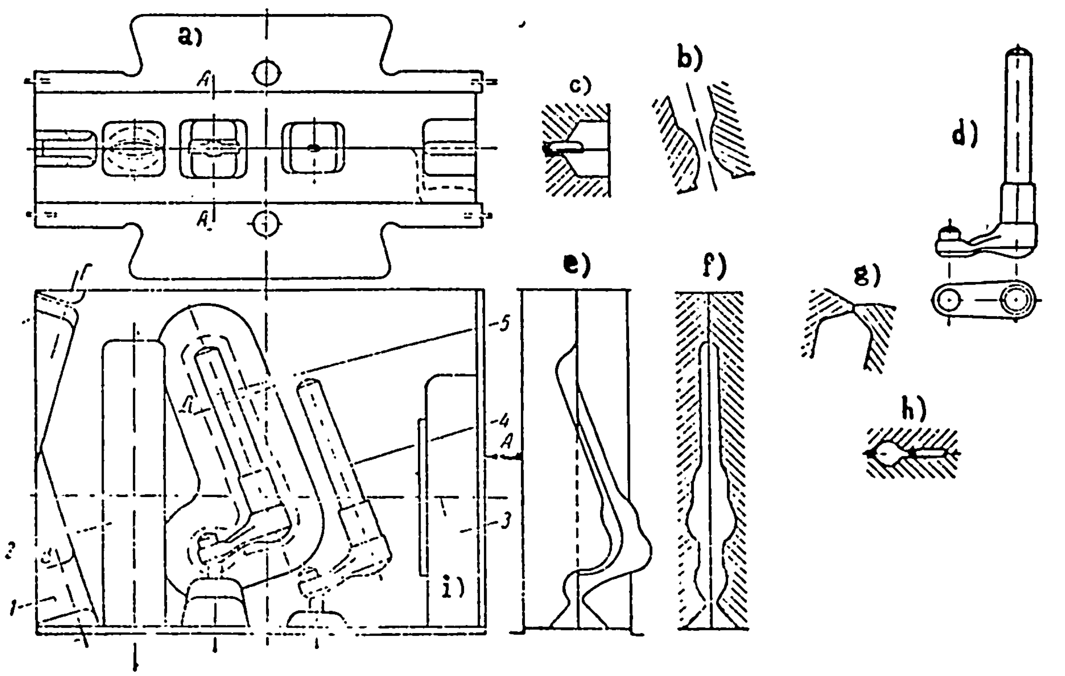

Fig.71 - Multipass Hammer Die

a) Tail; b) Section BB; c) Section AA; d) View of hot forging;
e) View along A; f) Section 55; g) Section GG; h) Section DD;
i) Axis of the key

used which is placed on the anvil under the die. The tightening is accomplished by means of a wedge and key (Fig.72).

Material Used for Hammer Dies. The material used for multipass dies, in majority of cases, is alloyed steel (see Vol.6, Chapter IV).

For dies where great firmness is not required, grade Y7 carbon steel may be used. For the purpose of saving alloy steel, the die passes are often made in the form of inserts. In such a case, the stamping block (cube) can be made from grade 40X and even from grade 45 steel.

Stamping with Crank-Type Presses. The features of a crank-type press (Fig.73) used for hot stamping are: strength (to lower the deformation), sturdy guides (to have the slide-bar movements precise and exact) and ejectors (lower and upper) for the stand and for the slide bar).

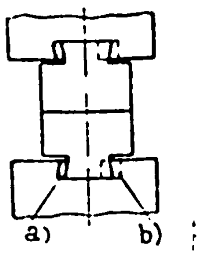

Fig.72

a) Wedge; b) Key

Typical characteristics of hot stamping crank-type presses are shown in Table 21.

Many of the operations performed by hammer presses are also performed by crank-type presses. Among these is stamping in open dies with the formation of projecting edges (burrs), extrusion, punching and different combinations of other operations.

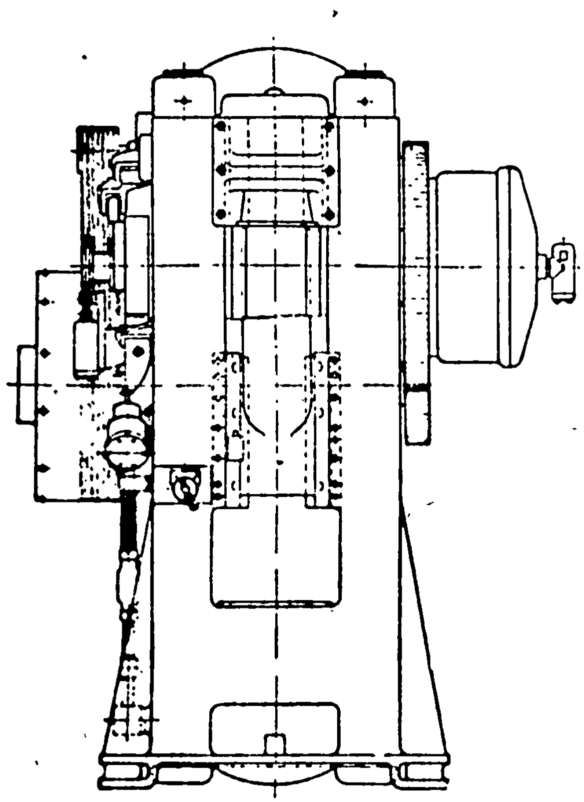

Fig.73 - Hot Stamping Crank-Type Press

When handling large quantities, or in mass production, the use of open dies in crank-type presses is a progressive step forward offering the following advantages, when compared to operations with hammers: first, the precision is higher, especially of the height of the forging; this is accomplished by the press mechanism alone by setting the low point of the upper die at a fixed position. Next, is the possibility of reducing the stamping slopes due to the presence of ejectors. This works for the reduction of metal consumption and the work to follow becomes easier. Further, the productivity is

Higher, it is 1.5 to 3 higher than the productivity of hammer presses and it is due to the fact that with a crank press, transitions from one operation to another are accomplished in a single stroke. Other advantages are: possibility of mechanization, and even of automatization of feeding the stock to the dies; reduced consumption of energy, greater safety and absence of vibrations.

Table 21

Specifications for Hot Stamping Crank-Type Presses (according to GOST 5808-53)

a)	b)	c)	d)	e)	f)
630	200	90	560	640×820	35
1000	250	80	560	770×990	55
1600	300	75	660	940×1200	115
2000	320	65	890	1060×1300	190
2500	350	60	890	1200×1400	—
3150	370	55	1000	1360×1500	—
4000	400	50	1000	1570×1620	—
5000	430	45	1150	1720×1780	—
6300	460	40	1150	1900×1930	—
8000	500	35	1240	2100×2150	—

a) Power in m; b) Length of stroke in mm; c) No of strokes/min; d) Maximum distance between the stand and the slide bar at its low point in mm; e) Dimensions of the stand in mm; f) Weight in m

A crank-type press can be used for every type of forging usually performed by hammers, if the following conditions are met:

a) The stock must be free of scale before entering the dies of the press, or it must be subjected to a heating by an induction heater, which practically produces no scale;

b) Forgings, with their portions differing sharply in cross-sectional areas, which in hammer forging require the use of rolling and drawing passes, such forgings can be handled by a crank press only if the stock is preliminarily shaped by another machine, or was periodically rolled before. The reason is that rolling operations on a crank press are hard to perform and are not practical.

The work should be done in specially designed stamping passes. With the upper and lower dies in a joint position, the depth of the recesses should absolutely be less than the height of the forging by the thickness of the projecting edge (burr). This is necessary to avoid thrusts by the press.

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Because, by its nature, the flow of metal in a crank press is unlike the deformation under a hammer it is, therefore, necessary to provide the dies under the crank press with preliminary passes to insure that the formation will proceed gradually (Fig.74).

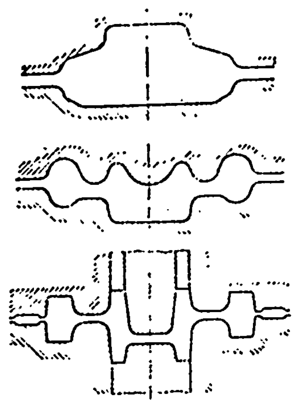

Fig.74 - Example of Consecutive Transitions in Forging by Crank Press

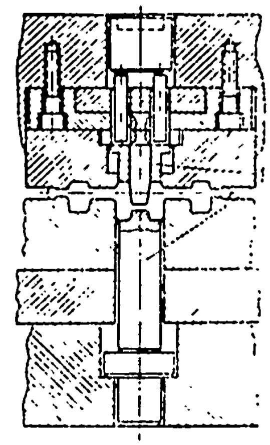

Fig.75 - Ejectors in Crank-Press Dies

When the stamping slopes are low, the bottom of the deepest recessed portion of the lower (also of the upper) die should perform as another part - the ejector (1)

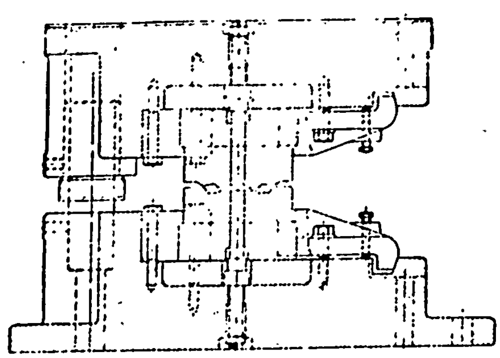

Fig.76 - Crank Press Die with Guiding Columns

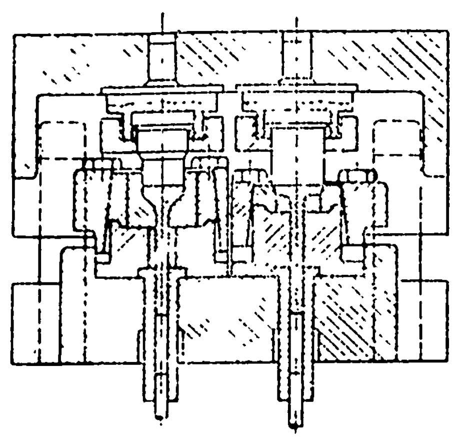

Fig.77 - Method of Forging a Valve in a Crank Press

(in Fig.75). The latter is actuated by ejecting devices in the stand and slide-bar.

Maximum precision in the upper and lower dies requires a guiding device (Fig.76).

The die-passes in a crank-press are usually designed as inserts in an iron ring, kept in place by bolts and shims (Fig.76).

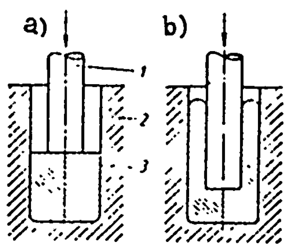

Fig.78 - Method of Pressing-In

1 - Upper die; 2 - Lower die; 3 - Stock

a) 1^{st} stage; b) Final stage

The dies are adjusted by bolts.

In selecting the tonnage of crank-presses for hot forging, the problem can be solved by considering the equivalent relation to the weight of the falling parts, namely, 1 ton of this weight is equivalent to 1000 tons of press power.

Stamping by Extrusion. The stock is placed in the matrix (lower die) with a hole in its bottom. The plunger (upper die) entering from above into the recess of the matrix compresses the stock and causes the metal to flow through the hole. In this deformation, part of the stock gets a smaller cross section. This process can serve as a substitute for certain upsetting operations of a horizontal forging machine, e.g., when the volume of a flange on a rod is so great that several intermediate steps are required to "gather" material. Example: the fabrication of a valve with a rod of 16.6 mm dia. and a valve disk of 83 mm dia. requires 7 - 10 transitions when fabricated on a horizontal forging machine and only two when produced in a crank-press by extrusion(Fig.77).

Pressing operations are used to obtain hollow products by the method in Fig.78.

Crank-presses may also be used for combined operations, i.e., one press for several operations, or the operations of a crank-press can be combined with those of another machine. Examples of such combined work are shown in Figs.77 and 79.

Horizontal Forging Machines. Method of forging in a horizontal forging machine is shown in Fig.80. The heated end of a bar is placed in the stationary (at the right) matrix (2), fastened to the immovable cheek of the machine (3). The position of the bar end is fixed by the prop (4). On starting the machine, the movable

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cheek (5) (left cheek) begins to move together with the movable matrix (6), the slide bar of the machine, and the upper die (7) (Fig.80 I). Before the upper die (7) touches the projecting butt end of the bar, the movable matrix (6) presses the bar to the immovable matrix (2), while the prop (4) moves aside. The bar is held fast in the tight part of the matrixes (Fig.80 II). With further movement of the slide bar, but before it reaches its extreme forward position, the upper die (7) upsets that part of the bar stock which is projecting beyond the tight place of the matrixes. The metal then fills the recesses (of the required configuration) in front of the tight portion of the matrixes (Fig.80 III). The shape-forming recess may be located in both upper and lower dies (Fig.81a) or only in the upper die (Fig.81b). On backward movement of the slide bar, the upper die moves out from the matrix recess, the matrixes move apart, the upset part of the stock is taken out, or drops out of the matrixes, and the upper and lower dies return to their original positions (Fig.80 IV). Depending upon the technological process, the same operation may be repeated, or the stock can be transferred from one pass to another, each transition being effected by one stroke of the machine. In several transitory operations (several die passes), the volume of the deformed metal remains constant, being equal to that of the bar portion projecting beyond the tight place of the matrixes during the first operation. Usually, one heating will provide several transitions.

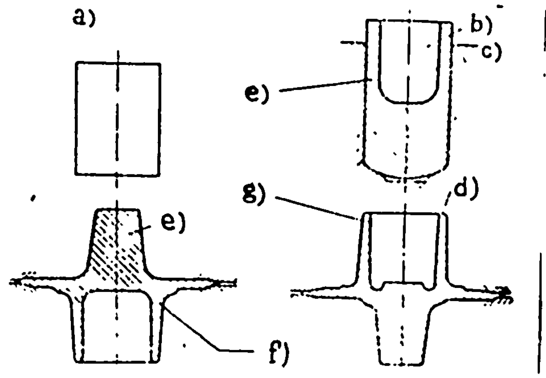

Fig.79 - Method of Using a Crank-Press for Combining Pressing-In with a Burr-Producing Stamping

a) Material; b) Upper die; c) Lower die; d) In the upper die; e) 1st pass - pressing-in; f) 2nd pass - rough; g) 3rd pass - clean

Besides the front type of props shown in Fig.80, back-type props are used for short pieces (Fig.82a and b), and pincer or tong-type props for very short pieces.

The stock for a horizontal machine is usually round (squares is less common)

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precision-rolled metal. Mostly, the stock to be forged has a length suitable for forging of several pieces.

When the stock is fed by hand with the aid of very simple devices, the length of the stock should not exceed 2 mm for a diameter from 50 to 60 mm (Bibl.5). For greater thicknesses, a length of 2 m is permissible only if the machine is provided with special lifting and manipulating devices (Bibl.5).

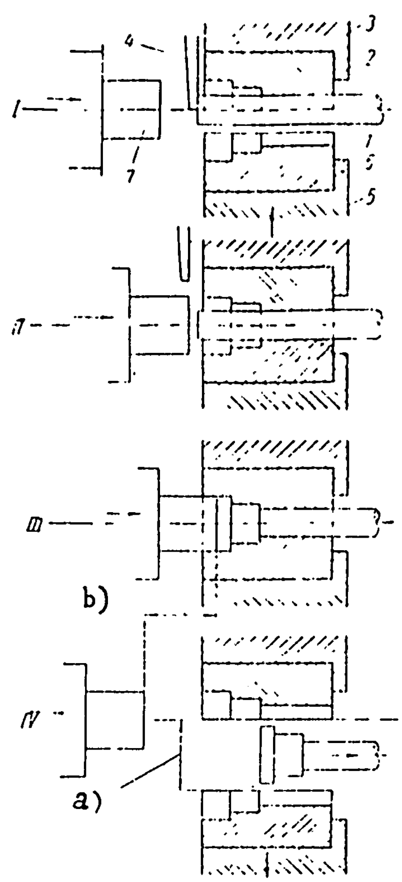

Fig.80 - Method of Forging in a Horizontal Forging Machine
a) Opening of the matrixes;
b) Working stroke

The predominant operations in a horizontal forging machine are pressing-in and upsetting. These machines are suitable for other operations (bending, squeezing, cutting off, etc.).

The advantages of a horizontal forging machine include: high productivity, prevention or reduction in projecting edges (burrs), forging of such shapes as rings without waste, a desirable macrostructure, etc. However, the horizontal forging machine, while advantageous for certain types of forging, is no substitute for a stamping hammer or for a hot-stamping machine.

The volume of the stock to be forged is determined by the volume of the finished forging and the volume of wasted material. The volume of the stock V_{oc} should be distinguished from the volume of that portion subject to upsetting V_{uc}, i.e., the projecting portion from tight place of the matrixes, which undergoes a deformation.

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The volume of the upset portion may be greater or less than the volume required for it as a forged piece. The usual waste from burning is $V_{r} \approx 2\%$ of the volume of the forging; the waste due to burrs is $V_z \approx 1 - 2\%$ of the forging volume, or of the upset portion; the waste due to punched-out material depends upon the configuration and the technological process selected.

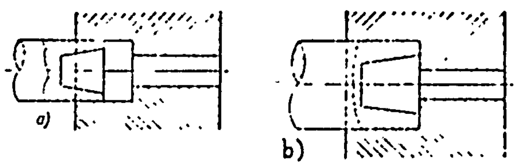

Fig.81 - Shape-Forming Recess
a - Simultaneously in the upper and lower dies; b - Only in the upper die

The diameter of the stock to be forged depends upon the configuration of the finished forging.

To reduce the number of operations, it is desirable to have the diameter of the stock as large as possible, provided the length of the portion subject to upsetting is not less than ~ 0.4 of the diameter of the stock and should exceed the length after the upset by not less than 15 mm (Bibl.34).

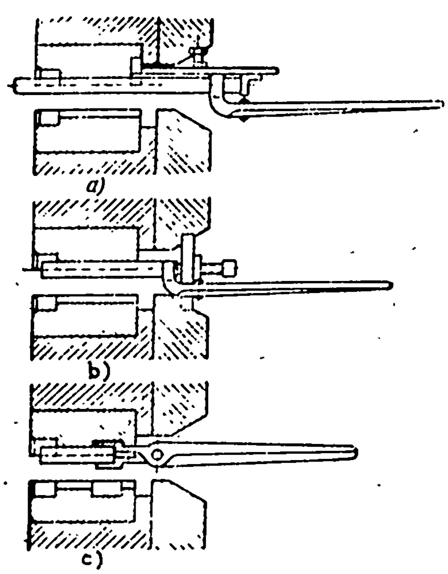

Fig.82 - Rack-Type Props

For forgings of the type of shafts with flanges, the diameter of the stock should equal the diameter of the shaft. For ring-type forgings, the diameter of the stock should equal, or be nearly equal to the diameter of the hole. For long hollow forgings, which are to have the shape of a drinking glass (Fig.83), the cross-sectional area of the stock should be equal, or be a bit smaller than the minimum circular cross-sectional area

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of the finished forging.

Regardless of the configuration of the recesses in the upper or lower dies, the upsetting of that end which projects itself from the tight place of the matrix can be effected only if the length of that end does not esceed 3 times (2.5 times is even better) the length of the diameter of the stock. If the length of the end is greater than just mentioned, a preliminary "gathering" of material should be effected.

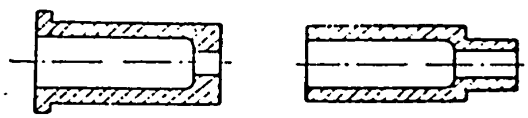

Fig.83

The "gathering" usually takes place in the recesses of the upper die (Figs.84a and b). The conical surface of the recess, preferably, should be small, about equal to the diameter of the stock (Fig.84c and d). In the "gathering" operation, the diameter of the upper-die recess, as well as the length of the portion subject to upsetting, must be within certain limits. (In the beginning of the operation, the end to be upset is outside the recess of the upper die.)

Following the letters shown in Fig.84, and assuming that $\frac{L}{d} = n$, $\frac{a}{d} = k$, $\frac{D_1}{d} = \alpha$, $\frac{D_2}{d} = \beta$, we get, when upsetting in a cylindrical die-pass ($D_1 = D_2$), $\alpha = \beta$; with the upsetting in a conical die pass and with a smaller diameter of the cone, $D_2 = d$, $\beta = 1$.

For repeated upsettings, the diameter of the stock d is substituted by d_1, which is the diameter at the peevious upsetting, remembering that when the upsetting takes place in a conical die-pass, d_1 is assumed to be the average diameter of the cone . (Fig.84b and d).

The values n, k, and α are interrelated. The value n is used to find the values of k and α (Bibl.43) from the following equation:

$$k \approx 0.85 \sqrt{n}, \text{ but no more than } 3;$$

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$$\alpha \approx 1.73\sqrt{\frac{n}{n-k}\left(\frac{\beta}{2}\right)^2 - \frac{3}{2}}$$ (Bibl.43)

When the values of k and α are found, the recess in the upper die can be determined as follows (Bibl.43):

$$l = d(n - k);\; D_1 = d\alpha\; D_2 = d$$

The value β is given in advance.

As was mentioned before, in repeated upsettings, the diameter d is substituted

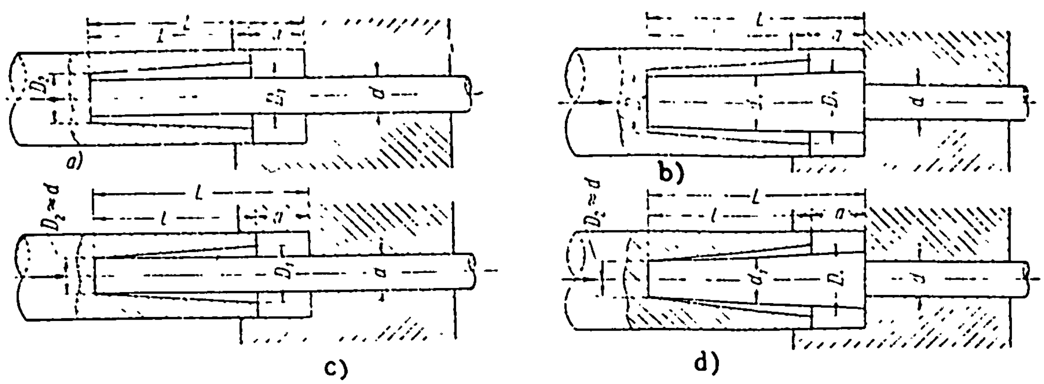

Fig.84 - The "Gathering" of Material in the Upper Die

by d_1.

A general view of a horizontal forging machine is shown in Fig.85, the basic specifications of this machine are given in Table 22.

See Fig.86 for the design of the die for a horizontal forging machine and the consecutiveness of the technological process.

The "gathering" of material takes place in the recess of the first pass of the upper die (1). The front portion (a) of pass (1) in the matrix directs the upper die during the upsetting operation. The insert (3) - the squeezing portion of the pass - exerts pressure on the stock, squeezing it in one direction and imparting to it an oval shape at the place of the squeeze. The diameter of the oval is now

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smaller and is about equal to the diameter of the opening of the finished forging. The tight portion (b) of pass (2) holds the stock in place during the upsetting.

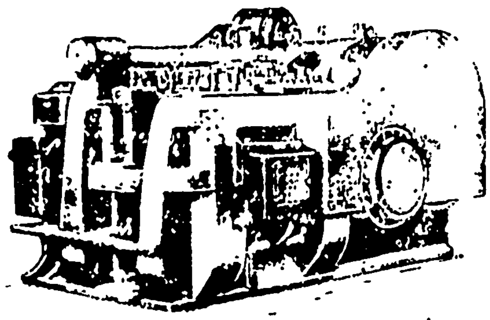

Fig.85 - Horizontal Forging Machine

In the second pass, the upset-producing upper die (4) is performing the preliminary shaping of the forging in the recess (5); at the same time, the projected part (d) marks the position of the opening to be. The squeezing insert (6) squeezes the stock in a direction which is perpendicular to the direction produced by the squeezing insert (3) of the first pass. This calls for turning the stock over an angle of 90° in its transition from the first pass to the second.

The final shaping of the forging is effected in the third pass; the opening is almost punched through by the sharpened plunger (7) which is part of the upper die (8). With the punching, the enlargement of the material on every side is also taking place and the forging gets its final dimensions. The squeezing insert (9) of the third pass performs the final squeeze; it makes a perfect circle at the place of the squeeze and is forming a cylindrical portion equal to the diameter of the opening.

The fourth pass is only for punching, the shape of the forging there is not changed. The punching is effected by a punching plunger (10) and by punching insert (11) located in the matrix.

In a die of the above type, there is also an additional pass (12) whose function is to cut off the cylindrical end (13) produced by the punching of the opening.

In this particular case, the projecting edge is very small and is removed by abrasion on a grinder, if it is formed at the butt end. If a circular burr is formed, it can be removed by the cutting pass of the die (Fig.87).

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In the example described above, the forged portion was separated from the stock by the punching operation, which is the usual case of forgings with holes along its axis. In other cases, the die pass is provided with a cutting part (Fig.88).

Table 22

Specifications of Horizontal Forging Machines

a)	b)	c)	d)	e)
100	70	55	95	8
160	90	63	75	12.8
250	110	85	55	20
400	190	125	45	40
630	230	160	35	70
800	250	180	33	85
1000	280	200	31	110
1250	310	220	27	135
1600	350	250	26	175
2000	390	280	25	220
2500	430	310	23	275
3150	480	350	21	350

a) Power in m; b) Length of stroke of the slide bar after closing of the matrixes; c) Length of stroke of the immovable matrix in mm; d) Strokes/min; e) Weight in m, up to

The matrixes (the lower dies) are secured to the cheeks of the machines with the aid of special shims. They may be of the one-piece type for small machines, or compound for large machines.

The upper dies are held in place by holders, directly or indirectly. The holders are either of one-piece construction, or they are compounded of several parts. They are located in the slide bar, to which they are secured by means of shims. The operating parts of the dies are made from alloyed steel (see Vol.6, Chapter IV).

Forging by Screw Friction Presses (Bibl.46). Screw-type friction presses are suitable for: 1) forging with open dies, similar to hammer forging, with formation of projecting edges in the plane of separation of the dies (Fig.89a); 2) forging with closed dies with separating or nonseparating matrixes (Fig.89b); 3)forging of bolts and rivets. The field of application of these presses is limited, chiefly because of their low productivity.

Specifications of such presses are given in Table 23 and a general view of the press is shown in Fig.90. The press is provided with an ejector at the bottom.

The force required for forging is

$$P = 0{,}01\sigma_{vp}F,$$

where P is the power of the press in m; σ_{vp} is the strength of the metal at the

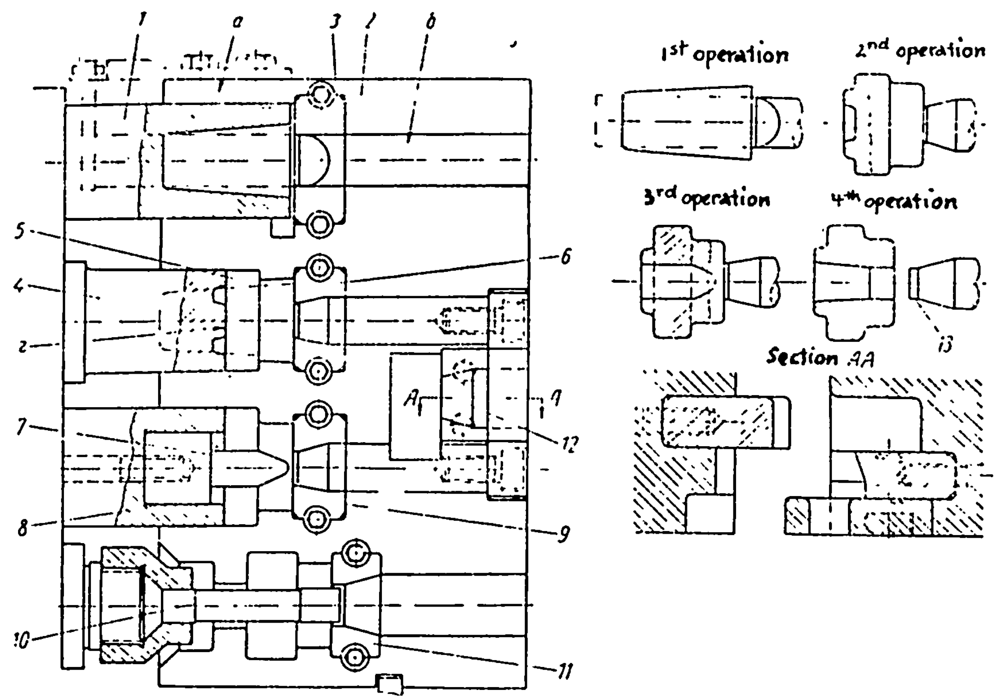

Fig.86 - The Design of the Die for a Horizontal Forging Machine

temperature of forging in kg/mm^2; F is the projected area of the forging in mm^2.

The dies for the screw-type friction press should be provided with guides, either of the lock type (Fig.91), or with cylindrical guides (Fig.92). The matrix (the lower half of the die), if of the movable (separating) type, is shaped conically and is held by a band which keeps the matrix securely in place (Fig.93).

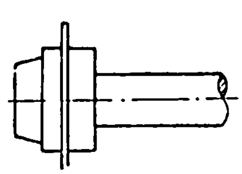

Fig.87

Forging by Hydraulic Presses (Bibl.46). Hydraulic presses are used for the following operations: 1) forging in closed dies (Fig.94) in which the matrix is of the movable type consisting either of two parts (Fig.95) or of several parts (Fig.96); 2) punching or piercing performed as a separate operation (Fig.97), or in combination with other operations, such as upsetting flanges, etc. (Fig.98). 3) drawing pierced pieces through a ring (Fig.99), or by means of rotating rolls; 4) forging with open dies with formation of protruding edges in the plane of separation of the dies (Fig.100); 5) some other work, particularly in combination with other operations.

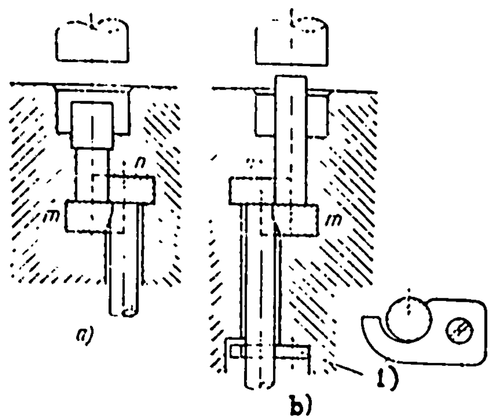

Fig.88 - The Cutting Part of the Die
a - Displacing the stock; b - Displacing the cut-off part
1) Support

The first three types of above forgings are typical for hydraulic presses. Some of the products produced by hydraulic presses are shown in Fig.101.

A hydraulic press can be used for forging large complex pieces with the use of multipass dies, for example, crankshafts.

As in other presses, a hydraulic press is also provided with an ejector. Before the stock enters the press, care should be taken to remove the scale from the stock after the heating. The effort required for forging is found by using the following equation:

$$P \approx k\,\sigma_{vp}F$$

where P is the effort in kg; σ_{vp} is the strength of material at forging temperature in kg/mm^2; F is the projected area of the forging, in mm^2; k is a coefficient equal to 2-6, depending upon the relative thickness of the walls and upon the complexity

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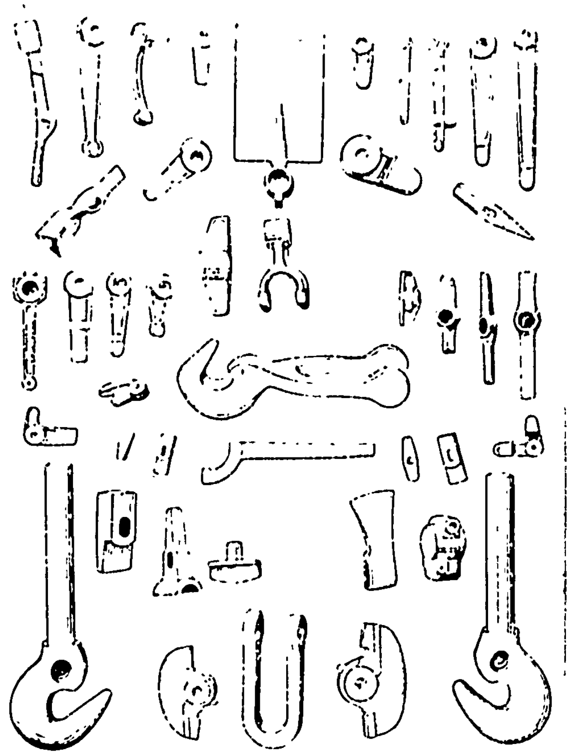
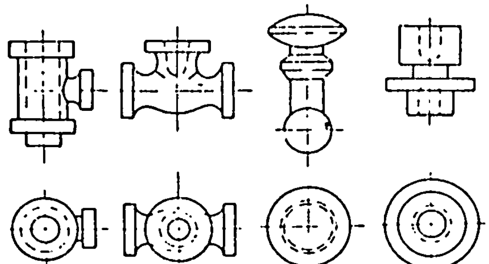


a)



b)

Fig.89 - Samples of Forgings Produced by a Screw-Type Friction Press

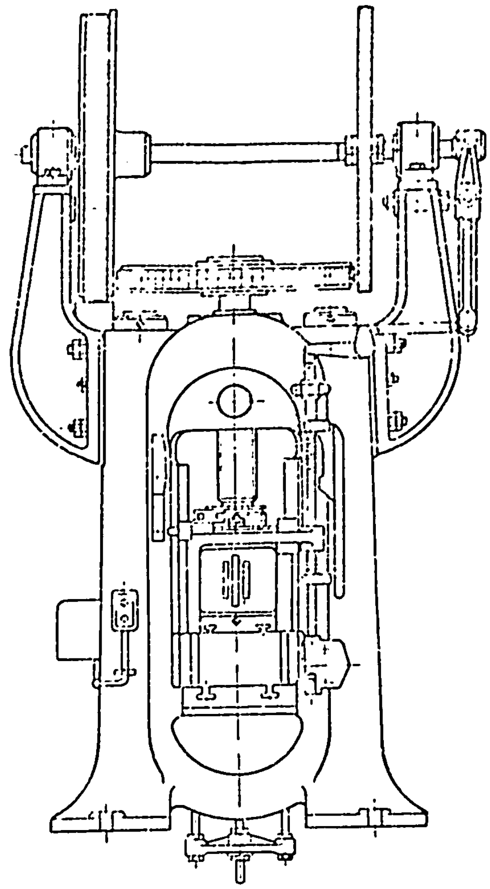


Fig.90 - Screw-Type Friction Press

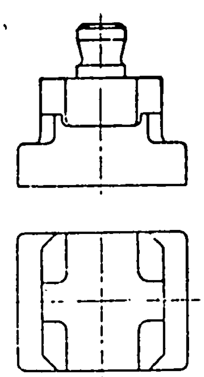


Fig.91

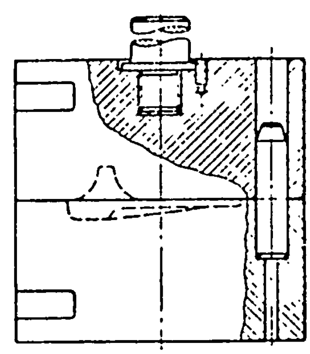


Fig.92

of the configuration.

Blacksmith-Type Forging Operations for Narrow Products. The horizontal bending machine shown in Fig.102 (bulldozer) is a type of horizontal press with its slide bar driven by a crank-type mechanism. The data shown in Table 24 may be used as a guide to the specifications of this type of machine.

Table 23

Specifications of Screw-Type Friction Presses (from GOST 713-49)

a)	b)	c)	d)	e)	f)
40	240	170	310	410 × 360	25
63	270	190	350	450 × 400	22
100	310	220	400	500 × 450	19
160	360	260	460	560 × 510	17
250	420	300	530	650 × 590	15
400	500	360	670	750 × 670	13
630	600	430	740	880 × 790	11

a) Rated force in m; b) Length of stroke in mm; c) Least distance between the slide bar and the stand in mm; d) Distance betwenn the guides in mm; e) Dimensions of the stand in mm; f) No. of strokes per minute

The work performed on these machines are predominantly bending operations on heated stock, and occassionally, combined with other additional operations, such as punching holes, cutting out, etc.

The stock mostly used is differently shaped rolled material, and in some cases, already forged or stamped stock.

Samples of products produced by a horizontal bending machine are shown in Fig.103.

The forging is effected by one or several transitory operations, depending upon the configuration of the finished product. The die passes are located one on top another (Fig.104).

Consideration should be given to the fact that precise dimensions can be obtained only for the internal radii r (Fig.105). Additional transitory operations are required to obtain precise dimensions of the external radii (Fig.106).

The vertical type of a forging machine is a high-speed press (600 - 800 strokes per minute) with several (3-5) slide bars made to move simultaneously by the con-

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necting rods of a crankshaft.

Each slide bar has its own stand whose height can be adjusted. A general view

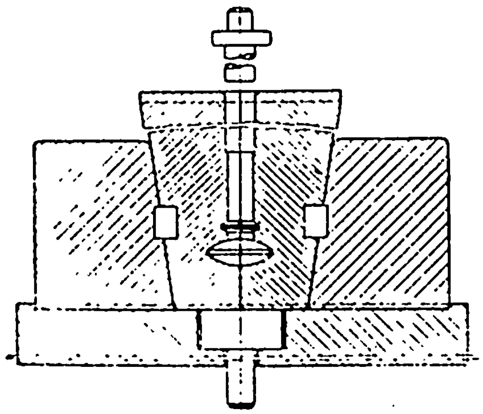

Fig.93

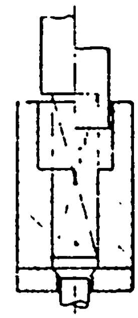

Fig.94

of a vertical forging machine with three slide bars is shown in Fig.107. Such a

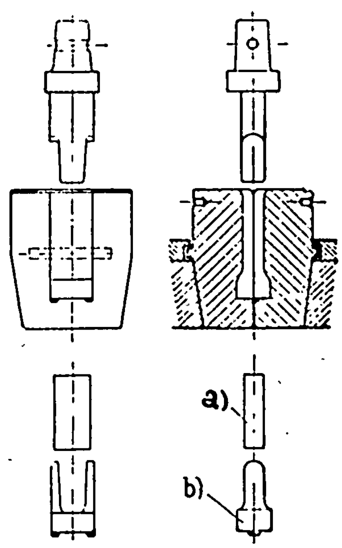

Fig.95

a) Stock; b) Forging

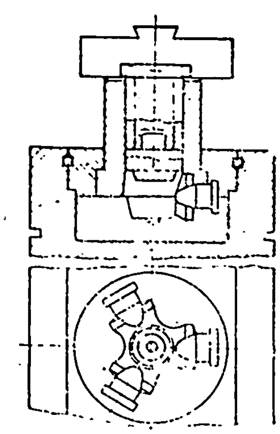

Fig.96

machine is used in production of small pieces having a simple configuration (Fig.108). The predominant operation is the drawing out by means of shaped strikers in sSTATl stages (Fig.109).

Rotary Forging Machines. The method of operation of a rotary forging machine

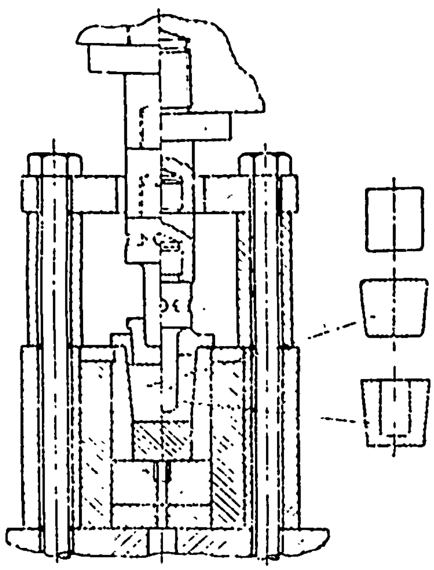

Fig.97 - Piercing Operations

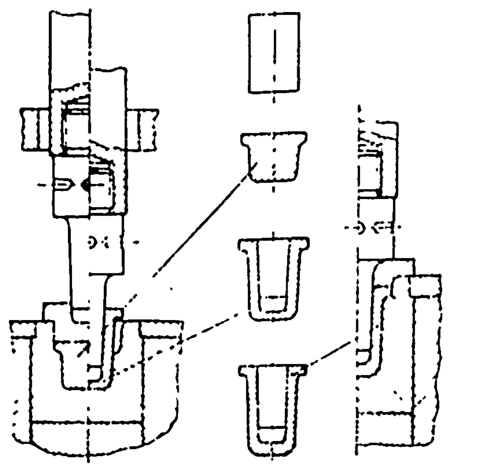

Fig.98

is shown in Fig.110. The slide bars (small hammers) (4) carrying the strikers, can

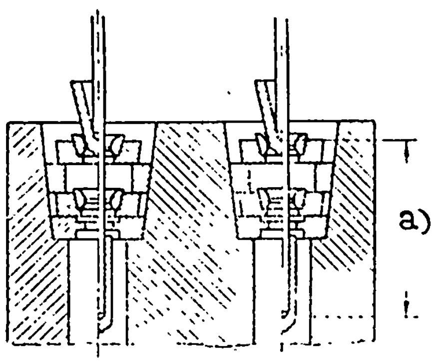

Fig.99 - Drawing Through a Ring

a) Length of plunger stroke

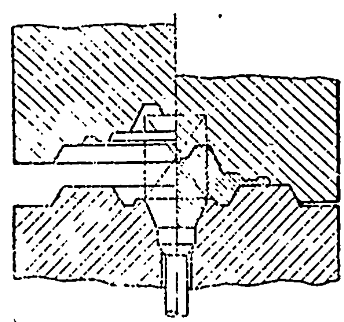

Fig.100 - Forging with Open Dies

slide along the grooves located radially in the head of the spindle (3). Thrust rolls (6) are located at the outside butt ends of the slide bars. The head of spindle (3) is inside of a ring (1). Roll (6) can move freely in the groove of

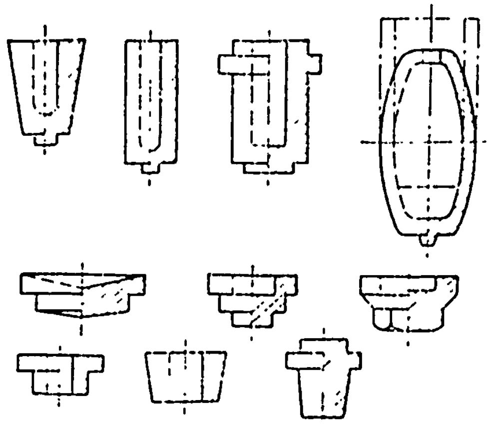

Fig.101

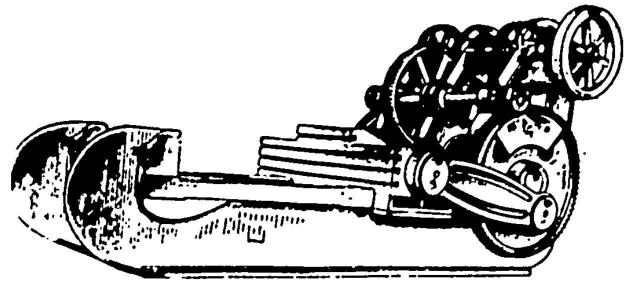

Fig.102 - Horizontal Bending Machine

ring (1). With the relative rotation of ring (1) and spindle (3), the rolls (2) will by means of rolls (6), push the slide bars in the direction of the axis, along which

Table 24

Specifications of Horizontal Bending Machines

b) \ a)	15–30	50	100	150	200	250	300	400	500
c)	350	375–400	400–420	450–500	470–500	500–530	550–600	600	750
d)	20–11	18–11	16–9	14–9	12–7	9–7	7–6	6	6
e)	8–6	10–8	15–12	20–15	25–20	30–25	40–30	45–35	50–40

a) Maximum effort in m; b) Items; c) Length of stroke of slide bar in mm; d) No. of strokes per minute; e) Size of electric motor in hp

takes place the closing of the two halves of the die (5).

In machines of the so-called 1st type, having a rotary instrument, spindle (3) rotates and ring(1) remains stationary. The opposite takes place in machines of the

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2nd type with a nonrotating instrument. In this case, ring (1) rotates with roll (2) and spindle (3) remains stationary.

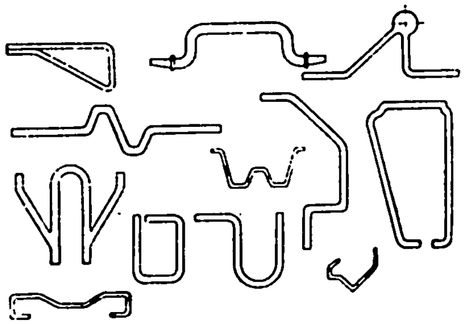

Fig.103

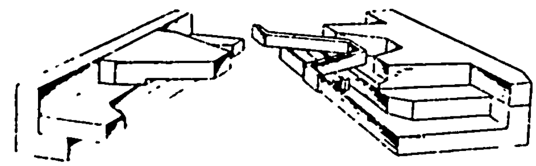

Fig.104

The movement backward of the slide bars is effected by the centrifugal force in machines of the 1st type, and by springs in the machines of the 2nd type. The number of slide bars is from 2 to 4.

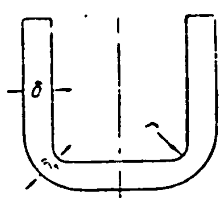

Fig.105 - Reduction of Thickness $\delta_1 < \delta$

The technological process of a rotary forging machine is the drawing out of the forging by means of shaped swage hammers. Bars, rods and tubes are used as stock. The machine of the 1st type can produce only round shapes, whereas the machine of the 2nd type can produce not only round, but also square, rectangular and other shapes. For this reason, the machine of the 2nd type is also known as the Universal. Products produced by the Universal Forging Machine are shown in Fig.111. The size of the machine depends upon the diameter of the bar or pipe to be fabricated (20-75 mm).

A rotary forging machine is very productive. For example, products of the type shown in Fig.111 can be produced at the rate of 100 to 600 pieces per hour, depending upon the complexity of the forging.

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The equipment for rolling consists of two rolls rotating in the opposite direction to each other (Fig.112). Attached to the rolls are the sections of the die

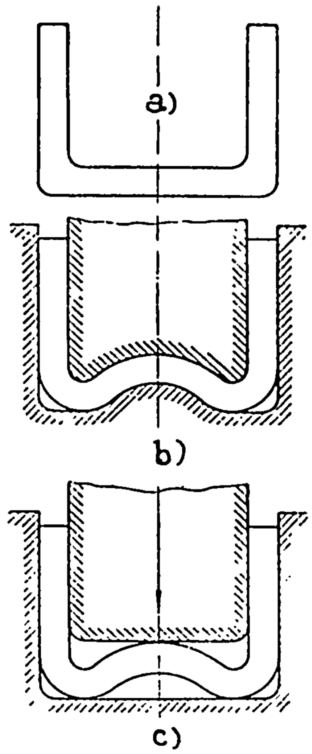

Fig.106 - Two Transitory Operations to Obtain Precise External Diameter

a) Forging; b) 1st Transition (end of process); c) 2nd transition (beginning of process)

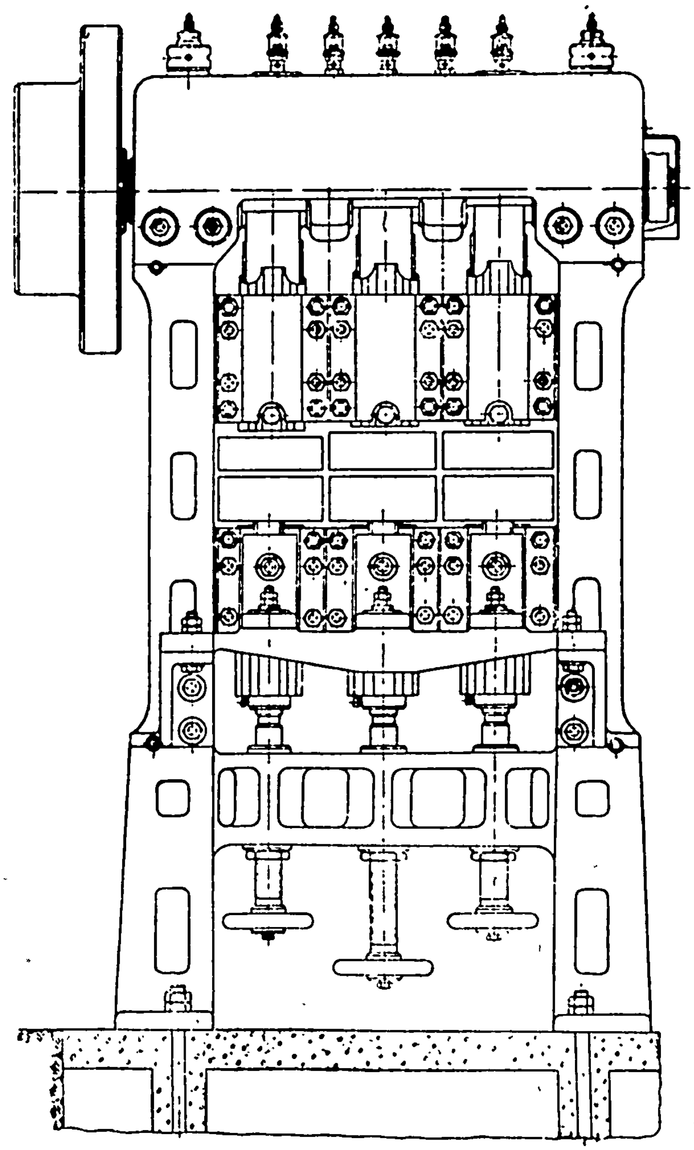

Fig.107 - Vertical Forging Machine

with the required passes. The feeding of the stock occurs at the moment when the die sections begin to separate. The stock is squeezed in the sections of the die.

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Simultaneously with the squeezing, the stock is being pushed out.

The basic operation of the forging rolls is to draw out the stock and to impart

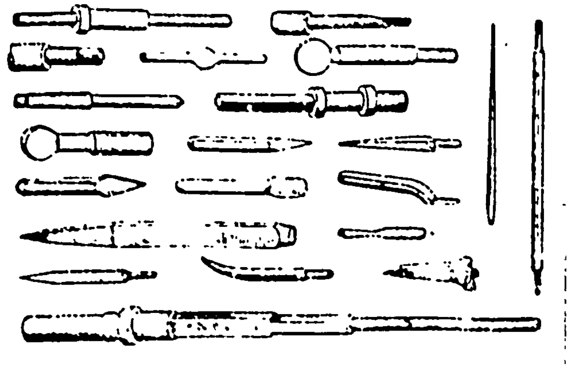

Fig.108 - Samples of Products Produced by a Vertical Forging Machine

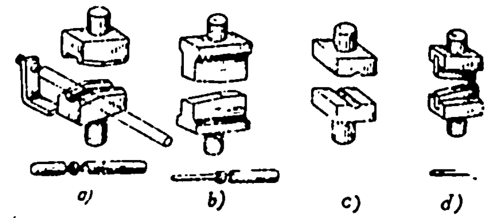

Fig.109 - Preparing the Stock for a Valve

a - Squeezing the bar; b - Rough drawing out of the tail; c - Finishing the tail; d - Cutting off the tail from the bar

to it the configuration required, in the longitude, or in the cross section.

The rollers are used either for a complete forging operation (Fig.113), or in combination with other machines (hammers, presses, horizontal forging machine, etc) (Fig.114). In the latter case, the rollers may perform from start to finish, or as a forerunner to operations on other machines, particularly in case of multi-shaped forgings.

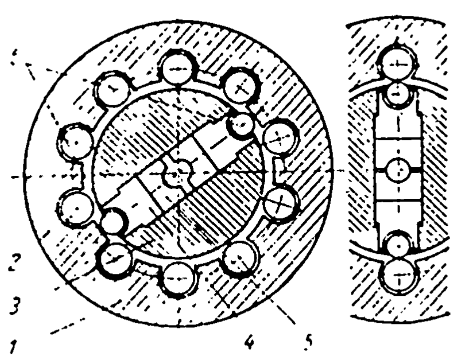

Fig.110 - Operation of a Rotary Forging Machine

The so-called roller stamping is also used, which makes it possible to produce a chain of products with complex configuration (Fig.115).

Depending upon the diameter of the rolls, the latter can handle forgings of

Simultaneously with the squeezing, the stock is being pushed out.

The basic operation of the forging rolls is to draw out the stock and to impart

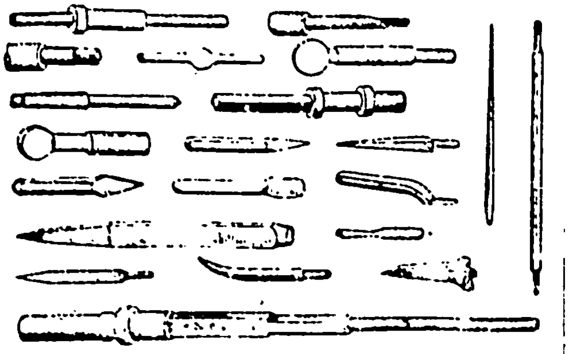

Fig.108 - Samples of Products Produced by a Vertical Forging Machine

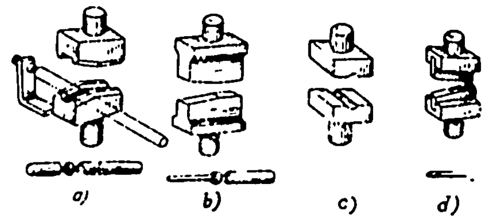

Fig.109 - Preparing the Stock for a Valve

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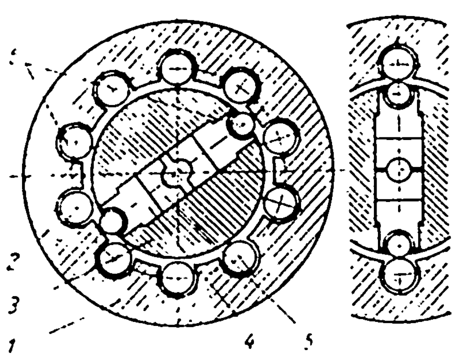

Fig.110 - Operation of a Rotary Forging Machine

The so-called roller stamping is also used, which makes it possible to produce a chain of products with complex configuration (Fig.115).

Depending upon the diameter of the rolls, the latter can handle forgings of

250 to 1250 mm in length. In the production of the smith forge type of products, several other machines of the roller type entered the market, particularly machines for enlarging.

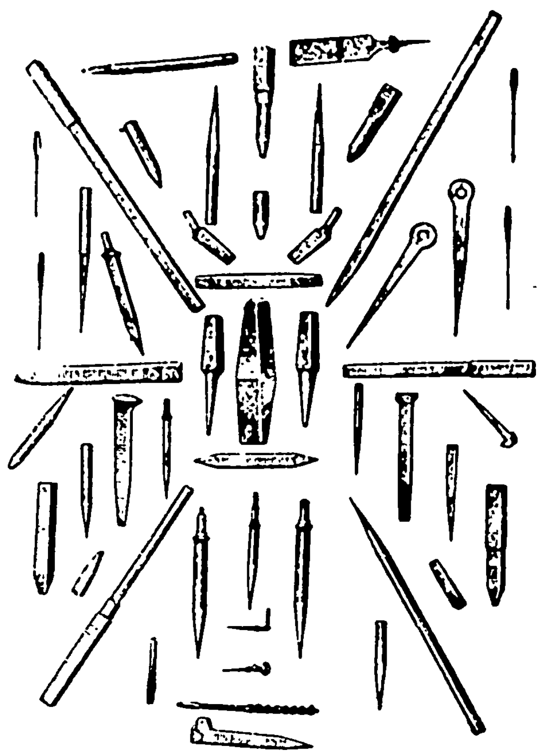

Fig.111 - Samples of Products Produced by a Rotary Forging Machine

Enlarging machines are used to produce ring-shaped products having thin walls (seats of roller bearings, water rings, etc). As stock for this purpose are rings of a smaller diameter, but with thicker walls, forged in advance by horizontal forging machines or by hammers.

Methods of enlarging are shown in Fig.116. The stock (1) is placed on roll (2) to which the rapidly revolving squeezer roll (3) is brought in contact. This causes the stock (1) and roll (2) to revolve. The enlarging operation is continued until the stock touches the calibrating roller (4) serving to insure a true center.

The method of enlarging ring-shaped items is very productive and makes it possible to obtain products with thin walls whose tolerance is very small (Bibl.1,16).

The Cutting Off and the Cleaning of the Protruding Edges (Burrs). The edges which are formed along the line of separation of the dies during the forging with open dies, are removed with the aid of cutting dies, installed in cutting crank presses.

The edge may be cut off either when it is cold, or hot. The cutting-off operation, during the hot state, is usually performed on products forged by a hammer with a weight of falling parts above 1 - 1.5 m. The cutting press, in this case, works in combination with the hammer.

There may also occur internal edges. These are arch-like, and are the result of

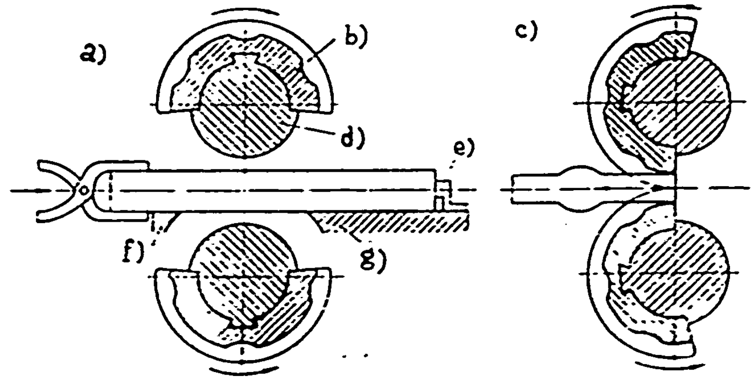

Fig.112 - Rollers at Work

a) 1st moment; b) Die section; c) Last moment; d) Roller;

e) Thrust; f) Front stand; g) Back stand

marking the place for holes during the forging, before they are punched out by a punching die.

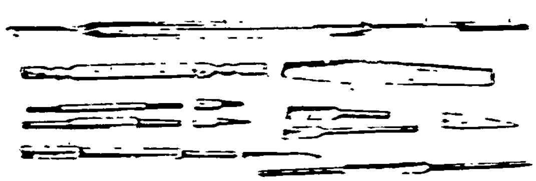

Fig.113 - Samples of Products Produced by Forging Rolls

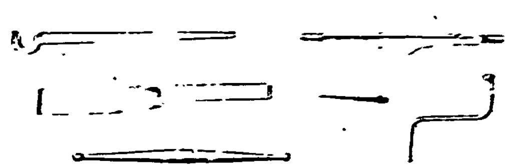

Fig.114 - Samples of Products Produced by Rolls in Several Operations

The cutting off of external edges and the punching out of internal ones can be accomplished in a combination die with one stroke of the press (Fig.117).

d for cutting off the edges can be calcul STAT by using the following equation:

$$P = \sigma_{vp} \delta S$$

where P is the effort of the press in kg; σ_{vp} is the strength of the material at the temperature of the cut-off place in kg/mm²; δ is the thickness of the cut-off edge in mm; S is the perimeter of the edge, measured around the cut-off plane.

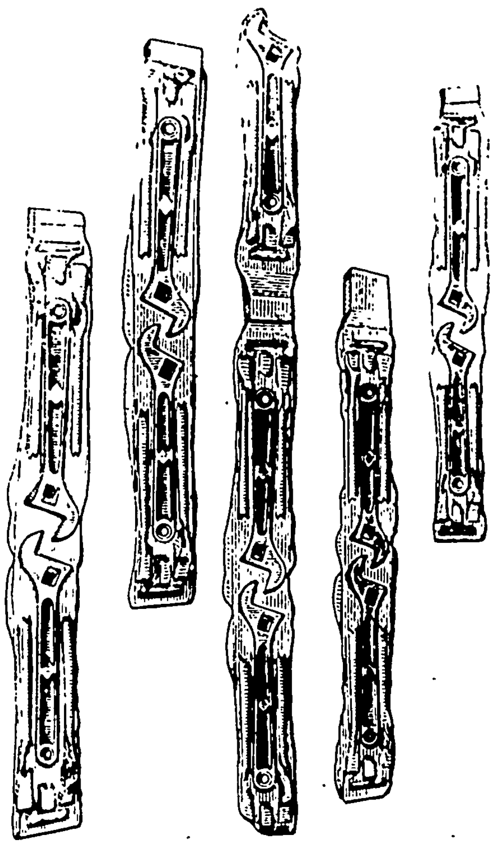

Fig.115 - Samples Produced by Rollers

The upper and lower halves of the die are made from alloyed stamping steel, and also from instrument carbon steel, (see Vol.6, Chapter IV).

The roughness remaining after the removal of the edge by the cutting die, also, the very small end edges produced in the forging and cutting of radially-shaped edges by horizontal machines and by the closed matrixes of a press, are removed by a grinding machine.

The Trueing of Forgings. Certain forgings, especially those having complex configurations, require a trueing operation, after the cutting off of the protruding edges. The trueing may be "cold", or hot and is effected in hammers, either in the final pass of the hammer die, or in special trueing dies (Bibl.36, 1), or in crank (cutting) presses.

"Hot" trueing by crank presses is effected in the trueing die, or in a combined die (a cutting and trueing die). The same is performed in the case of hammer

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trueing.

The same method is applied for "cold" trueing. In hammer operations it is done after the annealing and normalizing required for medium-zize or small pieces made of a material which is not very brittle. The crank presses are able to handle small

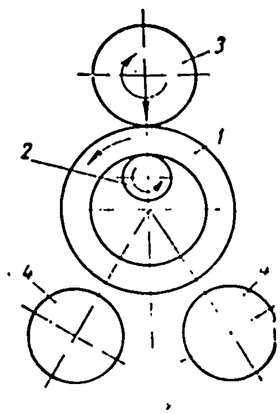

Fig.116

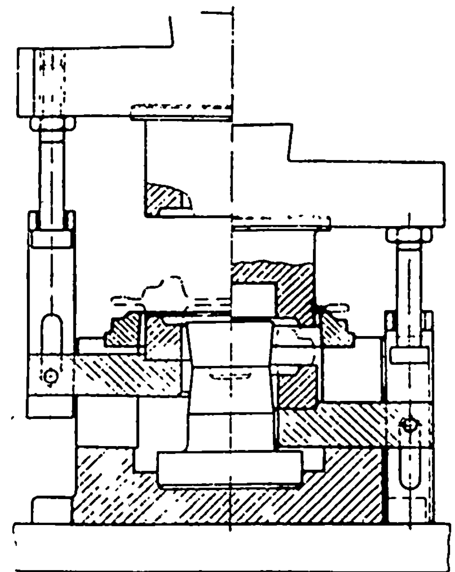

Fig.117 - A Combination Die

forgings with any configuration and by the same methods, as in hot trueing (Bibl.36, 1).

Calibrating (embossing, coining, etc). Calibrating is a finishing operation and implies the use of pressure. Forgings of precise dimensions, with precise weight and high quality surfaces are made possible by calibrating.

Very often, calibrated surfaces required no machining. Calibrating can be performed on cold or hot forgings. Cold calibrating (coining) can produce a maximum precision in the dimensions of a forging and a high quality of its surface. Hot calibrating is better for large forgings, but the precision is not as high as in the cold process.

Calibrating is performed in crankthrow-type coining presses. It can also be performed in crank presses for hot forging, especially suitable for hot calibrating. Hammers and screw-type friction presses may also be used, but the results will not be as good.

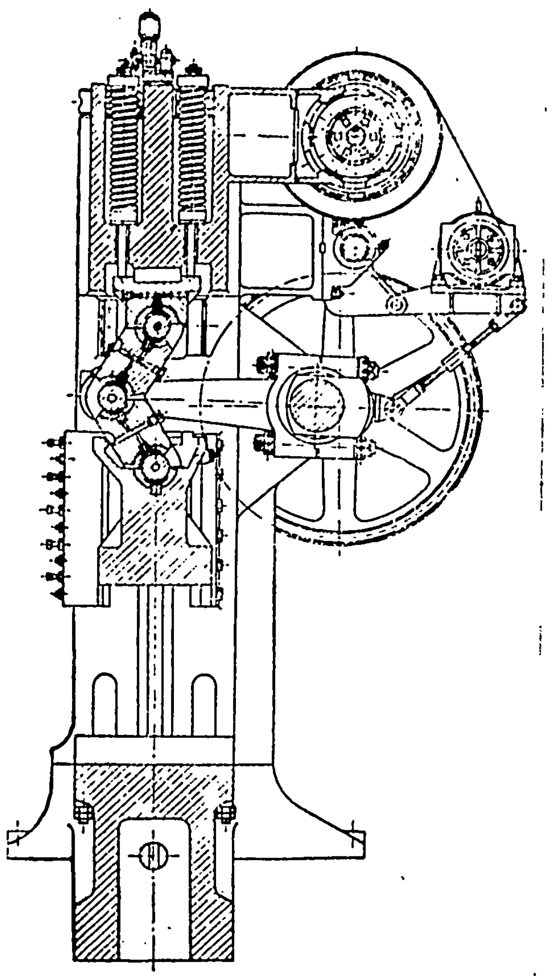

Fig.118 - Crankthrow-Type Coining Press

A sectional view of a crankthrow-type coining press is shown in Fig.118, while Table 25 shows the specifications of such presses.

Following are the types of cold calibrating-coining operations: flat surfaces, curvilinear surfaces of rotating bodies, voluminal coining and a combination of several operations.

Flat surface calibrating (Fig.119) is used to obtain precise distances between different (mostly parallel) planes in the body of the forging and to impart to them surfaces of high quality. In this operation, there will be an increase in those dimensions of the forging, which are perpendicular to the direction of the calibrating. The exactness which may be obtained as result of flat plane calibrating is shown in Table 26.

For tolerances permitted for dimensions perpendicular to the direction of calibrating, see Table 26a.

Allowances should be made in the dimensions of a forging subject to calibrating, the exactness of the dimensions should be higher (see Table 27).

It must be kept in mind, that by increasing the allowances for calibrating, the

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exactness of the dimensions after the calibrating is decreased, but the quality of the surface is improved.

Table 25

Specifications of Coining Presses

(from GOST 5334-50)

a)	b)	c)	d)	e)
63	40	50	270	310 × 310
100	40	50	290	370 × 370
160	45	50	320	440 × 440
250	50	45	360	540 × 540
400	55	40	410	660 × 660
630	60	35	470	790 × 790
800	65	33	500	860 × 860
1000	70	31	510	930 × 930
1250	70	29	580	1010 × 1010
1600	80	27	620	1120 × 1120
2000	80	27	660	1300 × 1300
2500	90	25	700	1400 × 1400
3150	100	20	760	1500 × 1500

a) Required effort in m; b) Length of stroke in mm; c) Strokes/min (normal); d) Maximum distance between stand and slide bar at lowest point in mm; e) Dimensions of the stand (normal) in mm

Calibrating Curvilinear Surfaces. An example of calibrating a curvilinear surface of a forging is shown in Fig.120 and the die for this operation is shown in Fig.121.

The calibrating is effected by exerting pressure. The piece is pressed a few times, being turned over after every squeeze at a certain angle around its axis.

Curvilineal calibrating is not as precise as the calibrating of a plane surface.

Three-Dimensional Calibrating is basically used as a finishing operation with the simultaneous increase in the precision of every dimension and of the weight. Three-dimensional, or voluminal calibrating is performed in a die with recesses which are a duplicate of the forging configuration and dimensions (Fig.122). If a protruding edge is formed, it may be removed by abrasion. The precision is not as great in a plane surface, being 30 - 40% lower.

Voluminal calibrating may be used for calibrating heated forgings. In this case, the required effort of the press is less (considerably less) than in cold calibrating, but the precision and the quality of the surfaces is lower. A combined

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operation consists of two calibrations done consecutively, first the volume and after the surface.

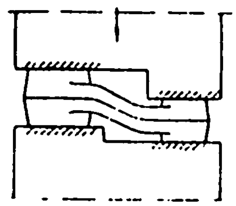

Fig.119

The effort required for calibrating is found by using the following equation:

$$P = KF$$

where P is the effort in m; F is the projected area of the surface subject to calibrating in cm^2; K is the specific pressure in m/cm^2

Values of K in m/cm^2

Steel	Voluminal Calibrating	Surface Calibrating
Carbon steel	20 - 30	13 - 16
Alloyed steel	up to 40	16 - 20

Preliminary Operations before the calibrating of forgings consists of in cutting off and cleaning of the protruding edges and removing the scale by etching, or

Table 26

Tolerances for Dimensions between Calibrated Surfaces after Flat-Plane Calibrating (Bibl.40)

Area of the Calibrated horizontal Projected Surface in cm^2	Tolerances ± in mm	
	Usual Exactness	Exactness experienced in Industry
< 3	0.1	0.05
3-10	0.15	0.08
10-20	0.2	0.1
20-40	0.25	0.15

in a drum by streams of sand or small shot. It is desirable to combine these two cleaning operations, i.e., the etching with the mechanical cleaning.

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The Calibrating Dies consist of a top and bottom plates (see Fig.121,1), two intermediate plates (Fig.121,2) and two operating plates (Fig.121, 3).

Table 26a

Tolerances for Dimensions Perpendicular to the Direction of the Pressure, when Calibrating (Bibl.40)

b)	c)	a) d)	a) e)
20—40	< 0,25	+1,5 −0,5	+1 −0,3
	0,25—0,5	+1,2 −0,5	+0,8 −0,3
	> 0,5	+0,8 −0,5	+0,5 −0,3
40—75	< 0,25	+2 −0,5	+1,2 −0,3
	0,25—0,5	+1,5 −0,5	+1 −0,3
	> 0,5	+1 −0,5	+0,8 −0,3

a) Tolerance in mm; b) Diameter or width of forging in mm; c) Ratio of forgings thickness or width; d) Usual exactness; e) Increased exactness

Table 27

Allowances and Tolerance in Dimensions of Products Subject to Cold Calibrating (Bibl.40)

a)	b)	c) d)	c) e)	f)
< 30	< 10	0,3	0,1	0,4
< 30	10—30	0,4	0,2	0,5
30—80	< 10	0,4	0,2	0,5
30—80	10—30	0,5	0,25	0,6
30—80	30—80	0,6	0,3	0,8
80—120	< 10	0,5	0,25	0,6
80—120	10—30	0,6	0,3	0,8
80—120	30—80	0,8	0,4	1
120—180	< 10	0,6	0,3	0,8
120—180	10—30	0,8	0,4	1
120—180	30—80	1	0,5	1,2

a) Length of product in mm; b) Thickness (in the direction of the pressure in mm; c) Allowances for calibrating in mm; d) Usual exactness; e) Increased exactness; f) Tolerance for forging (+), in mm

Special Features in Forging Aluminum, Magnesium and Copper Alloys (Bibl.2).

Aluminum, magnesium and copper deformed alloys are known for their following features:

1) Small temperature intervals (see earlier in text) are required for forging

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and stamping. These intervals should be strictly maintained to insure a forging of good quality.

2) These alloys are sensitive to the rate of deformation. Increasing the rate of deformation will lower the plasticity of the metal, and will also lower the interval of the critical degree of deformation* (Table 28).

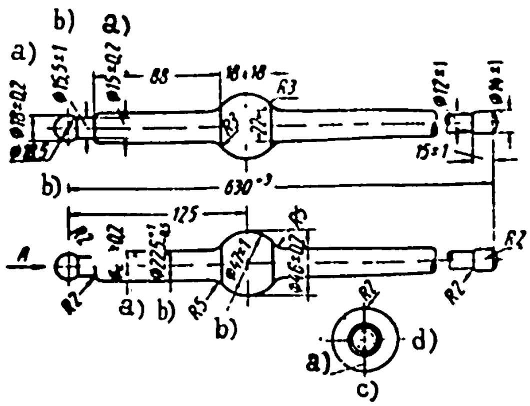

Fig.120

a) After coining; b) After forging; c) Line of die separation; d) View of along A

3) Sensitiveness to the state of stress; the more the deformation tends towards all-around contraction, the higher will be the plasticity. For stamping, therefore, closed dies are to be preferred and cut-out strikers are to be used for forgings. The stamping slopes should not be higher than 1.5 - 3%.

4) Sensitiveness to the irregularity of deformation, which lowers the plasticity and causes irregularity in the structure of the forging which, in its turn, lowers the fatigue quality of the metal. Therefore, the forging of a complex piece should be effected in several transitory operations, changing the shape gradually, from simple to complex. The separation of the dies should be so designed, as to prevent the protruding edge (burr) from locating itself in places of greatest stress, which the finished product will experience when at work.

Abrupt changes are to be avoided and the dies are to be lubricated.

For methods of forging and stamping aluminum, magnesium and copper alloys, see Bibl.2

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* The critical degree of deformation is that value of deformation, which at the operational temperature will produce the maximum growth of the grains.

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SHEET METAL STAMPING

Any part, or an assembly of parts of a machine is distinguished by the following features:

1) The shape of the part;

2) The precision of its dimensions;

3) The quality of the surface forming that part;

4) Its strength.

In determining the shape of the part the design should be governed by economic considerations which are the deciding factor in the problem of apportioning the metal which, in its turn, is the basis of the kind of operation required.

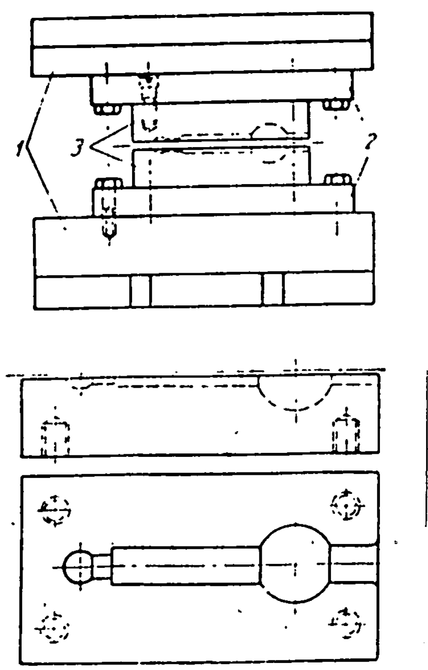

Fig.121 - Example of Calibrating a Curvilineal Surface

1 - Top and bottom plates; 2 - Intermediate plates; 3 - Operating plates

As far as precision is concerned, in sheet metal stamping it depends upon the nature of the stamping operation. As an example, calibrating and cleaning operations can produce a third and even a second class of precision.

The quality of the surface, as well as the precision, vary for different operations. A surface of the best quality may be effected by calibrating and cleaning which can produce a 6-8th class of cleanliness.

The strength of the part is the result of the fact that in stamping, the fibers do not cross each other, but are oriented in accordance with the outlines

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of the shape of the die (Fig.123). Another achievement of stamping is the strengthening of the surface layer which makes the part stronger.

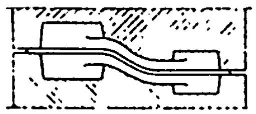

Fig.122

Presses for sheet metal stamping are of a great variety. There are the so-called universal presses which can be used for many products, and specially designed presses. In other words, the stamping of any product in any quantity is not limited by the absence of a suitable press.

Table 28

The Critical Degree of Deformation of Aluminum and Magnesium Alloys

(Bibl.2)

Alloy	Interval of Critical Degrees of Deformation during the Operation in %	
	Under Hammer	Under Press
D1	3-15	10-50
AK2	3-18	10-60
AK5	6-23	20-60
MA2	Do-10	0.3-10
MA3	6	Do-10

There are presses of various designs. For stamping of large quantities, the press is designed to fit the particular part to be stamped and the nature of the operation. Such presses are sturdy and very productive, but are expensive and take a lot of time to build.

For small quantities, presses of universal application are in use. Also in use are dies with working parts made, not from steel, but from other material (zinc based alloys, for instance), which can easily be machined, or changed to another

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form.

For stamping small quantities of parts having a simple configuration - dies of a simplified design are used. Above all, it must be borne in mind that the unification of operations and the standardization of the parts obviates the necessity of designing dies individually to fit only a certain product and makes it possible to design dies able to handle a great quantity of parts.

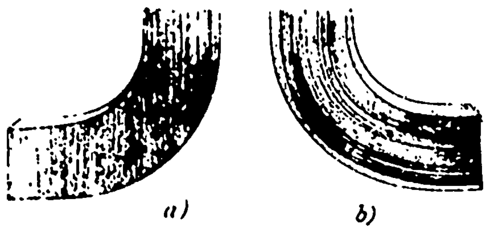

Fig.123 - The Disposition of Fibers
a - The part was cut; b - The part after stamping and bending

Parts stamped by a comparatively small die in a small or medium sized press may be welded together into a large stamping to be handled by a large press.

In going over from one method of shape-changing to another it is necessary to redesign the part. This should be done without changing the previously joined surfaces and without changing their positions.

Samples of sheet metal stampings are shown in Fig.124

TECHNOLOGICAL DATA FOR SHEET METAL STAMPING

A List and Nature of Sheet Metal Stamping Operations

Depending upon the temperature of the material, sheet metal stamping is divided into cold and hot operations.

Depending upon the nature of deformation, operations are: separating, forming and complex.

Separating operations are those resulting in the destruction of the deformed parts, such as, cutting, cutting off, cutting out, chipping, piercing, cleaning, etc.

The forming, or rather form-changing operations, result in changing the shape of the deformed portions of the material and their dimensions, such as bendin

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bending combined with enlarging, profiling, rolling, drawing, trueing, shaping, pressing, etc.

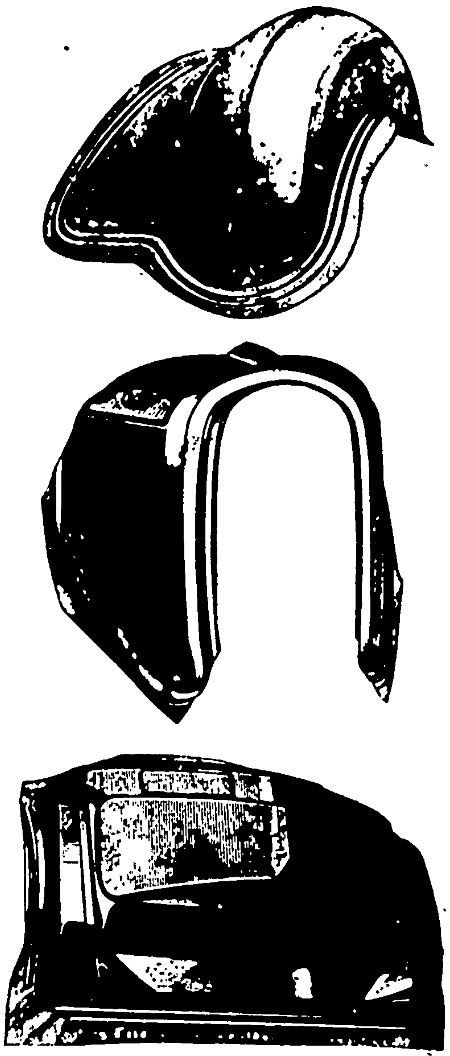

Fig.124

The complex operations are those resulting in the change of shape and dimensions of the deformed portions and in their destruction.

Separating Operations. Slitting. This is used to divide the sheet into strips, or to divide a wide band into narrow ribbons; the direction of the slit is along a straight line. The slitting is effected by means of sheet shears (guillotine), or by disk shears (rollers). Both of these have a universal application.

The effort in kg, required for slitting a material with sheet shears is shown below:

$$P = 0.3 \frac{S^2}{\tan \alpha} \tau_o$$

where α is the knife slope in degrees; S is the thickness of the sheet in mm; the τ_o, which is the resistance to being cut in the die, can be found in Tables 29 and 30.

The thing to consider in shears is the thickness of the material to be cut and, for guillotine shears - also the length of the cut. The force Q in kg, required to cut the material with disk shears is:

$$Q = 0.32 S^2 \cos 0.5 \alpha \tau_o$$

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where α is the angle of seizure of the material by the disks, which should not exceed 20°.

Table 29

Values of τ_o for Various Materials

Material	τ_o in kg/mm^2
Paper*	3
Paperboard	3
Paperboard, Bristol*	6
Asbestos*	3
Mica	11
Rubber**	1
Leather, soft*	1
Leather, tanned*	5
Leahter, sole*	9
Textolite	10
Celluloid	7
Fibers	11

* The upper die is a knife

** Knife as the upper die, also lubricated.

Cutting Off is the separation of part of the length from a flat or profiled strip or from a ribbon. The cut-off end may be curvilineal, or straight. The cutting is performed by dies (universal type, or specially designed) in a press, and in some exceptional cases, by guillotine shears.

The cutting by dies may be one-sided (without waste) and two-sided (with waste). Profiled material is usually cut by the two-sided method.

The determination of the force required is explained below, in the description

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Table 30

Values of α_o and τ_v for Various Metals

Metals	σ_{vp} in kg/mm^2		τ_o in kg/mm^2	
	Annealed	Hardened	Annealed	Hardened
Lead	2.5-4	-	2-3	-
Tin	4-5	-	3-4	-
Zinc	15	-	12	-
Aluminum	8	17	7	13
Duralumin	26	48	22	38
Copper	22	30	18	25
Brass	28	50	22	35
Bronze, rolled	40	60	32	50
German silver	35	60	28	50
Melchoir	30-38	-	-	-
Sheet steel:				
with 0.1% C	32	40	25	32
" 0.2% C	40	50	32	40
" 0.3% C	45	60	36	48
" 0.4% C	56	72	45	56
" 0.6% C	72	90	56	72
" 0.8% C	90	110	72	90
" 1.0% C	100	130	80	105
Silicon steel	55	65	45	56
Stainless steel	65-70	-	52	56
20XGC (normalizing at 900°, annealing at 600°)		60	-	-
30XGC (normalizing at 900°, annealing at 650°)		65	-	-
25H, hot rolled without annealing		48	-	-
25H3 (normalizing at 900°, annealed at 650°)	-	60	-	-
65G	70	90	-	-

STAT

187

of the "Chopping-out Operation", and the force required when guillotine shears are used, was given in the part dealing with "Slitting Operations".

Cutting Out is the method of obtaining from a sheet, or from other stock, a part with a closed or unclosed contour. This operation is performed by shears (rounded, disk, guillotine and vibration types) or by special dies in presses.

Chopping Out is used to obtain a piece with an outside contour from a ribbon, strip, sheet, stock or from waste material. The work is performed on presses with special dies.

The force P, in kg, required for chopping out by means of the flat butt ends of the lower and upper dies is:

$$P = L \cdot S \cdot \tau_o$$

where L is the perimeter of the chopped-out piece in mm; and τ_o is the resistance to the cutting (see Tables 29 and 30).

The force P required for chopping out and also for piercing (see below) may be made smaller by the following methods:

a) By heating the material, which lowers the value of τ_o. The material is not to be heated, when its thickness $S < 2.5 - 3$ mm; materials which cannot be stamped cold, such as textolite and getinax, are the exception.

b) Arranging the location of the plungers (when a multiplunger die is used) in stages, so that the butt ends of the plungers will also be arranged in stages. A two-stage or a three-stage arrangement is recommended. Since the entire perimeter L will be made up of two l_1 and l_2, or of three l_1, l_2, l_3 perimeters, it is necessary to determine the force required for each stage and select the greatest.

c) Using a plunger or matrix with sloping (wave-shaped) cutting edges; part of the edge may remain parallel to the stand of the press.

The force P in kg, required by rubber die locked-in in a ring, may be determined by using the following equation:

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$$P = Fp$$

where F is the lower plane of the rubber die in cm^2; p is the specific pressure of the rubber die in kg/cm^2 the value of which is approximately the same as for chopping out and piercing of materials with various thicknesses as shown in Table 31.

Table 31

A Guide in Determining the Values of p Required in Chopping Out and Piercing Operations

Sv mm	pv kg/cm^2	
	Light Nonferrous Alloys	Soft Steel
0.4	40	110
0.6	60	170
1.0	90	230
1.0	125	-
1.3	160	-

When the upper and lower dies (plunger and matrix) are made of steel, there will be a clearance Z_s between them. The optimum value of a two-sided clearance (at which the cracks appearing on the blades of the plunger and of the matrix meet) (Fig.125), is found by using the following equation:

$$Z_s = S \cdot x$$

where x is the coefficient, whose value depends upon the material used. The values of x are shown in Table 32.

A chopped-out piece will have the dimensions of the matrix, and a punched-out piece will have the dimensions of the plunger.

With the clearance between the two halves of the die at its optimum value Z_s, the surface of the hole, or the controur of the chopped-out piece will consist of a

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shiny belt and of a conical rough part (Fig.125). When the clearance is less than the minimum allowed, the result will be a secondary cut with the formation of a

Table 32

The Values of the Coefficient x which Determines the Size of Clearance in Chopping Off and Piercing Operations

Material	Coefficient x at Room Temperature			
	25°C			600°C
	Optimum	Minimum	Maximum	Optimum
Copper, brass, zinc, aluminum	0.08	0.04	0.25	0.04
Steel, soft 0.1 - 0.2% C	0.1	0.05	0.35	0.05
Steel, medium hardness 0.2 - 0.4% C	0.12	0.06	0.4	0.06
Steel, hard 0.5 - 0.8% C	0.14	0.07	0.5	0.07

second shiny belt on the conical surface. This second belt will not be shiny all over, but will be torn in places. A clearance greater than the maximum allowed, also dull cutting edges of the die will produce a burr. A burr of less than 0.1 mm is easily removed by tumbling in a drum.

The sloping cutting edges of a die, in a chopping-out operation, are distributed on the lower half (matrix) of the die, if the butt end of the upper half (plunger) is flat. In a punching-out operation, the sloping cutting edges are distributed on the plunger (the mirrow surface of the matrix being flat). In a chopping-out operation the sloping cutting edges can do the bending and shaping at the same time.

The border of a piece stamped out by a rubber die is inferior to the border of a piece when a steel die is used.

<u>Punching</u> is the formation of an internal contour (hole) and is performed by a press equipped with specially designed dies. The values of the force required, of clearances and of other items is determined the same way as in chopping-out

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operations.

A Cutting Off operation is the removal of the surplus and waste material, the shape and the dimensions of which have been formed by one of the complex, or form-

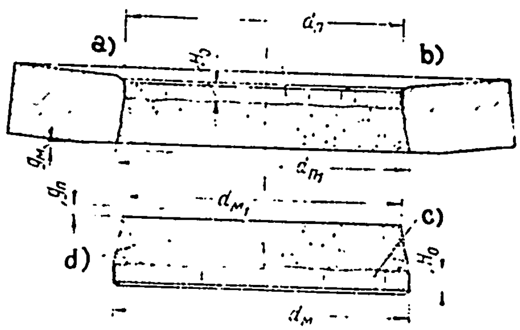

Fig.125 - View of a Punched-Out Hole and the Contour of a Chopped-Out Piece
a) Punched-out hole; b) Shiny belt; c) Shiny belt; d) Chopped out

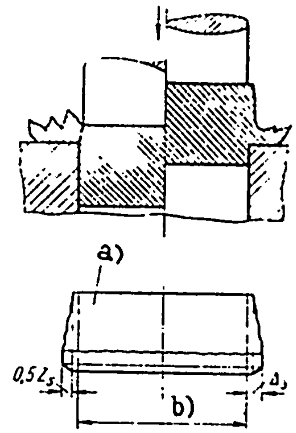

Fig.126 - Method of Cleaning
a) Chopped-out stock; b) Finished part after cleaning operation

changing operations. This operation is performed in presses by universal type, or specially designed dies, or by disk cutters on a lathe, or by other machine tools used for pressing or rolling.

A Cleaning operation is the elimination of the roughness resulting from chopping out or from punching the external or the internal contour (the entire contour, or part of it) of a piece. Also, to make the contour surface smooth, to obtain precise dimensions and to make the contour perpendicular to the plane of the piece (Fig.126). The work is performed in presses by specially designed dies.

The value of the surplus material added in anticipation of a cleaning operation, in the case of a single cleaning of surplus material added on one side only, is

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$$\Delta_z = 0.5\ Z_s - mS$$

where m is the coefficient determining the amount of surplus material to be provided for a cleaning operation; it is equal from 0.10 - 0.40 depending upon the hardness and thickness of the steel. Repeated cleaning operations are used for parts having a thickness of $S > 1.5 - 2.0$ mm.

When preparing the stock for a chopping-out operation, the amount of surplus material required for the subsequent cleaning operation should be anticipated (Fig.126).

A Hewing operation is the formation of an external, or of an internal contour in a nonmetalic material, such as leather, paper, rubber, cardboard, etc. The work is performed in a press by hewing matrixes or plungers, or by striking the dies with a hammer. The cutting edges of the die should cut at an angle equal to $\beta = 20 - 30^\circ$.

A Splitting operation is either the splitting of the entire thickness or the partial splitting of the thickness of a piece. A partial splitting anticipates other operations to follow, such as bending. The work is performed in a press by a die with its working part shaped as chisel. The cutting edge of the chisel must have the equired contour. The angle with which the chisel strikes the material is: for steel $\beta = 70^\circ$; for copper $\beta = 60^\circ$; for zinc and aluminum $\beta = 50^\circ$.

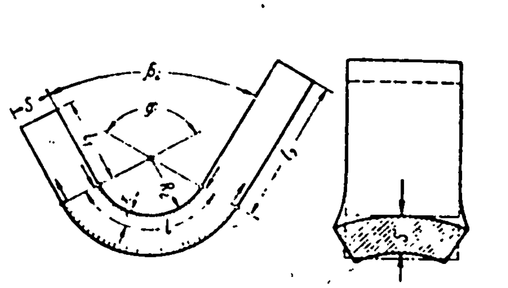

Fig.127 - View of a Bent Strip

Shape-Changing Operations. Bending is used to insure the necessary disposition of parts of a sheet or of a strip in two or more planes, at an angle rounded as a circle or as any other curve. The work is performed in a press, or by a bending

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machine equipped with universal type, or specially designed dies.

The bending of a material results in elastic and plastic deformations. The lengthening of the outer fibers produces a stress causing the width to become

Table 33

Values of Coefficient k, which Determines the Minimum Bending Radius, Depending upon the Material and the Direction of the Bend

Material	k	
	The Axis of the Bend across the Fibers	The Axis of the Bend along the Fibers
Copper and zinc	0.25	0.4
Soft brass, aluminum	0 3	0.45
Brass, hardened	0.5	1.2
Soft steel for drawing in depth	0.5	1.2
Steel of medium hardness	0.8	1.5
Duralumin TM (clean edges)	1.3	-
Duralumin LT (cleaned edges)	2.5	-

smaller, while the pressure on the inner fibers produces a stress causing the same width to become larger. As a result of these two opposing stresses, the rectangular cross section becomes bent (Fig.127). With a thickness equal to S, and with a width more than (20 - 30)S, this influence is shown only at the borders of the strip. In the bending zone, the thickness of the material becomes somewhat smaller (S').

Since the stresses on the outer fibers is $\sigma = f(\frac{S}{R_g})$, where R_g is the radius of bending, therefore, if the value of R_g is small, the value of the stress σ on the fibers approaches the limit of strength, when the material is stretched to σ_{vp} (see Table 30). The result in this case will be the crushing of the material (cracks).

The minimum radius suitable for bending may be determined (approximately) by using the following equation:

$$R_{g\ min} = S \cdot k$$

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The values of the coefficient k depending on the material and the direction of the bend, is shown in Tables 33 and 34. Trimming the edges before bending permits a reduction of k to 1.5, or occasionally to 2. The effect of the elastic deformation is that the material becomes springy during the bending. Although the angles

Table 34

Value of Coefficient k, to Determine the Minimum Bending Radius to Magnesium Alloys

Composition of the Alloy in % (Mg - the rest)		k					
		Cold bending			Hot bending		
Al	Zn	Mn	Annealed	Hardened	340°C	205°C	135°C
6.5	1	0.15	5 - 9	10 - 17	2 - 3	6	-
3.0	1	0.2	3 5	6 - 10	1 - 2	-	4
-	-	1.2	4 7	8 12	1 2	-	-

of the die are made smaller by α_n (the angle of springness) it does not eliminate to a certain extent the lack of precision in cold bending.

The length L of the material to be bent is the sum of all lengths of the straight portions plus the lengths of the neutral axes of the bent portions. In Fig.127, for example, $L = l_1 + l + l_2$. The length of a neutral axis is found by using the following equation:

$$l = \frac{\pi\varphi}{180^\circ}(R_g + x) = 0.017\varphi(R_g + x)$$

where φ is the angle of the arc l, in degrees ($\varphi = 180^\circ - \beta_g$); x is the distance from the inner area to the neutral axis, in mm, equal to x = Sm; the value of m, depending on the value of $\frac{R_g}{S}$ is to be selected as follows:

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$\frac{R_g}{S}$	0,5	0,8	1	2	3	4
m	0,25	0,30	0,35	0,37	0,4	0,41
$\frac{R_g}{S}$	5	6	7	8	10	12
m	0,43	0,44	0,45	0,46	0,47	0,48

These values found by calculation should be verified experimentally.

In a case of bending without roundness ($R_g \to 0$), the length of the piece to be bent is equal approximately to:

$$L = l_1 + l_2 + \dots + l_n + 0{,}5S(n - 1).$$

where l_1, l_2 .... l_n are the lengths of the straight portions in mm; and n is the number of bends.

The unclosing in a ribbon or in a strip especially in cases of bending without rounding ($R_g \to$ min), should be so performed that the direction of the rolling is perpendicular to the axis of the bend. If more than one axis is present, the angles formed by the direction of the rolling and axes of the bends should be the same.

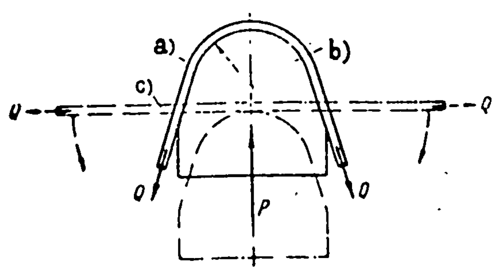

Fig.128 - Method of Bending with Stretching Broken Line - Beginning of Operation. Solid lined - End of operation

a) Part; b) Plunger; c) Stock

Bending with Stretching. This operation will also bring the various portions to their required places. However, with bending, and regardless whether the stretching is made at the same time or at some other time, the material is stretched by 1-4% (Fig.128). Due to this fact, there is almost a total of springness in the parts ($\alpha_n \to 0$) which means a mich higher precision.

The work is performed in drawing presses equipped with special plungers (no matrixes). Bending with stretching is used mostly for large or medium pieces.

Profiling is used to obtain any profile required in a strip of a rectangular shape. The profile is obtained with the outlines changing gradually and in a consecutive order. The work is more often performed with the aid of special rollers in profile-bending machines.

Fluting is an operation by means of which flutes are formed on flat or hollow shapes to make them more rigid (ribs of rigidity). The work is performed by flute-rolling machines or by disk shears with the aid of universal type or special rollers.

Threading is a special application of fluting and is used to thread hollow sheet metal pieces, such as lamp sockets. The work is performed by specially designed rollers.

Border Rounding is the operation which with the aid of a die, or rollers imparts to a straight or curved border the shape of a ring, or of any other closed curve. The work is performed over the entire border at the same time, when presses and dies are used, or gradually, when done with the rollers of a rolling machine.

Trueing is the straightening of flat or shaped pieces. The work is performed in presses by universal type or special dies. This operation requires great pressure, an exception is the trueing of flat material by the method of bending over.

Drawing out (stretching) is used to obtain from a flat or hollow material a product having the required shape and dimensions, at the expense of the thickness of the original material. The work is performed in presses by specially designed dies.

The maximum force required to draw out a hollow specimen may be determined, approximately, by using the following equation:

$$P = F \cdot \sigma$$

where P is the force required for drawing out; F is the cross-sectional area of the specimen wall in mm; (in the case of a flat bottom, the cross section is measured in the rounded zone, where the bottom meets the wall); σ is the stress due to the drawing out and is equal to $n\sigma_{vp}$ in kg/mm^2. The coefficient n may be found in Table 35. In the case of a cylinder, the above equation becomes:

$$P = \pi S (d_1 - S)\sigma$$

where d_1 is the outside diameter of the drawn-out cylinder in mm.

In the case of a relatively thin material, the compressing forces have a tendency to bend the flange longitudinally which may result in formation of folds. To avoid the formation of folds, a device (a foldholder) is used which holds the material tight.

As a result of the compressing forces acting on the flange, its thickness will be increased, but at the same time, the stretching-out forces acting lengthwise along the cylinder, will make the lower portion of its wall - thinner. The changes in the original thickness S and hardness H_B when a cylinder with a flat bottom is stretched, are shown in Fig.129. The dotted line in Fig.129 represents the changes in thickness of a cylinder with a spherical bottom. The increase and the decrease in thickness, as compared to the original thickness, depends on many technological factors and on the design. In many products, the increase (+) may go up to 25-30%, and the decrease (-) to 30-35%. As the radius of the upper die R_P increases, the rate with which the material is becoming thinner decreases, but the thinness is spread over a larger zone. Therefore, it may be assumed that in a stretch-out operation the average thickness of the finished product is very near the original, also the average surface is very near the original.

Designating α_v as the coefficient of the change in the stretched surface, and designating β_v as the coefficient of the change in its thickness, we get:

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$$\alpha_v = \frac{F_v}{F_z} \text{ and } \beta_v = \frac{S_v}{S}.$$

The value of α_{vp} and α_v, depending on the basic technological requirements is shown in Table 36.

Table 35

The Value of Coefficient β Used to Determine the Required Stretching Force

m_1	0.55	0.57	0.6	0.62	0.65	0.67	0.7	0.72	0.75	0.77	0.8
β	1	[illegible]	0.86	0.79	0.72	0.66	[illegible]	0.55	0.5	0.45	0.4
$m_2 \ldots m_n$		0.7	0.72	0.75	0.77	[illegible]	[illegible]	[illegible]		0.95	
β		1	[illegible]	[illegible]	0.85	[illegible]	[illegible]	0.6		0.5	

The coefficient of the first stretching operation: $m_1 = \frac{d_1}{D_3}$

The coefficient of the subsequent stretching operations: $m_2 = \frac{d_2}{d_1}$; $m_3 = \frac{d_3}{d_2}$, and so on (see Fig. 139)

Table 36

Relation between Coefficients α_v and β_v and the Basic Technological Requirements (Bibl.44)

ρ	Z	q_s	v	α_v	β_v
		in kg/cm²	in m/sec		
> 3	> 1.05	[illegible]	< 0.2	1-1.03	1-0.97
3-2	1.05-1	[illegible]	[illegible]	1.03-1.08	0.97-0.93
< 2	[illegible]	[illegible]	[illegible]	1.08-1.11	0.93-0.9

Values: $\rho = \frac{R_m + R_n}{[illegible]}$; $Z = \frac{[illegible]}{2[illegible]}$; where [illegible] and [illegible] are the diameter length of the upper and lower dies; q_c is the pressure on the holdholder; v is the speed of stretching

In rough calculations, it is allowed to consider $\alpha_v = 1$.

In stretching, one of the results of the anistropy of the material is a wavy shape on the flange of the product, or on the edge of a hollow vessel. This wavy STAT uneven shape is shown in Fig.130. The number of waves is usually four: two of which are parallel, and the other two are perpendicular to the direction of the rolling.

If the waves are formed on a round body they are removed by turning the body on a lathe, otherwise they are simply removed by cutting.

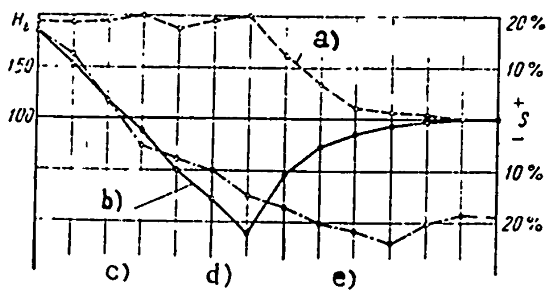

Fig.129 -

a) Change in hardness; b) Change in thickness; c) Wall; d) Radius; e) Half of bottom

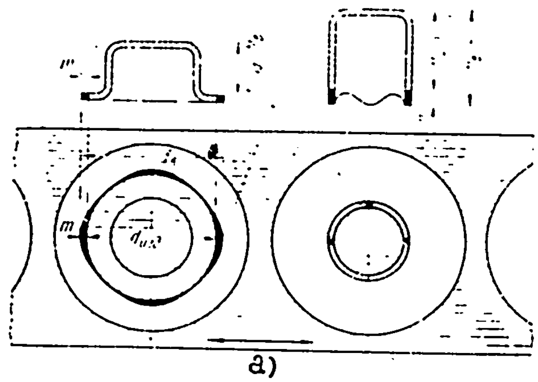

Fig.130 - Disposition of Unevenness (Waves) after Stretching

a) Direction of rolling

If the stock is flat, its dimensions depend on the area of its surface (F_v) after the stretching. If a smooth flange, or a smooth edge are required, the calculation of the surface must take into account the corresponding diameter of the flange $d_v = d_{izd} + 2m$, or the height after stretching $H_v = H_{izd} + m$; where m is the allowance for cutting off, equal to 1.2 mm, up to 5% of H_{izd} (see Fig.130). All calculations pertaining to a stretching operation deal with average dimensions (i.e., the value of S) must be taken into account). When $S < 1$, the use of the largest dimensions (instead of the average) is permissible, since the difference between the outer and inner dimensions is insignificant.

Generally, the relation between the surfaces may be expressed as: $F_z = \frac{F_v}{\alpha_v}$

The insignificant inaccuracy which appears in calculating F_z can be corrected during the operation. For example, if the value calculated for F_z turns out to be a bit smaller than required, increasing the pressure P_c of the foldholder, or reducing the values of R_m and Z_v, or starting the stretching before the chopping out (in combination dies), is sufficient to bring the necessary correction.

For round bodies, the relation between F_v and D_z may be expressed as follows:

$$D_z = \sqrt{\frac{4F_v}{\pi \alpha_v}} = 1.127 \sqrt{\frac{F_v}{\alpha_v}}.$$

In stretching operations on cylinders, the surface area F_v is calculated by using suitable geometrical equations. If the shape is complicated, it is divided into sections with simple shape and F_v is calculated as the sum of all areas.

If impossible to break up the complex shape into simple geometrical shapes, then to find the value of F_v the following equation is used:

$$F_v = 2\pi RL = 2\pi (r_1 l_1 + r_2 l_2 + \ldots + r_n l_n).$$

where R is the distance from the axis of rotation to the center of gravity of the complex body; L is its length; $r_1, r_2, \ldots, r_n$ is the distance from the axis of rotation to the center of gravity of each section of which the complex shape is composed; $l_1, l_2, \ldots, l_n$ is the length of each section into which the length of the complex body L is broken up and which may be assumed as straight lines. The finding of the center of gravity for L, and consequently the finding of R, is possible by using a rope (force) polygon.

The diameter of the stock may be found by using the equations quoted previously, it is:

$$D_z = \sqrt{\frac{8RL}{\alpha_v}} = \sqrt{\frac{8}{\alpha_v} \sum_{i=1}^{n} r_i \cdot l_i}.$$

In rectangular hollow vessels, the stretching, or the drawing out occurs only in the angles, whereas the rectilineal sections of the wall experience mostly the effect of bending. With this in view, a plan may be drawn up by which the dimension

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of the flat stock to be converted into a hollow vessel may be found. In this plan, the wall is broken into rectilineal sections and into circle parts (Fig.131). The

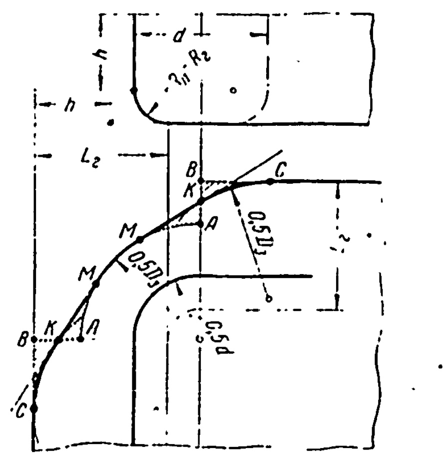

Fig.131 - Method of "Unbending" the Angle

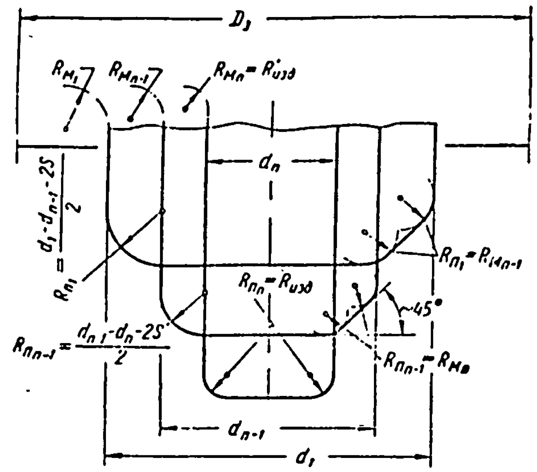

Fig.132

rectilineal sections will have the length L and the circle parts will have the diameter D (four angles of the vessel form a hollow cylinder with a diameter d). After the rectilineal and curved sections are drawn, a streamlined contour is found which will insure a gradual transition from the stretching (in the angle) to the bending (in the rectilineal section). For that purpose, segments BA is cut in half and a tangent is made to pass through point K to the part of the circle AA. After that, with a radius equal to 0.5 D_z the angles are rounded between tangent MK and the rectilineal parts of the contour BC.

In the case of complex shapes, the dimensions of the flat stock from which the complex shape is to be made, should have the theoretically found value verified experimentally.

The drawing out of articles having large depth is usually effected in more than one operation.

For the n^{th} (the last) drawing-out operation, the radius of the upper die should

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equal the internal radius of the article. Also, the radius of the lower die should equal to the external radius of the cylinder, if the article to be drawn out is a cylinder with a flange (see the dotted line to the left and on top of Fig.132 which illustrates the method of desigring the proper dimensions for a drawing-out operation), i.e.,

$$R_{p\,n} = R_{izd};\ R_{M_n} = R'_{izd}.$$

The equation below may be used to determine the radii of the matrixes for the intermediate and last drawing-out operations of a soft steel product without a flange, or for the last drawing-out operation of a product with a flange, it is to undergo another different shaping operation thereafter.

$$R_{M_n} = 0.8\sqrt{(d_{n-1} - d_n)\,S}.$$

In the above equation, if n = 1 $d_{n-1} = d_o = D_z$. The radii of the upper dies used in intermediate operations when designed without slopes (see left half of Fig.132) are derived from the following equation:

$$R_{p\,n-1} = \frac{d_{n-1} - d_n - 2S}{2}.$$

If the drawing-out operations (and therefore - the dies) are to be designed with slopes (see right half of Fig.132), then

$$R_{p\,n-1} = R_{M_n}.$$

With n = 1 R_p is found not from the equation but is taken as the radius of the finished product, since

$$R_{p\,n-1} = R_{p\,1} = R_{izd}.$$

A return drawing-out operation differs from the usual kind in that, that the outer surface of the stock (as the operation is proceeding from start to finish)

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becomes the inner surface. A return drawing-out operation is used for the purpose of obtanning a hollow double-walled finished product (Fig.133).

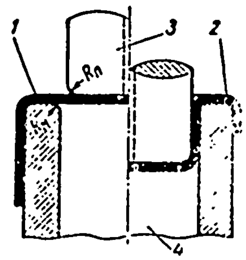

Fig.133 - A Return Drawing-Out Operation

1 - Stock; 2 - Finished product; 3 - Upper die; 4 - Matrix

In drawing-out operations done hydraulically, the die may contain only a matrix. Since the upper die is a liquid, the cost of the die is lower. Dies for hydraulic drawing-out operations differ in design. One of them is shown in Fig.134. As a rule, the application of the hydraulic method seems to be justified when handling moderate quantities of complex (in shape) medium and large-sized products. Because the production facilities of today make it possible to bring the liquid pressure to 400-600 kg/cm^2 - the thickness of sheet metal stock may go up to 3-6 mm.

A drawing-out operation using rubber as a matrix has the same application as drawing hydraulically. In this case, of all the working parts of the die, only the plunger is made of steel (Fig.135). The lower half (the matrix) is made of a plastic mass - rubber. As this allows to do away with the making of an expensive and hard-to-make steel die - the advantage in cost and time is obvious. Comparing the two types of operation (drawing hydraulically and using rubber matrixes), the advantage is on the side of rubber, both in cost and operationally. At the present time, rubber dies operate under a pressure reaching up to 300-400 kg/cm^2.

Drawing Forth is one of the varieties of drawing operations used to obtain hollow products of a required thickness and different cross sections of the walls. The work is effected in presses equipped with specially designed dies.

The dimension of the flat stock to be fabricated is found by using the following equation:

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$$D_з = 1.127\sqrt{\frac{V_c}{S}} = 1.127\sqrt{\frac{V_{izd}+V_{np}}{S}},$$

where V_c is the volume of the stock drawn forth (of the vessel); V_{izd} is the volume of the finished product; V_{np} is the volume of the added surplus material.

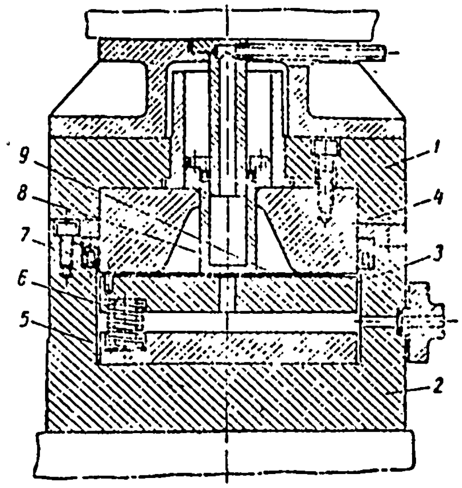

Fig.134 - Section of a Die for Drawing Out Hydraulically

1 - Body of matrix; 2 - Base of matrix; 3 - Foldholder; 4 - The matrix; 5 - Thrust plate; 6 - Foldholder spring; 7 - Tightening; 8 - Squeeze; 9 - Sheet metal stock

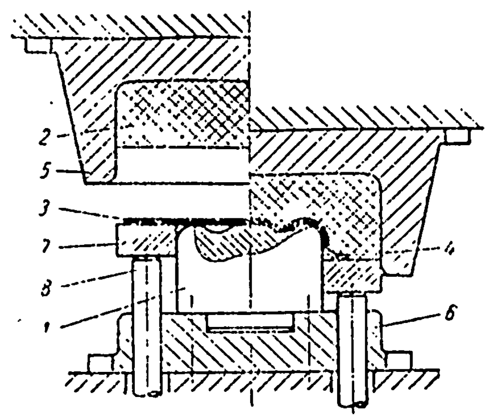

Fig.135 - A Drawing Die with a Rubber Matrix and Steel Plunger

1 - Steel plunger; 2 - Rubber matrix; 3 - Sheet metal stock; 4 - Finished product; 5 - Container; 6 - Lower plate; 7 - Foldholder; 8 - Tappet, actuated by a buffer

The working parts of the upper (plunger) and of the lower (matrix) dies are shown in Fig.136.

The number of drawing-forth operations and the dimensions (of the wall thicknesses S_1, S_2, ..., S_n, when several operations are used) may be determined by using the coefficient

$$k_n = \left(\frac{S_{n-1} - S_n}{S_{n-1}}\right) 100,$$

which gives us

$$S_n = \left(\frac{100 - k_n}{100}\right) S_{n-1};$$

$$S_{n-1} = \left(\frac{100}{100 - k_n}\right) S_n.$$

The value of the coefficient k_n which reflects the hardening resulting from the drawing-forth operation of different metals is as follows:

Material	k_n
Soft steel (C ≈ 0.15%)	30
Aluminum, zinc	40
Brass (cartridge)	50

The force required for a drawing-forth operation may be found from the following equation:

$$P = \pi \sigma_s (S_{n-1} - S_n)\,[d_{\text{м}} + (S_{n-1} - S_n)].$$

Shaping means to impart the required final shape to flat or hollow stock, or to their parts, at the expense of extending them locally and, at times subjecting the material to compression. The work is performed in presses equipped with specially designed dies.

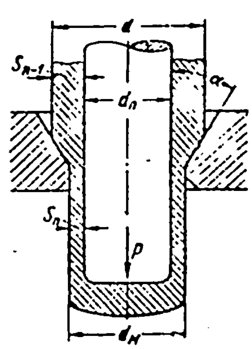

Fig.136

Shaping may also be effected by use of rubber or liquid.

Edging is a special form of STATing

116

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and its purpose is to impart the required shape to open edges of, or to holes in a flat or hollow stock with the object to shift the edge to another plane (surface). The work is performed by dies in presses.

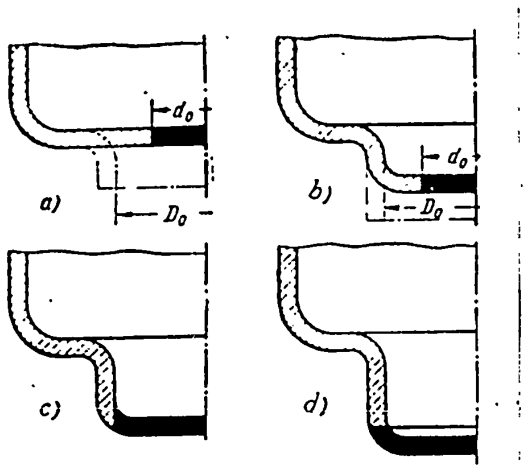

Fig.137

After completing the work, the edge will have a thickness S_o which will be less than the original. Various methods of edging of openings in a drawn-out material are shown in Fig.137 (Bibl.44). In Fig.137, a and b are obtained by edging c by punching and d by cutting.

Compression is the method of obtaining a hollow round body from a flat or hollow stock. The operation is performed gradually on compressing lathes by means of universal squeezers and special chucks made out of wood or cast iron.

The Technology of Sheet Metal Work

The Technological Process. Basically, the process is worked out in stages, as follows: 1) the shape, the dimensions of the material and the quality of the surface of the finished product are first to be analyzed; 2) a preliminary study and compilation of all data involved in the process is to be made; 3) the proper equipment is to be selected; 4) the preliminarily compiled data to be corrected; 5) experiments, or the making of a few samples to verify the suitability of the process; 6) final corrections are to be made and the process is finally to be selected. The work on 5) and 6) is carried out when it is organized for the production of complex products.

The Analysis of the Shape, Dimensions, Materials and Surface Quality of the Finished Product. The designer and the technician must make sure that the design and the technique will suit the purpose. The job of the designer is to select that combination of shape, dimensions, kind of material and surface quality that will insure the best performance in the kind of work, for which the finished product is designed. The job of the technician is to work out methods for the production of the finished product with a minimum expense in money and time. To accomplish this, the technician must take into consideration all of the above requirements, and also the quantity to be produced.

The Preliminary Compilation of the Data. This work should take into consideration the quantity to be produced and safety factors. Also economic factors, for instance, the production of a die for a few pieces is unprofitable, but in mass production, the cost of a die will quickly be repaid. The basic data here to be considered are: 1) the consecutive order of the operations; 2) the material (the shape or otherwise: whether it is a ribbon, strip, sheet, waste of a flat shape, or waste made usable after the shaping is complete); 3) the type of dies to be used (combination dies with automatic feeding attachments and of complex design for mass production, and simplified universal-type dies for the production of small quantities); 4) the feeding of the material and the removal of the finished product and waste; 5) basic figures, such as the percentage of waste and of usable material, the tempo of the operation, the width of the ribbon, the diameter of the flat stock, the diameters, when the operation proceeds in stages, the length of stroke of the slide bar, the heights of the die when open or closed, the force required for the press, the amount of surplus material required, etc; 6) sketches of each stage, when the operation proceeds in stages.

Selection of the Equipment. The selection of the proper equipment is also closely tied up with the quantity to be produced. If equipment is available, the selection is made from those not loaded with work and which are best suited for the purpose. If new equipment is to be used, its specifications should be in conformity with the process.

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The selection is to be based on the following basic values: the technology of the operation, the force and nature of work required, the length of stroke H_n, the dimensions and the shape of the stand and of the slide bar, the "die space" C_o and C_z (the heights when the die is open and closed), the dimension of the roller gap, feeding attachments, whether present or absent, the number of strokes, the

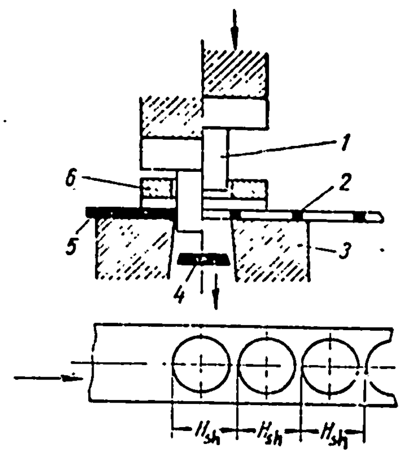

Fig.138 - Sectional View of a Simple Die.

1 - Plunger; 2 - Waste; 3 - Matrix; 4 - Finished product; 5 - Material to be stamped; 6 - Removing attachment

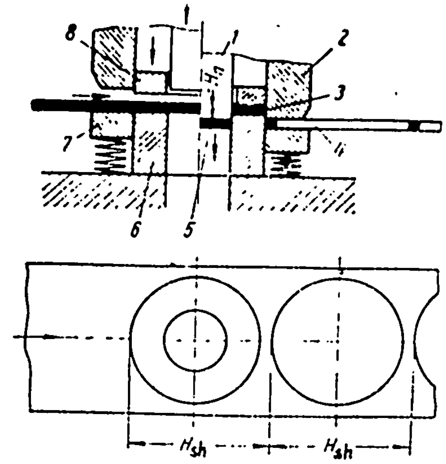

Fig.139 - Sectional View of a Combination Die

1 - Punching plunger; 2 - Chopping matrix; 3 - Finished product; 4 - Waste; 5 - Waste; 6 - Chopping plunger punching matrix; 7 - Removing attachment; 8 - Ejector

presence or absence of a cross piece on the slide bar, the presence or absence of a buffer, the reliability in operation and, especially, the sturdiness of the frame and the direction of the slide bar,and finally, the cost, if new equipment is used.

Correcting the Data. Very often, after the proper equipment is selected, the preliminarily obtained data must be recalculated or changed and new and finalSTAT

199

must be worked out.

Types of Dies. The dies used in sheet metal work may be divided into three groups:

Simplified dies performing one operation with a single stroke of the slide bar of the press and within the limits of a single phase of the operation H_{sh} (Fig.138). Dies of this type are distinguished by the simplicity of their design and low cost of making them. The productivity of these dies is directly related to the method of feeding the material or semi-finished product, and to the method of removing the finished product and the waste material.

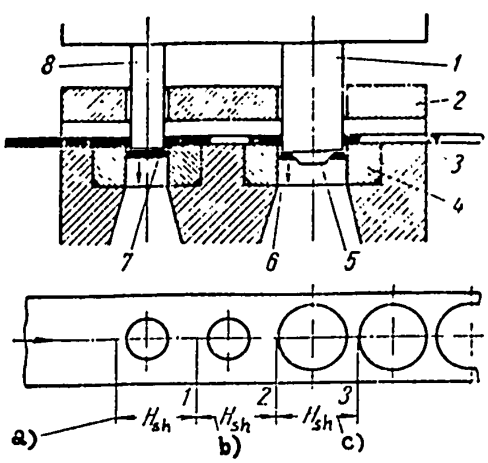

Fig.140 - Sectional View of a Consecutive Type Die

1 - Chopping plunger; 2 - Removing of attachment; 3 - Waste; 4 - Matrix; 5 - Catching attachment; 6 - Finished product; 7 - Waste; 8 - Punching plunger;

a) Transition to punching; b) Non-operating transition; c) Transition to chopping

Combination dies, performing simultaneously several different operations (more often two or three and seldom four) with a single stroke of the slide block of the press and within the limits of a single phase of the operation H_{sh} (Fig.139). Combination dies are more complex than simplified dies, but they are more productive and perform with great precision producing products with correct location of their component parts and good quality of their surfaces.

The consecutive-type of dies accomplish their work in several different operations with several strokes of the slide block of the press and during several phases of the process H_{sh} and with the number

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of phases equal or greater than the number of operations (Fig.140).

The consecutive type of dies may be just as complex as the combination type. These dies are very productive and are even better than the combination type when handling products of complex shape. Although the consecutive type is able to handle products of greater complexity than could be handled by the combination-type dies, the precision is not as good.

In dimensions, the consecutive type of dies are larger than the combination type.

SHEET METAL PRODUCTS

General Considerations

To be sure that the products obtained will be correct technologically, it is possible to produce only such changes in the shape, dimensions and material which: 1) do not change the principle under which the machine operates, do not change the parts and the assembly of parts and, indirectly, do not change the dimensions of parts joined together; 2) do not affect the replacement ability of the parts of a finished product.

Basic Considerations

Selection of Material. For sheet metal work, the material used has mostly the shape of a ribbon, strip or sheet. Sheets are used in those cases when the width of the ribbon or of the strip is unsufficient. If the width is sufficient, ribbons are to be preferred for thin articles ($S = 2 - 2.5$ mm) and strips - for thick products ($S < 2 - 2.5$ mm).

Materials possessing high fluidity σ_T, when used in operations of the separating type, are very good for cutting. For operations of the shape-changing type, a low fluidity σ_T is desirable. For drawing-out and drawing-forth operations, conditions are more favorable, the greater the difference between σ_{vp} and σ_{STAT} A

270

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fairly good ratio would be $\frac{\sigma_T}{\sigma_{vp}} \leq 0.065$.

The material selected for drawing operations should possess the physical and mechanical properties and geometrical requirements required from the product; a good amount of surplus material to take care of the thickness and a good surface quality are to be included in such a material. The microgeometry of a cold-rolled ribbon is in accordance with the 7th class of cleanliness, as per specifications of GOST 2789-51; a polished ribbon belongs to the 8-9th class.

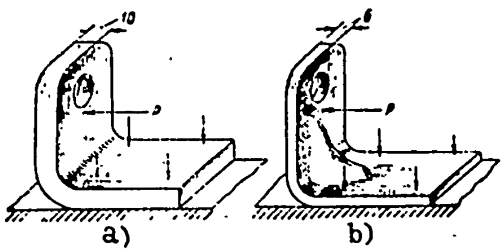

Fig.141 - Example of Ribs Imparting Rigidity

a) Wrong; b) Correct

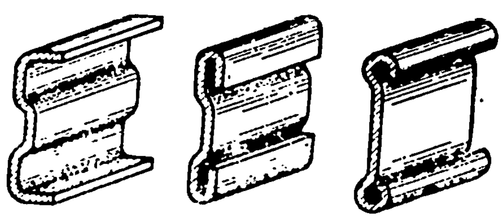

Fig.142

The following materials are used in sheet metal stamping: low-carbon cold-rolled steel ribbons (GOST 503-41); cold-rolled structural steel ribbons. (GOST 2284-43); hot-rolled steel ribbons (GOST 6009-51); rolled-steel thin sheets (GOST 3680-47); steel sheets (GOST 1386-47); black polished tin-plate (GOST 1127-47); roofing steel sheets (GOST 1393-47); thin sheets of quality structural carbon steel (GOST 914-47); common hot rolled carbon steel (GOST 380-50); hot rolled structural quality carbon steel (GOST 1050-52); brass sheets and strips (GOST 931-52); copper-zinc and brass alloys (GOST 1019-47); cold rolled ribbons made from nonferrous metals and alloys (GOST 3718-47); hot rolled copper sheets (GOST 495-50); copper ribbons for common use (GOST 1173-49); aluminum-bronze ribbons for springs (GOST 1048-49); brass ribbons for common use (GOST 2208-49); nickel and nickel-silicon ribbons (GOST 2170-49).

The Configuration Thickness of the Original Stock and of the Finished Product.

The most strict and all-around economy in the use of metal is a necessity. The use

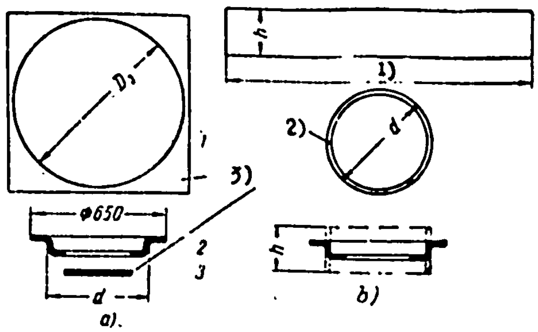

Fig.143 - A Flanged Ring on a Solid Sheet

a - Result-large waste; b - Ring from cylindrical stock, result-no waste; 1) Developed length; 2) Welded; 3) Waste

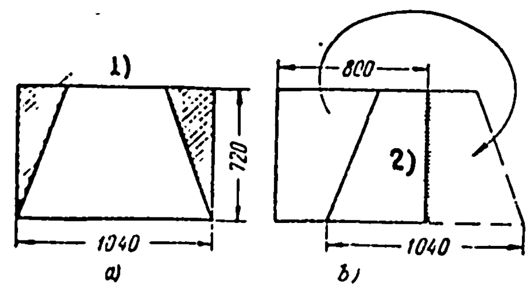

Fig.144 - a - Stock is solid, result large triangular waste; b - Welded stock-no waste

1) Waste; 2) Welded

of edging, of ribs to impart rigidity and of other methods used in sheet metal work, will save metal and reduce the weight of the finished product. If the material lacks the thickness required for the finished product, the latter is shaped as shown in Fig.142, when it is a drawing operation and the width is not to be changed.

In many cases, to reduce the waste of material it is advisable to use welding. Examples of advantages of welding are shown in Figs.143 and 144.

When a sheet is to be cut into strips, it is recommended to locate the strips in such a manner as to be able to place a maximum number of strips. Minimum allowances for any of the dimensions are advisable. There may be cases when the number of strips on a sheet will not conncide with the number of phases of the operation. In such a case, to save metal, a strip 1 (Fig.145) is cut off (waste of the end) with a width equal to b, after which the sheet is cut into strips having a

STAT

231

width B_{sh}; the waste 2 will be a fraction of a strip.

The cutting up into ribbons or strips is done in one of the following manners: either a single row or a multirow cut up. The percentage of usable material or of

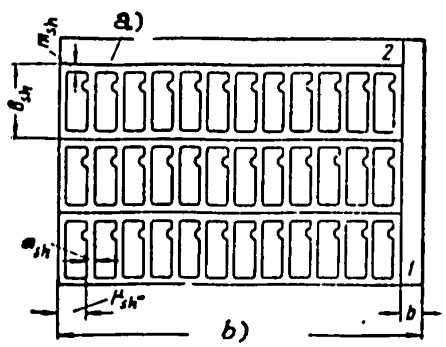

Fig.145 - A Typical Cut Up of a Sheet into Strips

a) Sheet (stock); b) Width of finished product

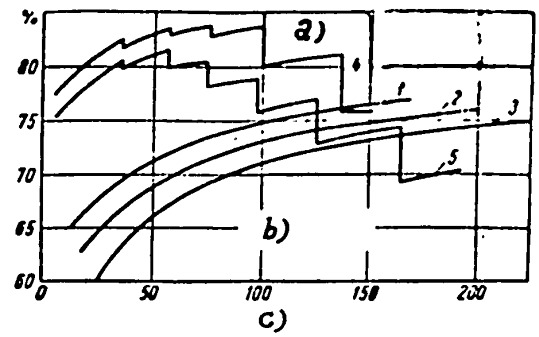

Fig.146

a) Waste; b) Utilized; c) Circle diameter

waste depends upon the diameter of the circle, row arrangement, thickness and shape of material. In Fig.146, the curves 1, 2, and 3 represent the utilization of a

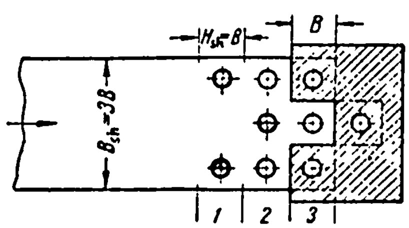

Fig.147

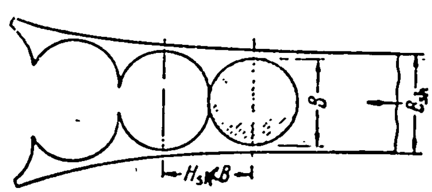

Fig.148

ribbon having corresponding thickness of 1, 2, and 3 mm in a single-row cut up. Curve 4 shows the utilization of a wide ribbon (up to 300 mm) 1 mm thick with shifted rows in a multirow cut-up. Curve 5 is drawn for a multirow cut-up of circles from a standard sheet 1 mm thick. A two-row cut-up may be effected with a single plunger, simply by turning the strip over.

STAT

180

The Cut-up without "Dikes" (Fig.147) is used for products requiring no great precision, for example, a three-row sheet for square nuts.

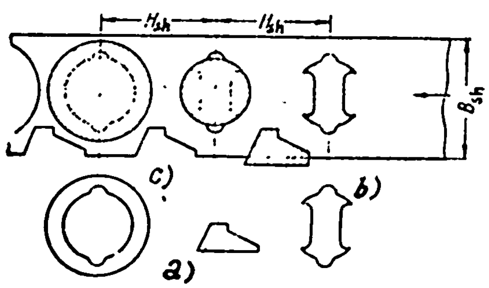

Fig.149 - Finished Products

a) 1st; b) 2nd; c) 3rd

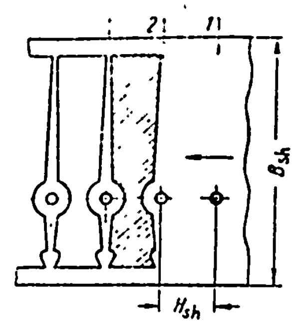

Fig.150

A Cut-up with Gaps (Fig.148) is mostly used for products to be drawn-out before being cut, or if the contour is such that removing a bit of metal makes no great difference.

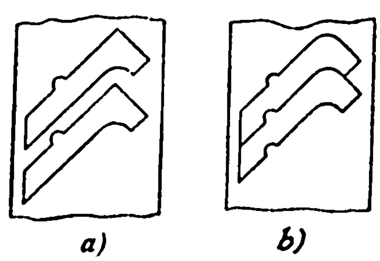

Fig.151 - Inasmuch as Possible the Contour of One Side should be the Mirror-Like Reflection of the Other Side (see Right Half)

a) Irrational; b) Rational

A Cut-up Combined Several Different Shapes (Fig.149) is advisable only if the variously shaped pieces belong to the same product, or are parts of the same assembly.

A Cut-up in which the Waste and Not the Product is Cut out (Fig.150) is used for long narrow strips.

An Example of a Cut-up which Anticipates that Welding is to Follow is shown in Figs.143 and 144.

In a Cut-up Anticipating Group Cutting, the parts composing the group should be of the same material and of the

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same thickness.

When planning a cut-up it is necessary to coordinate the minimum consumption of metal with the economics of the entire stamping process. The work should start with the large parts the waste of which may be of such size as to be suitable for parts of a smaller size.

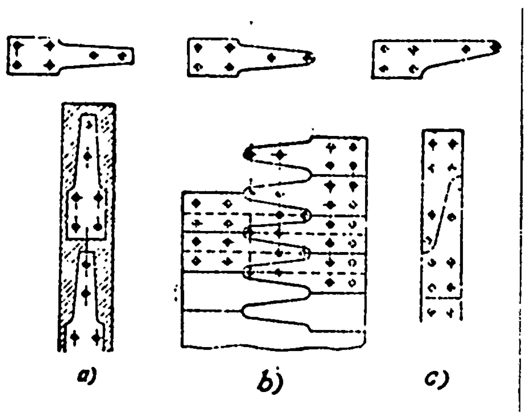

Fig.152 – The Same Part but Shaped and Laid-Out Differently Means Different Consumption of Metal

a – Is not practical; b and c – Are practical

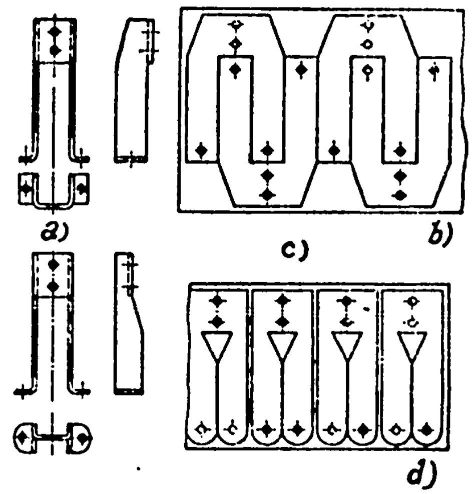

Fig.153 – Two Variations in Shaping the Same Part and Two Different Ways of Cutting Up

a) The part; b) Variation 1; c) The cut-up; d) Variation 2

Examples of coordination and of lack of coordination of the configuration with the cut-up are shown in Figs.151-154.

Saving of nonferrous metal may be obtained by segregating the product into the elements composing it, especially when only a small part of it is made from nonferrous metals. As an example, take a part of a watch made out of steel into which is pressed-in a brass insert with a hole drilled to hold a pin.

When measures are taken to insure the best utilization of metal, it is necessary, by all means and by all methods available (technological and design) to

STAT

solve the following problems:

1) Increasing the utilization of metal to a maximum;

2) Inasmuch as possible to utilize the metal for products of one kind (in the case, for example of product A, it is desirable to use the excess material for other pieces of the same product A).

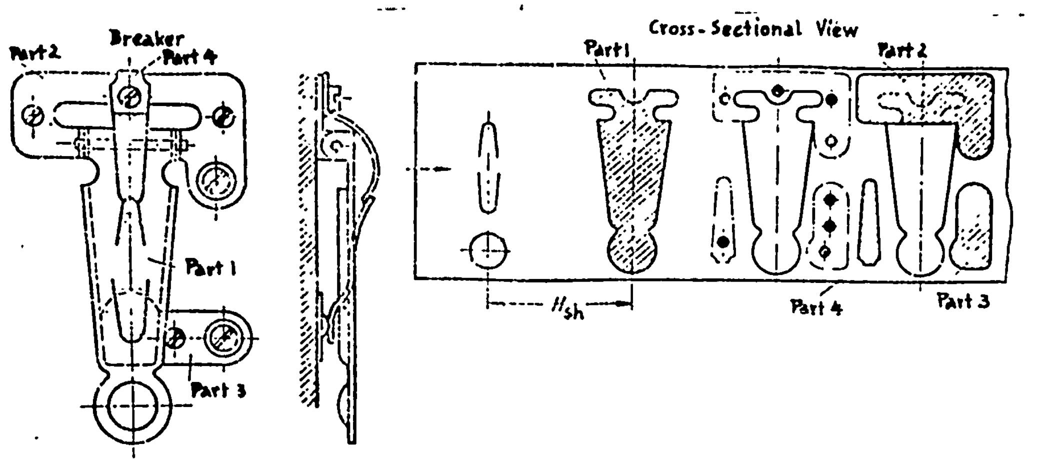

Fig.154 - The Configuration of the Parts Composing the Interrupter is Closely Related to the Way the Parts are Cut up; Parts 2, 3, and 4 Look as though They are Obtained from the Excess Material (Waste) of Part 1. (The interrupter sectional view is drawn to a larger scale than the sectional view of the cut-up)

A solution of both of these problems is acceptable only if there is no increase in weight, even if the quality, productivity and cost remain unaffected.

Data for Designing the Separating Type of Operations. With the use of upper and lower dies made of steel, the precision in stamping cold-rolled sheet metal is normally not higher than the 5^{th} class in chopping-out operations, and not higher than the 4^{th} class of precision in punching operations.

By taking special measures (such as making the process more complex or using dies of greater precision) the precision may be increased to the 4^{th} class in chopping out, and to the 3rd class in a punching operation. In hot operations, the precision is lowered (7th–9th class). Cleaning operations normally produce a 3rd class of precision, and if followed by calibrating, the precision may even reach the 2nd class.

Table 37

Minimum Sizes of Holes Punched by Ordinary Dies*

Material	Round	Square	Rectangular	Rectangular with Ends on a Circle
	Diameter	Side of Square	Smaller Side	
Soft steel	1	0.9	0.8	0.7
Brass, copper	0 9	0.8	0.7	0.6
Aluminum, zinc	0.8	0.7	0.6	0.5
Bakelite, textolite	P.U	0.6	0.5	0.4
Cardboard, paper	0.6	0.5	0.4	0.3

Remarks: Slightly smaller holes may be punched, but the steadiness of the die will be lowered

* The dimensions are in fractions of S

The precision for the relative locations of the chopped-out contour and of the punched-out hole depends mostly upon the selected type of die. Combination

Table 38

Minimum Sizes of Holes Punched by Rubber Dies in Nonferrous Alloys

S v mm	p = 170 kg/cm²	p = 100 kg/cm²			
	Round	Round	Square	Equilateral triangle	Roundness in the angles
	Diameter	Diameter	Side of Square	Smaller side	Radius
0.4	8	13	–	–	–
0.6	10	19	32	34	3
0.8	12	24	38	38	4
1	14	38	51	51	6
1.3	16	48	76	76	7

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type dies produce the best precision and the least precision is produced by the simplified type of dies.

One of the results of cold chopping and punching operations is the damaging of the surface to a depth of 0.15 - 1.0S. For each material, the depth of the damaged layer is directly proportional to the clearance Z_s and to the resistance to cutting in the dies τ_o, and inversely proportional to thickness S.

When rubber dies are used, the contour of the product, or of the holes, is

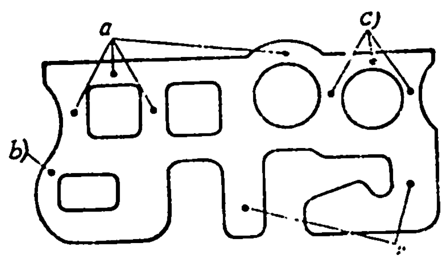

Fig.155

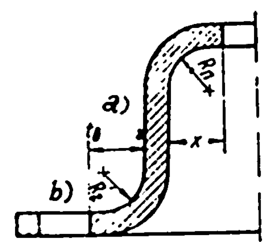

Fig.156

a) t_v or t_g; b) R_M or R_g

considerably worse than with steel dies.

The minimum sizes of holes punched by steel plungers and steel matrixes for various materials are shown in Table 37, for holes in nonferrous alloys punched by a rubber die - in Table 38. The minimum size of holes punched by a steel plunger located in a special sliding tube is of the order $0.4 \div 0.6$ S. When steel plungers are used, the minimum radii of a contour consisting of curved and straight lines may be taken from Table 39.

The location of holes and the minimum widths of a product, or of its portions, in the case of soft steel, should follow the following values: $a > 0.8$ S; $b > 0.9$ S; $c > 0.7$ S; $d > 1.5$ S (Fig.155). The minimum width of the product is $B > 1.5$ S.

In bent and drawn-out parts, the distances from the edges of the holes to the walls must satisfy the following conditions (Fig.156):

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$$x \geqslant R_p + 0.5\ S$$

$$t_v \geqslant R_M + 0.5\ S$$

$$t_g \geqslant R_g + 0.5\ S$$

The minimum dimensions for nonferrous alloys when chopped out by a rubber die, and when S = 1.3 mm, should not be less than 150 mm.

Table 39

Minimum Radii of a Contour Consisting of Straight and Curved Lines when Punched or Chopped by Ordinary Dies

Operation	Angle α at the Joint of Lines in °	Brass, Copper, Aluminum	Soft Steel	Structural Alloyed Steel
		Minimum Radius of Contour, in Fractions of S		
Chopping	$\geq$ 90	0.18	0.25	0.35
	< 90	0.35	0.5	0.7
Punching	$\geq$ 90	0.2	0.3	0.45
	> 90	0.4	0.6	0.9

Data for Designing Shape-Changing Operations. The mechanical properties of the material in the bending zone undergo a change.

The nature of the change in the basic mechanical properties for Grade CT steel and with S = 28 mm and R_g = 25 mm may be seen in Fig.157.

In a cold bending operation, the zone of critical deformations for different ratios of $\frac{R_g}{S}$ is shown in Fig.158. A part subjected to cold bending first, and to heating after, will age considerably in the bending zone, which results in brittleness. Therefore, no welding should be done near the zone of cold bending.

Both the cross section and the dimensions of the original stock undergo a change in the bending zone. The nature of the change is shown above in Fig.127.

When using dies for shaping angles, braces, small and medium sized shelves, the precision depending on the thickness of the material may reach the following precision values (Δ_{izd})

S in mm ...	up to 2	from 2 to 4	above 4
Δ_{izd} in mm ...	± 0.15	± 0.3	± 0.4

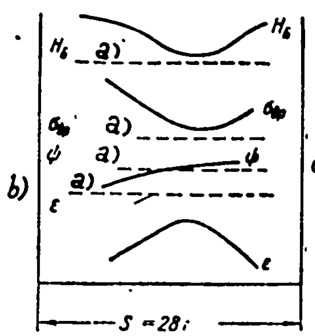

Fig.157

a) Originally; b) Outer fibers;

c) Inner fibers

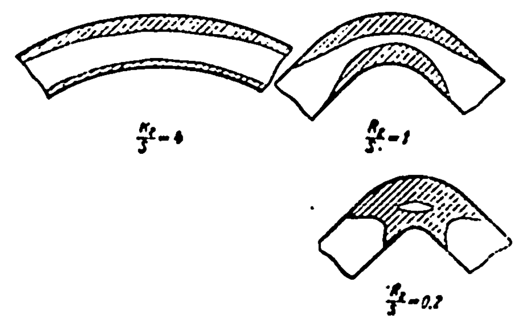

Fig.158

When bending a brace, wrinkles will appear in that portion, where the roundness changes into a vertical line, also the thickness in that place will be $S_1 < S$. The wrinkles and the decrease in thickness may be remedied only by additional operations, which may increase the thickness to $S_1 \geqslant S$.

The height H of the straight portion of the bent wall (shelf) should satisfy the condition $H > 2S$. If a lower height is necessary, provision should be made for impressing a groove (see right side of Fig.159), or an allowance should be made (by means of surplus material) for the mechanical treatment after the stamping.

When shaping the contour of a bent part, and if the axis of the bend is above the shelf (Fig.159, left side), local cut-outs should be provided. The dimensions of these cut-outs should be $a \approx S$ and $b \geq S$. If the axis of the bend is outside the limits of the shelf, (Fig.159), in this case no cut-outs are needed.

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The thickness of the shelf S of an open brace having an angle $\beta_g = 90^\circ$, if necessary, may be less than the thickness of the base ($S' < S$); for steel, in this case, the decrease in wall thickness should not exceed 30%, i.e., $S' \geq 0.7$ S.

Complex shapes, which are not practical for drawing operations, should be, inasmuch as possible, simplified, or separated into simple portions, to be joined later by stamping, welding or riveting, so as to obtain the required complex shape (see Fig.179, below).

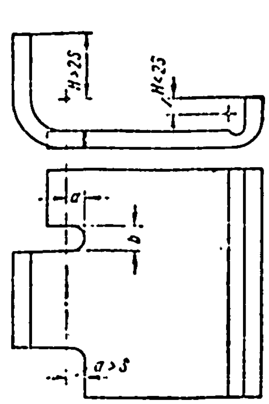

Fig.159 - Location and Dimensions of the Cut Outs and of the Groove

The volumes of hollow vessels should shape themselves with their dimensions, decreasing towards the bottom. The draftsman should indicate on the drawing which of the dimensions are required - inner or outer.

For complex parts it is necessary to work out a technological basis for the holes, external parts of the contour and other elements of the design.

In a drawing-out operation, the wall thickness is actually not equal to the thickness of the original part. This thickness may be determined, approximately, from the curves of Fig.129.

When drawing out a part having a large surface, heaps (hillcocks) may be formed. To avoid this, the flat surface may be made more rigid by means of long and intersecting ribs. Closed and symmetrical ribs are better.

Butt welding should be widely used for ring-shaped parts, regardless of the cross section of the ring, whether it is simple or complex.

In drawing out a rectangular-shaped vessel, the transition of the bottom to the side wall may be shaped without using a single large radius, instead of that, it may be done with a slope of 45° together with smaller radii for the transition

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of this slope to the walls and to the bottom.

If cracks are formed in the angles of a vessel being drawn out, parts of the angles of the flat original stock should be cut off.

The radii of drawn-out parts should be in conformity with the equations quoted before. Decreasing the radii at the expense of a more complex process may be done within the following limits:

Radius of the bottom $R \geq 0.1\ S$

Radius of the flange $R \geq 0.2\ S$

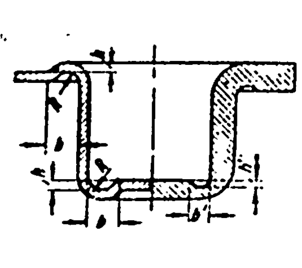

Fig.160

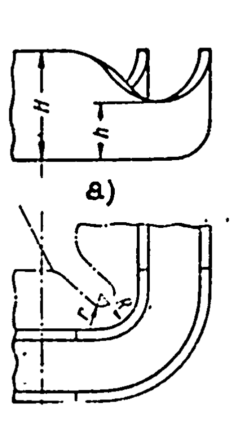

Fig.161

a) Contour of the stock

A further decrease of the radius to R = 0 is also possible, but the decision is with the designer, as shown in Fig.160 (left - typical shaping of a thin material, right - of a thick material). The relation between the values are: $b' = 2 - 5$ mm; $h' = 0.1 - 0.3\ S$; $R \geq S$ (but not less than 1 mm); $h \geq S$ but not less than 1 mm); $b \geq 2\ S$ (but not less than 2 R). In drawing out of parts with a warped cross section and with rounded and straight portions (Fig.161), the height h of the inner walls in the transition zone of two straight portions, should be such that $\frac{r}{R} \geq 0.6$. The height H of the straight portions, is not limited in the outer wall, but in the inner wall it is limited by the amount of metal in the middle portion of the product.

In a drawn-out product, the contour of the flange (especially if its outlines are complex) should be shaped by an equidistant curve. The width of the flange should be small, but not less than $R_M + (3 - 5)\ S$.

Round bodies (medium and large), which are hard for die drawing should be

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pressed out on a lathe. As a result of compression, the deviations in dimensions for a diameter up to 500 mm will be in the order of 0.3 mm; with a diameter above 500 mm the deviation may be from 0.3 to 0.5 mm. When the depth of the product is large, the allowance may be increased by 0.2 - 0.3 mm.

The building in of rigidity in the angles of a body being stamped is shown in Fig.162. When R has its maximum value, the elongation of the material, in the

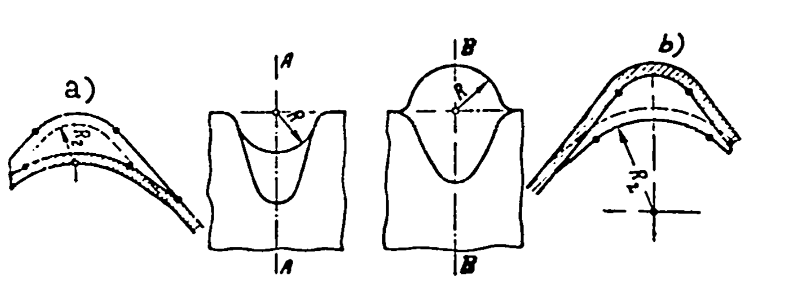

Fig.162

a) Section SS; b) Section BB

concave or convex portions, should not exceed 1.2 - 1.4 ε .

In drawing-out parts with edges of moderate heights, but also with unfavorable dimensions, folds will be formed on the edges. The formation of folds may be avoided by removing the excess material in the cut up (cutting-out triangles - Fig.163).

Ring-shaped hollow products, when designed may be shaped differently (Fig.164). From the standpoint of technology, the variation 1 is best. A ring made up of two halves (variation 4) is easily produced, but, in this case, the waste of metal will be great.

Methods of Assembly. The design and ease of operation of assembled parts determine, to a great extent, the quality of performance and the cost of a machine. The stamping process has great possibilities in this direction. As a rule, stamping is used for assemblies which are not to be taken apart. With its help, obtained by different technological methods (sheet metal work, volume stamping, cutting, etc) may be assembled.

Sketches of various assemblies are shown below, also shown are some of the methods applied in stamping.

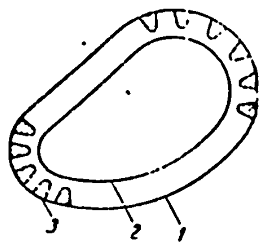

Fig.163 - 1 - The Contour of Flat Stock; 2 - Contour of the finished part; 3 - Metal portions to be removed

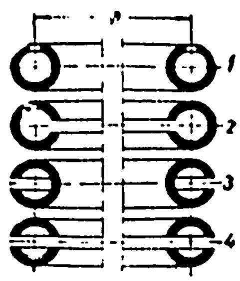

Fig.164

Figure 165 shows the method of producing rectilineal and ring-shaped seams (locks) used for joining parts. For some of the joints (seams) point welding or riveting is used. One group of seams is concerned only with hermatically tight joints, others combine it with strength and rigidity of the joint.

Various joints used for joining sheet metal products are shown in Fig.166. The formation of the angle of a sheet metal box (obtained by bending - not by drawing out) is shown by sketches a, b, c. The sketch d is shown as an assembly of three stamped parts. The box shown by sketch e may be obtained by bending a cut-out sheet.

Figure 167 shows a variety of sheet metal parts joined together. Shown are designs combining several flat parts, round bodies with flat parts and, finally, combining round bodies with round bodies.

Several methods of joining sheet metal parts are shown in Fig.168. For these methods, as a rule, are used bending, edging and shaping.

Figures 169 and 170 show examples of joining sheet metal parts with parts obtained by cutting. In the main, such parts have been formed by bending and shaping.

In Fig.171, a to c give an idea about designing of an assembly of bushings

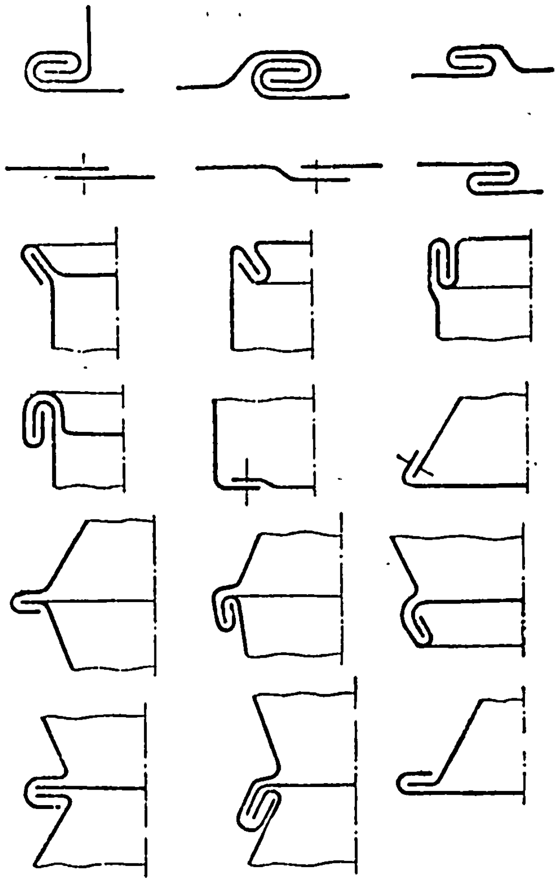

Fig.165

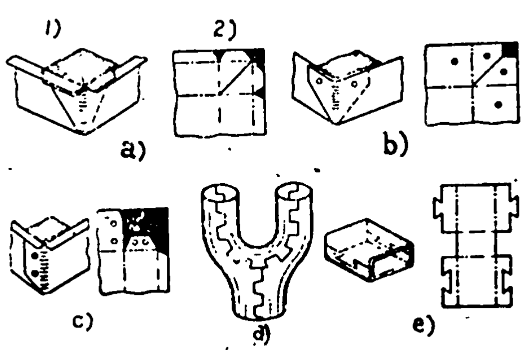

Fig.166

1) Joining an angle; 2) The cut-up

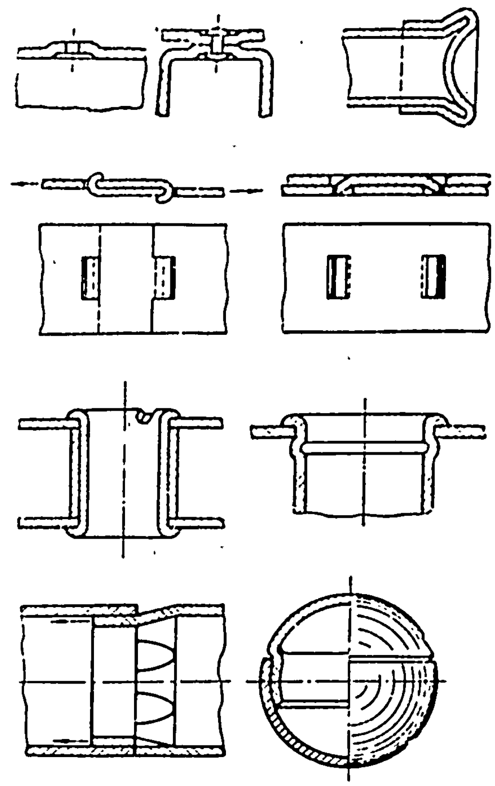

Fig.167

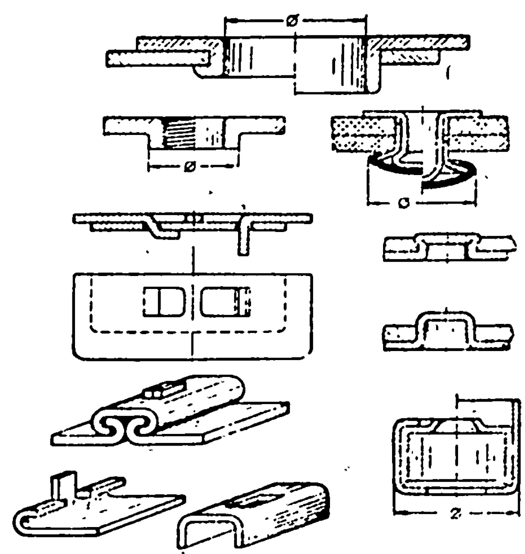

Fig.168

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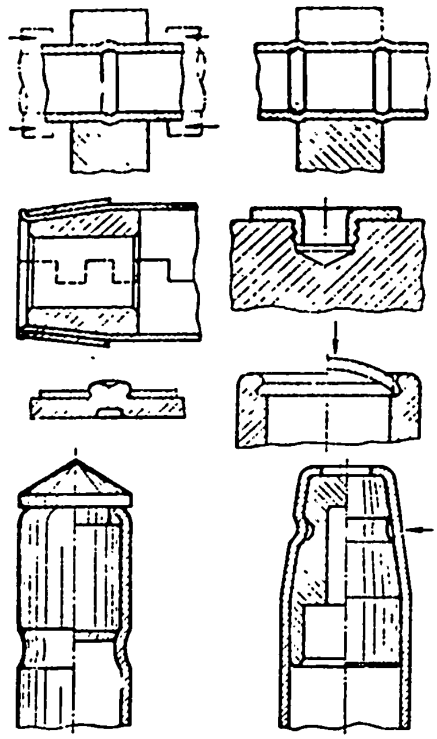

Fig.169

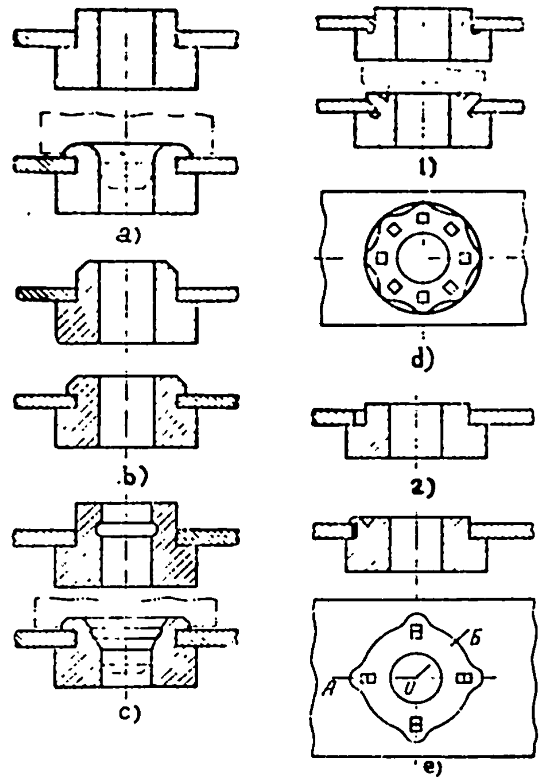

Fig.171

1) Partial spreading of the ring;

2) Section AO5

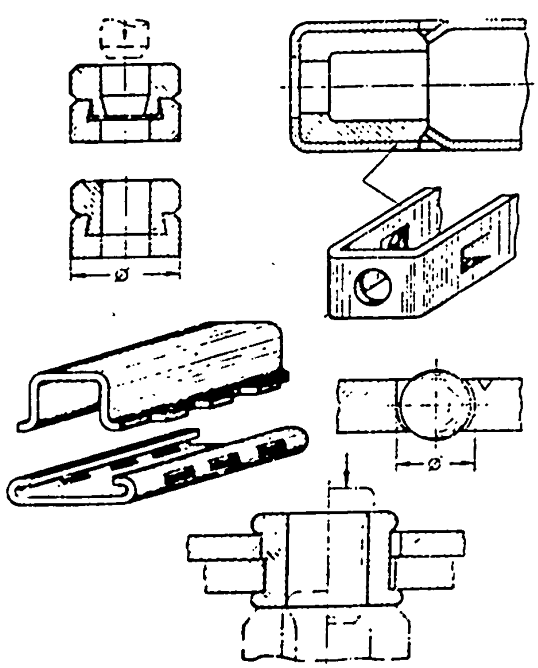

Fig.170

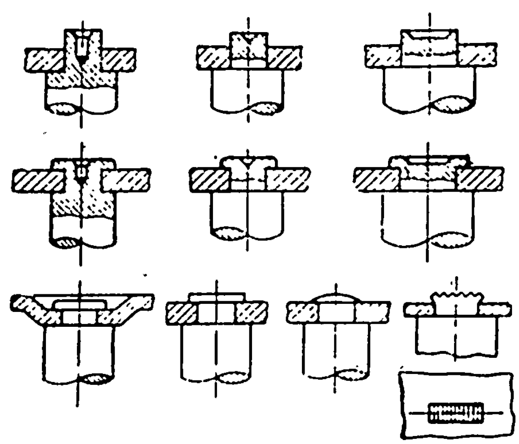

Fig.172

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(obtained by cutting) with sheet metal parts. In sketches d and e, it is evident that for an assembly the material may be deformed not along the continuous contour, but only partially.

Figure 172 shows examples of designing an assembly of rod-shaped material with sheet metal parts.

WELDED STAMPED PARTS

Welded stamped parts, resulting from the application of two processes - welding and stamping - have the following features:

1) Sheet metal stamping reduces the number of parts going into a welded stamped product (the method - bending);

2) Sheet metal stamping reduces the length of welding seams (the method - bending);

3) Technologically, welding raises the quality of sheet metal stampings.

General

The features of welded stamped parts and the problems to be solved when designing the parts are:

1. Imparting any complex shape (required by the designer) to the parts, or to the finished product, is, in majority of cases, easier to accomplish by welding of the component parts, the shape and dimensions of which may be relied upon to produce the required configuration. More often, these products are stampings (in sheet form or voluminal bodies), but they may also be from castings or from rolled material of certain grades.

Welded stamped products may be a combination of component parts produced by different methods (stamping, casting and rolling).

2. The technology of welding and of heat treatment is so perfected that most of the grades of structural steel may be welded with confidence.

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3. Welded stamped products are light in weight. This is effected by using quality material instead of castings and rolled metal having a higher fluidity and, also, by making the cross sections equal in strength. When changing from cast ingots to welded stampings, a reduction in weight is accomplished averaging 20 - 30% when changed from steel, and much more, compared with cast iron.

4. Welded stamped parts will insure stability of operation, though the machine may be loaded to a maximum. To do this, the design of the parts should consider, above all, the requirements for rigidity.

5. The possibility to combine in one assembly raw and heat treated metals, and also to combine in one assembly several different metals. Such possibilities open a new field for designers and technicians.

6. Welded stamped products are not limited because of dimensions.

7. The stamped components of a welded stamped product make it possible to increase the strength by a favorable arrangement of the fibers which, as a rule, do not cross each other.

8. Welded stamped parts from thick sheets may have allowances in the form of excess material, if necessary, and may have the same tolerance (for precision) as have voluminal stampings.

<u>Technological Classification of Stamped and Welded Material</u>. Stamped and welded products are divided into the following groups:

1. Stamped-welded stock which is not subjected to cutting after the welding.

2. Stamped-welded stock which, after welding, has part of its surface, or its entire surface subjected to a cleaning operation by cutting.

3. Stamped-welded stock which after welding has part of its surface, or the entire surface subjected to both, a rough and a final cleaning operation by the method of cutting.

Stocks of the first group, except in rare cases, should not be used if they are to be made into parts requiring great precision.

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Technological Requirements for Stamped-Welded Parts. When designing such parts, the shape, dimensions and the materials of each component element and of the finished product should be in conformity with the technological requirements for efficient stamping and welding.

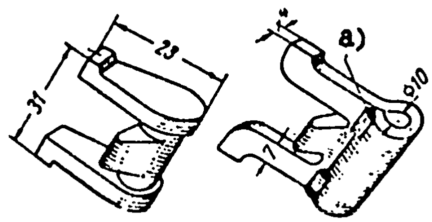

Fig.173

a) Welded

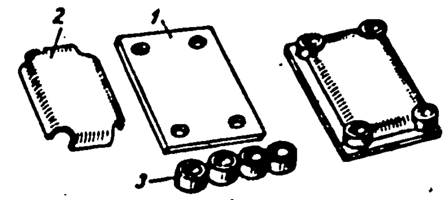

Fig.174

The technological requirements for stamping were described in the preceding pages. Requirements for welding are described in Chapter III.

EXAMPLES OF STAMPED-WELDED PRODUCTS

Below is shown a variety of stamped-welded parts made up mostly from sheet metal.

Figure 173 shows two variations of the same part - of a limiter. The sketch to the left is from a stock which has undergone volume stamping and had its surfaces treated by cutting all around. The sketch to the right is an example of the advantage of combining stamping with welding. In this case, cutting is limited to drilling and broaching the hole, meaning a lower cost.

The stamped-welded plate in Fig.174 consists of three separate parts 1, 2, 3. The welding seams are not continuous. After the welding and annealing, only the butt ends and the holes of part 3 are treated by cutting.

In Fig.175 are shown two variants of the same device - the movable part of a feeding mechanism. The device shown in Fig.175a was produced by volume stamping,

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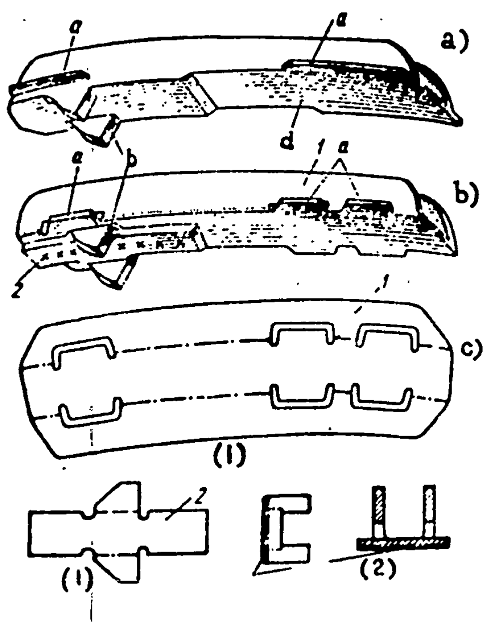
i.e., all of its surfaces have undergone an all-around finishing operation by cutting. The stamped-welded variant is shown in Fig.175b. It consists of a body (1) and a supporting piece (2). The cut-up of these two parts and the places finished by cutting are shown in Fig.175c. The guiding projections a and the planes d, serving as bases for the pins and as supports, are alike for both variants of the device.



Fig/175

(1) Cut-up; (2) Excess material for treating surface by cutting

Figure 176 illustrates a practical and an intractable (from the standpoint of technology) design of the same device. Variant a consists of part (1) having a closed deep impression (hard to finish by cutting), part (2), which is bent and of part (3), also hard to finish by cutting. In variant b, parts (1) and (3) require no special effort for finishing; and a pin is used to prevent the displacement of the part located in the recess of portion (1). The joined parts in both variants are replacable.

In Fig.177, to the left, is shown a cast support for a shaft which is arc-welded to the cheek of the sheet metal base. The sketch to the right shows the shaft support made from welded sheets consisting of a bent sheet metal box (1), (for the purpose of rigidity) which is point-welded to the cheek of the base and to part (2), which in its turn is arc-welded to the cheek of the base and to the rigid box. In this case, the use of stamping-welding insures a better and stronger assembly and simplifies the production.

Figure 178 shows a stamped welded and soldered head of a gasoline engine

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cylinder block. Standard sheets having a thickness of 3, 5, and 10 mm. Even if done by hand, welding of parts has more advantages than producing the entire part

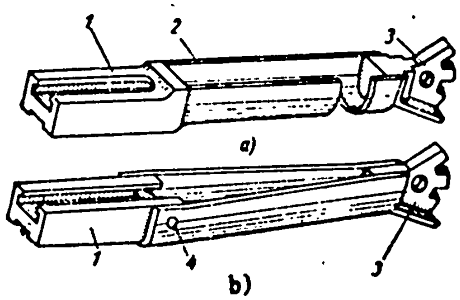

Fig.176

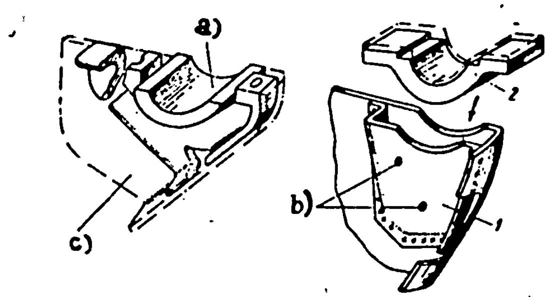

Fig.177

a) Shaft support; b) Drilled holes;

c) Cheek of the base

by casting. The advantages are shown below (for a head of a cylinder block):

Index	By casting the head	By stamping and welding	Saving in %
Net weight	8.15 kg	5.75 kg	29.5
Time consumed	30.4 min	22.5 min	26
Cost, in rubles	13.5	10.3	23.7

Figure 179 shows the design of an assembly subject to strenuous operations. In this assembly, considerable stresses are transferred from the tube to the cup. To avoid the possibility of the cup becoming wrinkled, it has a belt consisting of two flanges welded to the bottom edge of the tube. To make the welding easier, the edge of the tube is bent somewhat. The cup is made of two halves, each of which may be produced by drawing it out not too deep. This enables the use of a material that must not fulfill all the requirements of a material used for deep drawing.

An example of the full utilization of stamping-welding methods is the bed of

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a lathe.

To design the bed, attention was paid to the requirements for the planes joining each other and to the loads to be experienced by the bed. Technologically, the design of the bed is very simple and the bed itself is rigid and sturdy.

The drawing of the lathe bed is shown in Fig.180.

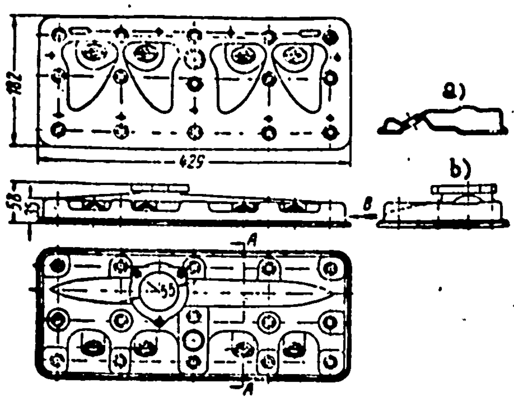

Fig.178

a) Section AA; b) View along B

The bed is made up of welded sheets, with all sheets of the same grade, namely steel Grade CT 2. The sheets joined longitudinally have a thickness of 3 mm. The transversely located baffles are 5 mm in thickness. Because of the possibility of using sheets of only a few thicknesses and due to the practical shapes and dimensions, the coefficient of utilization of material may be raised by 20 - 30%, as compared with the coefficient of metal utilization by ordinary stamping without welding.

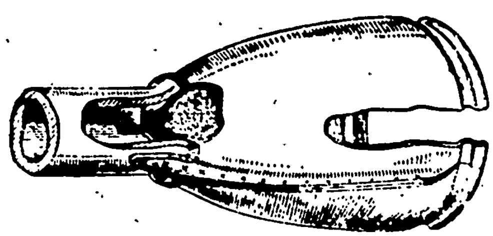

Fig.179

The stamping-welding method increased the rigidity of the bed. Because of this, only three supports were found to be necessary. The feature of this design is the almost complete lack of preparatory work to make the borders fit for welding.

Finally, the mechanical treatment is reduced to a minimum by fabricating the front guide from rolled sheet with one profile and the back guide from rolled sheets

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of a different profile.

COLD UPSETTING OF PARTS BY AUTOMATIC PRESSES

A great variety of small parts used for joining or to strengthen other parts may be produced by automatic presses designed for cold upsetting such as wheel

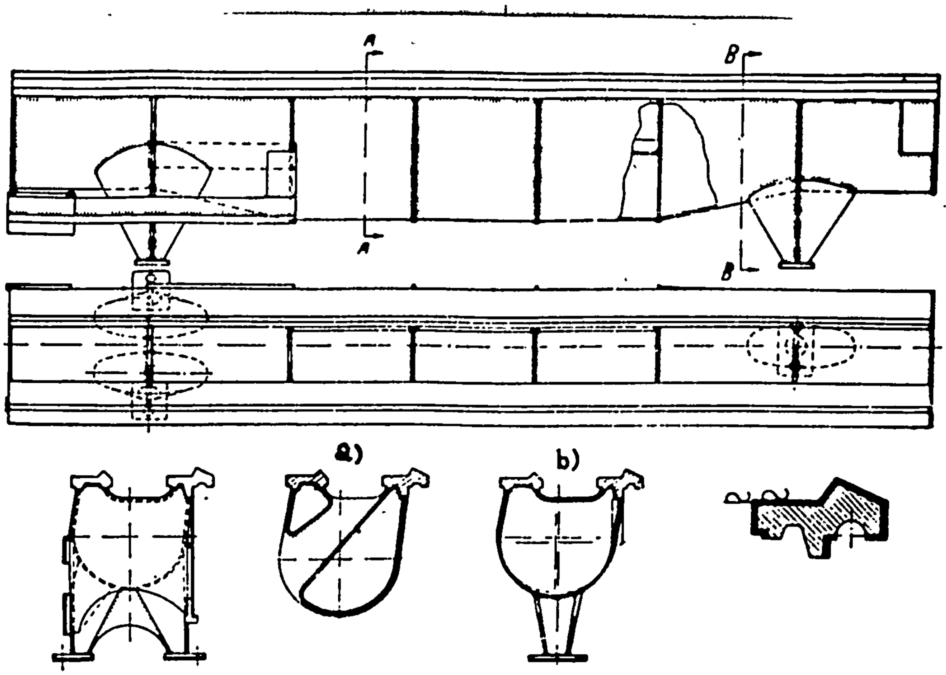

Fig.180 - A Stamped-Welded Lathe Bed

a) Section along AA; b) Section along BB

spokes, cap nuts, several types of connecting pins, valve tappets and their adjusting bolts, small rollers and balls, star-shaped devices for controlling brakes, special supports for containers used in the vegetable industry, spokes for bicycles and motorcycles, caps and many others (Fig.181). Cold volume stamping and upsetting will produce parts with a higher degree of precision and with better finished surfaces than is possible in hot stamping. On the other end, cold upsetting requires a sturdier and more powerful equipment.

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As a rule, cold upsetting is effected without producing extruding edges (so-called: flash, fins or burrs).

The production of the above-named parts by the automatic presses using pressure on the unheated parts, instead of cutting out the shape, is resulting in great savings of metal, in a tenfold increase of productivity, and in improvements of such properties as firmness and hardness.

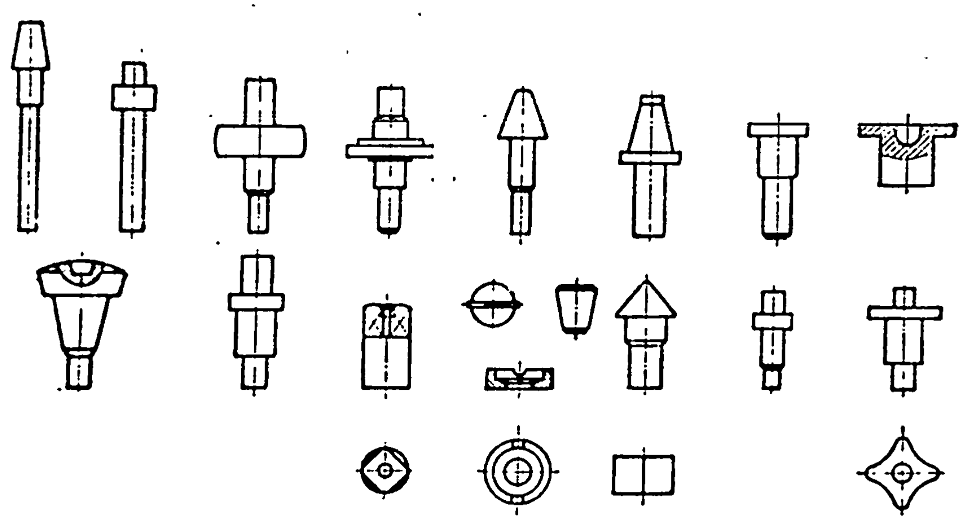

Fig.181 - Samples of Parts Produced by Cold Upsetting in an Automatic Press

In this cold process using pressure, the fibers do not cross each other, but are oriented along the contour.

The maximum diameter of a rod which may be handled by this cold process in automatic presses is 25 mm. As to the maximum length, it is not as yet possible to make it higher than 200 mm for standard presses, but specially designed presses are able to handle lengths up to 400 mm. With semiautomatic and automatic stamping serving as a preliminary operation, it is possible to do the heading (upsetting the heads), reducing and threading on pieces with a length up to 1800 mm.

Metals Used in Cold Upsetting

The metal used for cold upsetting of parts has, in most cases, a round cross section with a diameter from a few tenths of a millimeter up to 25 mm with a tolerance of 0.025 to 0.15 mm.

In isolated cases, the material may have a larger diameter and be not only round but have a different shape, such as rectangular, square, trapezoidical or oval.

Mostly used are: Grade 08 to 45 quality carbon steel and Grades A12 to A35; Grades of alloy steels used are: 35G2, 20X, 40X, 40XH, 15X, 25XHBA, 40XIA, 40XHM, 30XGCA, SHX9, 1X18H9T, Y10A, Y12A, and others; alloy nonferrous metals such as Duralumin D3P and DI; brass LS59, L62, L68; red copper; Monel metal, etc.

The metal used for cold upsetting has a good plasticity if its hardness H_B after annealing is: $H_B = 120 - 207$. For cold upsetting, usually, in use are steels with relatively large grains corresponding mostly to grains No.3 and No.4 out of eight grade numbers.

Grains of such size are in conformity with the plasticity of the steel required in upset operations.

The relation between the chemical composition and the properties of steel is described in Table 40. For the physical and mechanical properties of a calibrated wire, see Table 41.

A characteristic graph of a test with calibrated wire, stretched and cold-drawn, is shown in Fig.182.

The metal for cold upsetting having a diameter up to 16 mm is delivered in bundles; metal of a larger diameter is delivered in lengths up to 6 m.

The surface of the calibrated material must be smooth, shiny, without shells, cracks and other similar defects.

The outside diameter of a bundle is D_{out} = 100–750 mm, while the inside diameter is D... = 400–500 mm; the weight of the bundle, depending on the diameter STAT

Table 40

The Influence of the Chemical Composition on the Plastic Properties of Steel in a Cold Upsetting Operation

Chemical Element	Improves	Makes Worse	Additional Information
C		+	Increasing C by 0.1% will increase σ_v by 6–8 kg/mm^2. Cold upsetting of carbon steel containing C > 0.2% requires annealing to a structure of greatest plasticity – grained perlite.
Si		+	In a steel containing 0.45–0.5% carbon, the Si, if present, has very negative results on cold upsetting. The presence of Si > 0.2% lowers to a great extent the plasticity, causes a considerable heating of the metal during the deformation, reduces the firmness of the dies and requires a greater force for upsetting.
Mn		+	In carbon steel, the Mn content should not exceed 0.65%. The presence of Mn is dictated by the necessity the unfavorable effect of S
Cr		+	The presence of Cr lowers the plasticity of high carbon steels. Increasing Cr by 0.1% in steel Grade 40 will increase σ_v by 2.5 kg/mm^2. For steels containing less than 0.3% carbon, the presence of Cr has no great effect.
W	+		The admixture of 0.15 – 0.2% improves the cold upsetting and increases σ_T and σ_v, at the same time.
Mo, V	+		Improves the cold upset process and improves σ_T and σ_v
Al	+		Steel, with 0.03 – 0.05% of Al added as a deoxidizer, has high plastic qualities and tends to become a grained pearlite.

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243

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material, is G = 30 - 80 kg.

Steel for cold upsetting is delivered in annealed or normalized condition, etched by a weak acid solution and neutralized by lime milk.

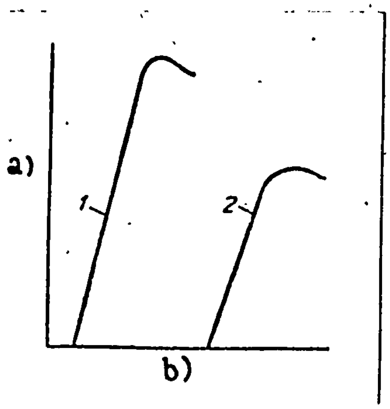

Fig.182 - Characteristic Graph of a Test Performed by Stretching Two Calibrated Cold-Drawn Wires

1 - Steel wire with a diameter of 5.1 mm, with (σ_T = 64.8 kg/mm^2, H_B = = 152); 2 - Brass wire, 5.1 mm in diameter, (σ_T + 38.4 kg/mm^2, H_B = 126)

a) Load; b) Deformation

METHODS FOR FORMING HEADS

The upsetting of parts used for fastening or for joining other parts together is performed mostly by horizontal cold upsetting automatic presses.

The forming of the heads of these parts (heading) may be effected in the matrix, in the plunger and simultaneously in both halves of the die (Fig.183 a-m).

The working speed of the plunger at the beginning of the upset is v_{work} = = 0.14 1.4 m/sec. The speed of deformation $v'_z = \frac{\varepsilon}{t} 100$ equals 1300-20000%/sec (see Table 42), where ε is the rate of deformation in upsetting; t is the time period of deformation, in seconds.

THE PRECISION AND CLEANLINESS OF STAMPED SURFACES

Cold volume stamping and upsetting by cold upsetting automatic presses and by crankthrow (coining) presses will produce parts with a precision along the axis equal to 0.03 - 0.05 mm.

The precision in the plane perpendicular to the movement of the plunger depends on the precision with which the dies are made, how correctly is the plunger

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positioned in relation to the matrix and on the ability of the die to withstand wear.

Table 41

The Values of σ_T, σ_v and N_B of a Calibrated Wire in Cold Upsetting Process (Data Furnished by Author)

Diameter in mm	σ_T v kg/mm^2	σ_v v kg/mm^2	$\frac{\sigma_T}{\sigma_v}$	N_B average	$\frac{\sigma_v}{N_B}$
Steel					
6.2	37.3	41.1	0.91	109	0.38
6.2	65.5	67	0.98	137	0.49
7	67.6	70 1	0.95	140	0.5
7	44.1	45.8	0.96	123	0.37
8.6	36.2	41.6	0.87	123	0.34
8.6	48.2	55	0.88	143	0.38
8.6	56	59.2	0.94	152	0.39
8.6	49	53.3	0.92	131	0.41
5.1	64.8	69.3	0.94	152	0.45
5.12	43.7	49.3	0.89	134	0.37
7	43.5	49.5	0.88	134	0.37
Brass					
5.1	38.4	48.5	0.79	126	0.38
5.1	35.4	42.8	0.83	123	0 35
10.4	39.2	51.8	0.76	143	0.36
7	36.4	44.2	0 82	92	0.48
7	42.9	50.4	0 85	107	0.47
Aluminum					
7.9	23.05	34.1	0.68	–	–

To obtain a higher degree of precision, calibrating operations are used, such as: reducing and volume and surface coining (Table 43).

Parts requiring threads of the 2nd and 3rd class of precision are usually made by a cold upset combined with reducing and threading.

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Table 42

Speed of Plunger at the Beginning of Deformation and Rate of Deformation

Types of Automatic Presses		Minimum and Maximum Dimensions of the Automats in mm	Assumed Value $\frac{h_o}{d}$	Angle of Crank Position at the Beginning of Stamping in Degrees	Speed of Plunger v v_{work} in m/sec	Rate of Deformation v_z in %/sec
Single-strike, cold upsetting	With a single piece matrix	ø 3 - 10	2	42-45	0.25-0.4	4350-1800
	With a separating matrix	ø 4 5 - 6			0.7-0 8	9000-6000
Two-strike cold upsetting	With a single piece matrix	ø 3 - 20	3		0.7-1	6000-1300
	With a separating matrix	ø 6 - 25			0.75-1 3	6000-1300
Nail forming	With a universal type matrix	ø 6 - 20	1 5	20	1.25-1 4	7800-2300
	With horizontally positioned squeezing and cutting matrixes	ø 1 2 - 4 5			0.5-0.9	20,000-12,000
Cutting (may possibly be used for repeated stamping operations	With a crank-lever drive for the slide block	ø 10 - 20	-	40	0 5-0 65	-
Nut stamping	Multi-operational	ø 12	-	20	0 14	-

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FORCE REQUIRED FOR COLD UPSETTING

The force required for cold upsetting is determined by the conditions affecting the deformation, by the properties of the deformed metal, by the shape and

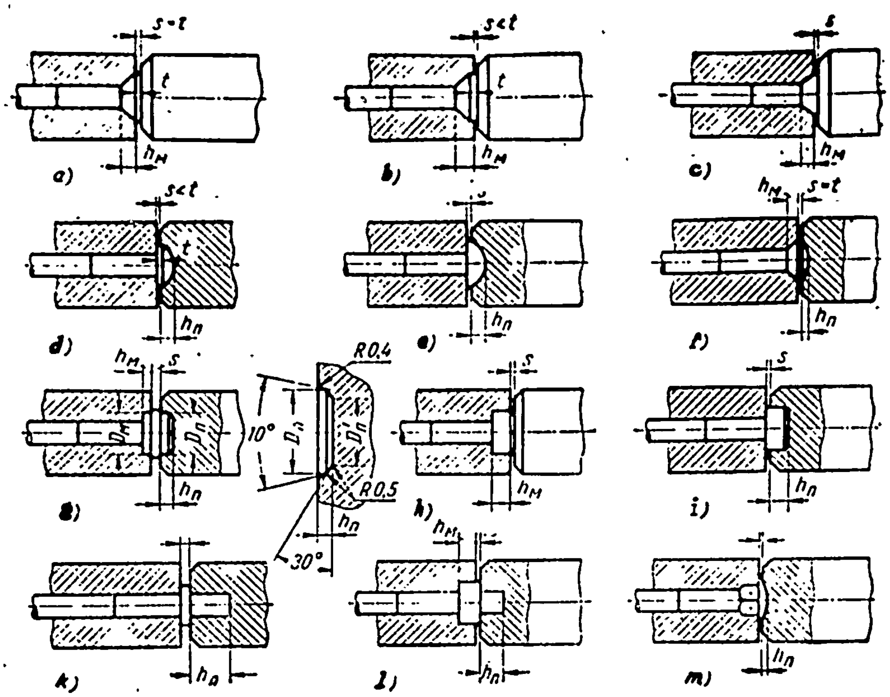

Fig.183

dimensions of the stampings and also by the degree of precision and cleanliness of the surfaces.

The specific pressures required to effect the shaping of steel are assumed to be as follows:

Operation	Specific Pressure in kg/mm^2
Upset of heads (heading) of round shape	150–160

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Operation	Specific Pressure in kg/mm^2
Upsetting hexagonal heads	250-270
Volume stamping	180-250
Calibrating coining	200-250
Pressing-out hollow products	250-350
Electro Upsetting	10-15
Reducing (squeezing the rod)	300-330

To determine the force required for upsetting, use can be made of the following equations, although only approximate values may be obtained. The force required

Table 43

Accuracy and Smoothness of Surface, Obtained for Volume Stamping

Operation	Precision Class for Degree of Deviation, in mm	Smoothness Class
Hot volume stamping	3^{rd} - 4^{th}	2^{nd} - 4^{th}
Cold volume stamping	2^{nd} - 3^{rd}	6^{th} - 8^{th}
Stamping with electric heating	± (0 025-0 1)	3^{rd} - 5^{th}
Die stamping	± (0.05-0.25)	6^{th} - 9^{th}
Reduction	2^{nd}	8^{th} - 10^{th}
Impact extrusion	2^{nd} - 4^{th}	6^{th} - 7^{th}
Static extrusion on complex instrument	2^{nd} - 4^{th}	9^{th} - 10^{th}

for a cold upset of round parts with, or without burrs (fins) is:

$$P \approx \sigma'_T \alpha \left(1 + 0.05 \frac{D}{h}\right) F \ kg,$$

where α is a coefficient found in charts of Figs.184 and 185; σ'_T is the true resistance to deformation, in kg/mm^2; D is the diameter and h is the height of the upset head in mm; F is the projected area of the stamped-out head (including the burr) in mm^2.

The force required for upsetting of round bodies (without producing a burr) made of Grade 10-20 in mm steel is:

$$P \approx \beta \cdot \sigma_T D^2,$$

where coefficient β = 0.5 - 0.6; σ_T is the minimum value of the index of the limit of fluidity of the material, as shown by GOST in kg/mm^2; D is the diameter of the stamped part in cm.

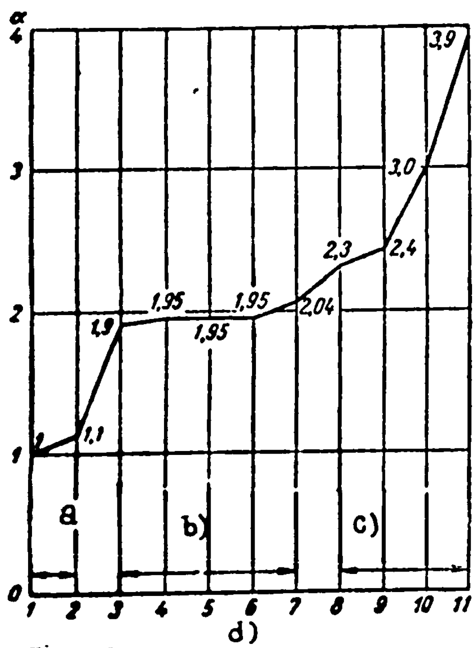

Fig.184 - Chart Showing Values of Coefficient α in Swaging without a Burr

a) Operating nest not filled; b) Normal swaging, nest fully filled; c) Combined swaging, coining; d) Number of experiment

The value of the deforming force, when found for a new, complex and untested process, should be verified experimentally on a testing machine or by a hydraulic press.

Values of the force required for the upsetting of different parts is shown in Table 44. The data was furnished by several authors.

In Fig.187 two curves (a and b) are drawn as an example of relation between the force required for upsetting and the stroke of the plunger S. The material upset is: a) semiround head with formation of a burr; b) hexagonal nut made from Grade 15 steel.

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Table 44

Force Required for Cold Upsetting (Experimental Data)

No.	Shape of Head	Head and Rod Dimensions in mm			Material for Parts	Force required, in tons	Remarks	Source of Data
		d	D	h				
1	Cylindrical	3 2	4 8	0 8	Steel 10 ($\sigma_T \geq 18$)	2	Work carried out on a testing machine	Data by Author
2	Semiround, with burr h = 0 22 mm thick; s = 0.1 mm wide	4.43	D=6 68 / D_1=8 84	3 06	Steel 15 ($\sigma_T \geq 21$)	22		
3	Semiround	4 8	6 4	3	Aluminum	1 5		
4	Semiround	4 8	7 9	4	Steel 20 ($\sigma_T \geq 21$)	7.3		
5	Countersunk	6	11	2.9	Steel 15	27.8	By cold upsetting in automatic press	Data by A.N.Gladkikh
6	Countersunk castellated	6	11	2 9	Steel 15	29.7		
7	Countersunk castellated	6 4	11 9	5 5	Steel 25 ($\sigma_T \geq 25$)	20	Tested on cold upsetting automatic and vertical crank press	Data by author
8	Countersunk	9 5	15 8	6 1	Steel 15	25		
9	Semiround	9 5	16 7	5 6	Steel 15	30		
10	Barrel-shaped	10	16 2	7	Steel 35	25	Tested on cold upsetting automatic press	Data by V.A.Popov
11	Hexagonal	10	16 2	7	Steel 35	44		
12	Semiround with square under head	10	21 34	4 8	Steel 35 ($\sigma_T \geq 30$)	100	Side of square 10 mm; height of square 4.8 mm	Data by N.E.Linsley
13	Semiround with square underhead	16	34	8 6	Steel 35	200	Side of square 16 mm; height of square 6.3 mm	
14	Semiround with square underhead	19 05	40 4	9 4	Steel 35	300	Side of square 16 mm; height of square 6.3 mm	
15	Hexagonal nut	10	22	9.5	Steel 15 ($\sigma_T \geq 21$)	60	Tested on a hydraulic testing machine	Data by author

Remarks: Symbols in the Table are: d - diameter of upset part of product; D - diameter of upset head, round without burr, or of the circle circumscribed around the square or hexagonal shape; h - height of upset head or of product; D_1 - diameter of upset head with burr.

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SELECTION OF THE NUMBER OF TRANSITORY OPERATIONS REQUIRED AND CALCULATIONS FOR CONICAL PLUNGERS

Cold upsetting of parts may be effected in 1, 2, 3 and more transitions (strikes). The number of strikes required depends on the configuration and dimen-

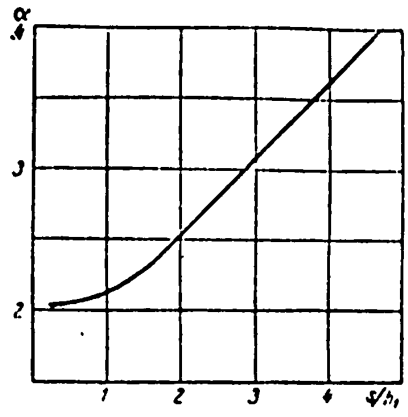

Fig.185 - Chart Showing Values of Coefficient α in Swaging with Formation of a Burr h_1 Thick and s Wide (Bibl.29)

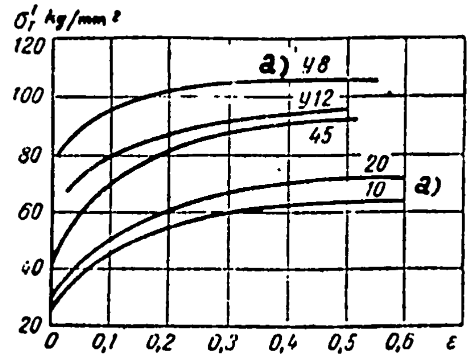

Fig.186 - Chart Showing the True Resistance to Deformation (Data by L.A.Shofman)

a) Steel

sions (see Table 45).

The number of transitions, or the relative acceptable length of the upset part $\frac{h_o}{d}$ is determined by the quality of the material and its diameter, i.e., it is a function of the firmness of the stem from its longitudinal bend.

The maximum acceptable value of $\frac{h_o}{d}$ is shown in Table 46 (data by V.A.Popov shows these values are applicable in upsetting by automatic presses).

A two-strike upsetting operation is the most widely used for a great variety of parts used for fastening or for joining other parts together.

Products, if the length h_o of their portion to be upset is less than 2.5 d, as an exception, are upset not with one, but two strikes, if:

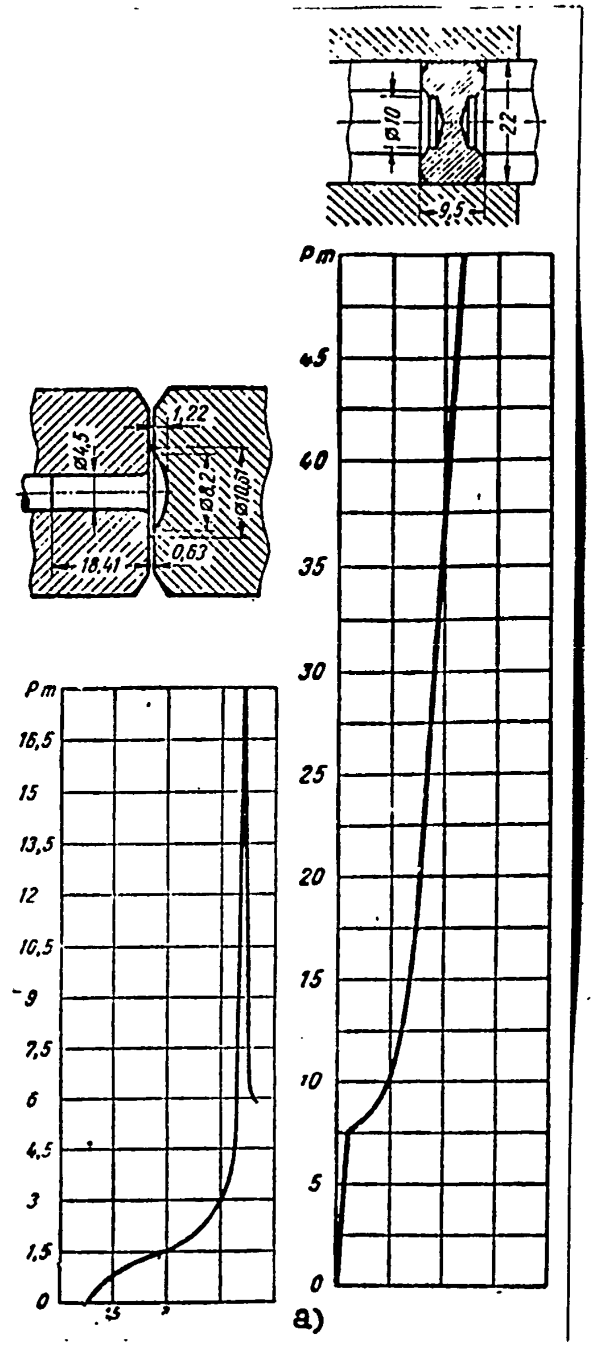

Fig.187

a) Length of plunger stroke

a) The ratio $\frac{D}{h} > 4.5$ (flat head);

b) The head to be upset is to have a shape and dimensions requiring special treatment (rivets with semielliptical heads used in cases where the joints must be be reliable);

c) The head is hard to upset. For example, cylindrical heads, countersunk heads with square underheads, square countersunk heads.

When the part to be cold-upset is of a new and untested design, the selected number of transitions required should be verified experimentally.

Parts, especially complex technologically, may require four, and sometimes five transitory operations. In many cases, especially in upsetting steel parts containing more than 0.2% carbon, an intermediate annealing and a repeat upset should be effected.

Parts upset with two or three strikes and parts which have undergone annealing have their repeat upset in horizontal presses equipped with bunker-type loading devices.

A repeat or a secondary upset makes it possible to widen considerably the number of parts suitable for upsetting, including parts with inordinary configurations and dimensions.

Table 45

Number of Transitions to be Selected in Upsetting Parts Having Stems

No of Strikes	Relative Sizes of Upset Portion of stock and of Heads			Fig No	Sample List of Upset Parts	Remarks
	$\frac{h_o}{d}$	$\frac{D}{h}$	$\frac{D}{d}$			
1	≤ 2.5	≤ 4.5	≤ 2 2	188	Rivets, screws, etc, with semiround countersunk or semicountersunk heads	1. Upsetting in 2 and 3 is usually done in one matrix I (Fig 189a and b)
2	2.5 - 5	4.5-8.5	2 2 2 6	189	Stock for bolts, rivets, screws, etc, with cylindrical heads, or heads with square underheads	2. Preparatory (conical) plunger 2 (Fig 189a) and intermediate (in 3-strike operation) and finishing 3 (Fig 189b) are set consecutively before the strike
3	5-8	8.5-10	2.6 4		Screws with crosshead cut, bolts hexagonal inside and outside and other complex parts	3. Plungers set on skis sliding in slide block vertically or in an arc

The diameter of the base of the cone (of a conical plunger) D_k is: (specifications of auto plant named after Stalin) (Fig.190).

$$D_K = \sqrt[3]{\frac{24}{\pi} \operatorname{tg} \frac{\alpha}{2} V + d_K^3} - 2 \operatorname{tg} \frac{\alpha}{2} n;$$

where d_k is the diameter of the cylindrical hole of the conical plunger or the smallest diameter of the stock; V is the volume of the deformed portion of the stock (from the plane of the larger base to the plane of the cone's smaller base; n is the distance from the plane of the large base not reached by the conical plunger

$$n = a - b + 1.5$$

where a is the distance crom the front butt end of the matrix to the plane of the

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large base; b is the distance from the front butt end of the finishing plunger to the front butt end of the matrix (this may be taken as $\alpha \approx b + 1.5 \approx \frac{1}{3} n$); α is the plunger cone angle; The optimum angle of the cone for the first upset operation is equal to $6^\circ \pm 15'$, for the second upset (with a 3-strike upset) is $12^\circ \pm 15'$.

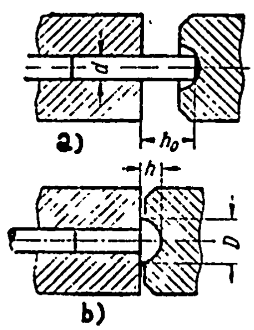


Fig.188 - Method of Upsetting in One Operation

a - Start of operation; b - End of operation

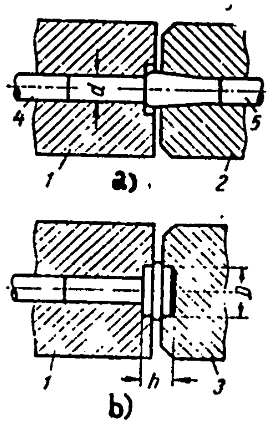


Fig.189 - Method of Upsetting in Two Steps

a - End of 1^{st} step (upsetting of head)

b - End of 2^{nd} step

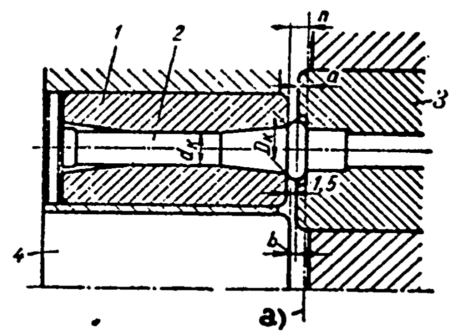


Fig.190 - Longitudinal Section of a Conical Plunger

1 - Conical plunger; 2 - Thrust pin; 3 - Matrix; 4 - Finishing plunger

a) Plane of the base

With $\alpha = 6^\circ$ $D_k = (1.2 - 1.3)\, d_k$; with $\alpha = 12^\circ$ $D_k = (1.5 - 1.7) d_k$.

Equations to determine D_k without calculating the volume V are given in Table 47 (data by ZIS).

UPSETTING OPERATIONS WITH MATRIXES

The type of matrix to be chosen for upsetting depends upon the length of the stem of the upset part, on the nature of the work and on the quality required for the finished product (Table 48).

Single-Piece Type of Matrixes for Upsetting (Fig.191). A wire or a ro is fed periodically by rotating channeled rollers (2) through the hole of the cutting matrix (3) until the wire or the rod reaches thrust stop (4). The forward movement

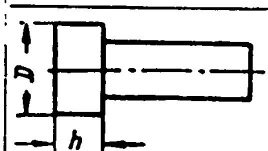
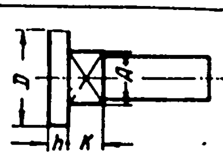
Table 46

Acceptable Values of $\frac{h_o}{d}$

Diameter of Stock in mm	Upset Material	
	Steel, Grade 10 Brass Л68	Steel Grade 35 and 40X
3-7	1.7	2
7.1-10.5	2.3	2.45
10.6-16.5	2.5	2.65

of the cutter (5) cuts off a piece which, by means of a special holding device (6) is transferred to the line of upsetting.

Table 47

	$D_K = \sqrt[3]{6\,\mathrm{tg}\,\frac{\alpha}{2} D^2h + d_K^3} - 2\,\mathrm{tg}\,\frac{\alpha}{2}\,n$; with $\alpha = 6°$ $D_{K1} = \sqrt[3]{0{,}314 D^2h + d_K^3} - 0{,}1n$
	$D_K = \sqrt[3]{6\,\mathrm{tg}\frac{\alpha}{2} D^2h + 0{,}4A^2K + d_K^3} - 2\mathrm{tg}\,\frac{\alpha}{2}\,n$; with $A > 1{,}1d_K$ и $\alpha = 6°$ $D_{K1}^* = \sqrt[3]{0{,}314D^2h + 0{,}4A^2K + d_K^3} - 0{,}1n$

* D_{k1} is the diameter of the base of the plunger cone in a 2-strike upsetting.

a) Sketch of part; b) Equations

When the plunger (7) is moving towards the matrix (8) the cut-off piece is first pushed in the hole of the matrix until it is stopped by the stem of the ejec-

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Table 48

Selection of Type of Matrix for a Cold Upsetting Operation

Matrix Type	Stem Length	Type of Work for Matrix	Quality of finished part	Remarks
Single-piece type	$l \leq 8d$	1. Stamping and upsetting; 2. Reducing the stem (here, the matrix consists only of a matrix proper and an eye for the stem	The finished part is smooth; no burrs under the head	The maximum length of a part to be handled in a single-piece matrix depends on the force pushing the part out and on the strength of the ejector pin.
Separating type	$l \geq 8d$	1. Stamping and upsetting; 2. Flattening, making deep impressions and similar work; 3. Stem bending; 4 Holds stock tight to prevent part from moving longitudinally	The pass in the matrix is cone-shaped to make the ejecting of the part easy. A small burr may be formed under the head at the place of the die separation.	Stem reducing is not done in a separating matrix. In special automatic presses equipped with separating type matrixes, it is possible to upset heads from long rods (up to 1800 mm), or to do reducing by the plunger of the ends by cutting. In this case, the matrix is made with passes and grooves placed transversally.
Universal type (Either a single-piece or a separating type matrix may be placed in the bed of the matrix		1. Stamping and upsetting; 2 Stem reducing (if the upsetting was done in a single piece matrix	The quality of the finished product depends on the type of matrix placed in the bed of the matrix	Special automatic presses are also good for 2-sided upsetting simultaneously. During the upsetting, the separate parts of the matrix press each other To ease the ejection, the matrix parts move apart. The cutting and moving of the stock is done in automatic presses with single-piece matrixes. In this case, separating matrixes for transverse deformation are not used

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tor (9). The upsetting of the head takes place with the further movement of the plunger. As the plunger returns to its place, the upset piece is pushed out by the ejector (9) from the matrix.

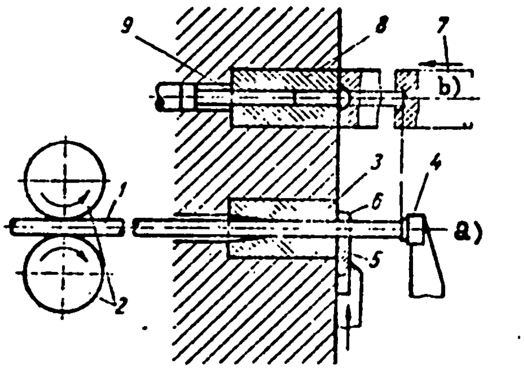

Fig.191

a) Line of feeding; b) Line of upsetting

If the matrix is of the single-piece type, the length of the stamping stem is determined by the position of the ejector (9).

Upsetting with Matrixes of the Separating Type (Fig.192). The wire or rod (1) is fed periodically by rotating channeled rollers(2) through the cutting matrix (3) and through the open matrix parts (4 and 5) until it reaches the turning stop (6). The matrix part (4) moving to the right cuts off a piece with its butt surface. The cut-off piece is then carried by matrix parts (4 and 5) to the upsetting line where it is squeezed to keep it tight in place. For this purpose, the clearance between the matrixes is from 0.02 to 0.2 mm. The projected portion is swaged by the plunger into a head of required shape. Thereafter, matrixes (4 and 5), with the aid of relieving spring (7), return back to the feeding line. During their return, the matrix parts separate with the aid of roller (8) descending by means of a sloped plane (9) (or wedge). The stamped part is ejected from the open matrixes by the material itself, at the next feeding cycle.

The length of the separating-type matrix determines the length of the part to be upset.

More often, the matrixes of the separating type have a square cross section; matrixes with a hexagonal cross section are also used.

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<u>Upsetting with a Universal (Combined) Type of Matrix.</u> Universal-type matrixes which are single-piece matrixes divided in half, are used for cold upsetting.

The principle is the same as in upsetting with single-piece matrixes, the only difference being, that to ease the ejection, the pressure between the two halves is somewhat weaker.

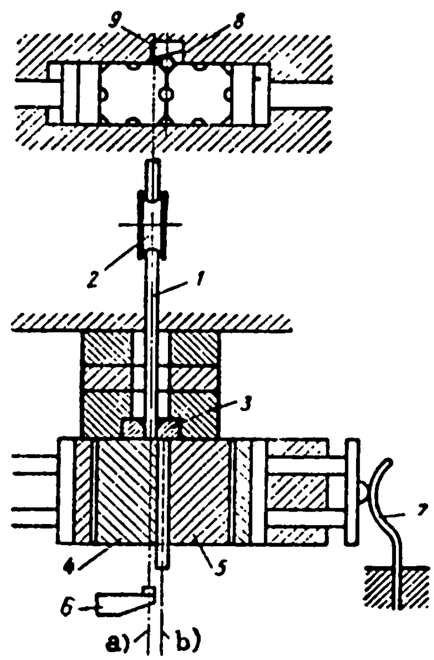

Fig.192

a) Line of feeding; b) Line of Upsetting

<u>Upsetting of Semispherical Heads with Straight Notches.</u> The upsetting is performed in a two-strike cold upsetting automatic press with a single-piece matrix and is done in a two-step operation (Fig.193).

The plunger operating nest is made by deeply impressing it in a hydraulic or screw-friction type of press.

The curve in Fig.194 represents the force necessary for deeply impressing the nest in the plunger, made of U10A steel.

The force required to exert the pressure may be determined from the following equation:

$$P_{vyd} \approx \gamma \sigma'_T F,$$

where $\gamma \approx 3.5 - 3.75$; σ'_T is the true resistance to the deformation of the instrument steel in kg/mm^2 (may be determined approximately by using the curve in Fig.186, assuming the condition of maximum deformation); F is the projected area of the nest under pressure in mm^2.

The force required to exert pressure necessary to shape the plunger nest for

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upsetting semiround heads with straight notches is shown in Table 49.

Stamping of Screws with Inside Hexagons. The material used is steel grade-10. The operation is as follows: First, the upsetting of the head is performed on a two-strike cold upset automatic press with a single-piece matrix (Fig.195). Next, the upset pieces are annealed (t = = 880 - 900°C) and, thereafter, a repeat upset is performed in a crank-type or automatic press, where the inside hexagonal and the final shaping of the head is accomplished with a single strike (Fig.196)

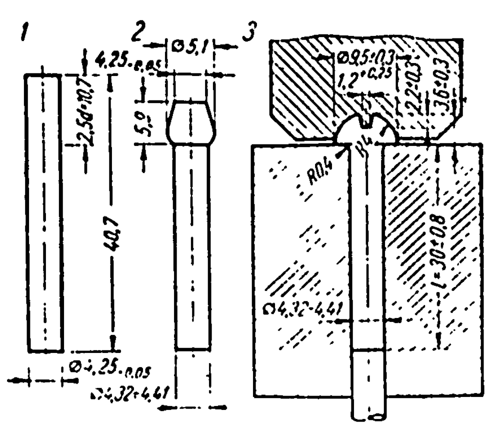

Fig.193 - Transition Steps in Upsetting a Semiround Head with a Straight Notch

1 - Cutting off; 2 - 1st step of upswtting; 3 - Final upsetting of head with notch

The head sizes of screws (the second and third steps of the operation) and of plungers are shown in Tables 50 and 51, these being the specifications of the plant "Stankonormal".

Stamping of Screws with Cross-Shaped Nests in the Head. The shaping of screws with cross-shaped nests in the head may be performed by the open and closed methods (Figs.197 and 198).

Table 49

Force Required for Shaping the Nest

Screw	Diameter of Nest D in mm^2	Required Force P in m
M4	6.5	11.2 - 14.5
M5	9.96	24.5 - 26.2
M8	12.94	35 - 44.2

The shaping by the open method is performed by cold upsetting in a three-strike automatic press, or in a two-strike automatic with a repeat operation in a single-strike automatic press.

With the open method, the head is upset first and the shaping follows after.

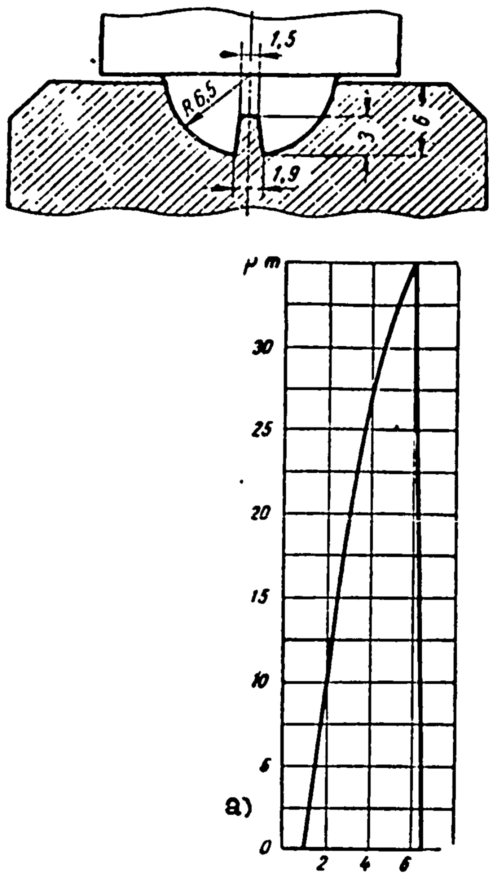

Fig.194

a) Length of plunger stroke

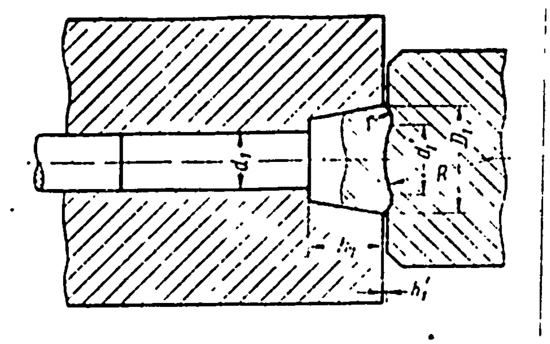

Fig.195

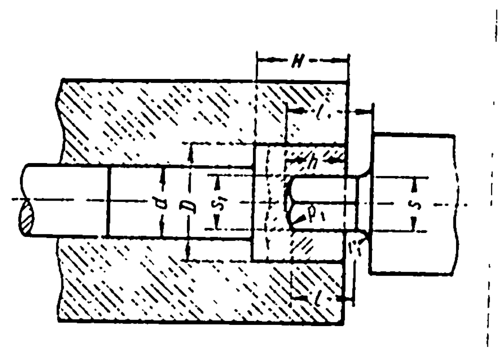

Fig.196

When a repeat operation is required, there should be an intermediate annealing before the part goes to the automatic press.

The closed method of shaping is accomplished in two operations; the head is upset in two transitory operations, the nest is shaped simultaneously with the head during the second operation.

With the closed method, besides fewer strikes required, truer shape and dimen-

Table 50

Sizes of Screw Heads and of Plunger Operating Nests (see Figs.195 and 196)

a)	b)					c)				
	d_1	D_1	h_1	h_1'	d_1'	d	D	H	h	d)
M8	$7,04^{+0,04}$	$11,5^{+0,1}$	$5,6\pm0,2$		8	$7,04^{+0,02}$	12	$8\pm0,5$	5^{+1}	$6^{+0,2}_{+0,1}$
M10	$8,84^{+0,04}$	$11,5^{+0,1}$	$7,6\pm0,2$	1,5	10	$8,84^{+0,02}$	15	$10\pm0,5$	6^{+1}	$8^{+0,2}_{+0,1}$
M12	$10,67^{+0,04}$	$17,5^{+0,1}$	$9,6\pm0,2$		12,5	$10,67^{+0,02}$	18	$12\pm0,5$	8^{+1}	$10^{+0,2}_{+0,1}$
M16	$14,68^{+0,12}$	$23,5^{+0,2}$	$17\pm0,2$		14,5	$14,68^{+0,02}$	24	$16\pm0,5$	10^{+1}	$12^{+0,3}_{+0,1}$

a) Screw; b) Heads obtained by cold upset in automatic presses; c) Heads after final finishing operation; d) Size S (under key)

Table 51

Dimensions of Plungers in mm

a)	D_1	b)				c)					
		d_1'	R	r	h_1'	l	l_1	r_1	R_1	s	s_1
M8	$12_{-0,2}$	$8^{+0,2}$	4			6	10,8	7	6	6,3	6,2
M10	$15_{-0,2}$	$10^{+0,2}$	12	1,5	1,5	7	12,9	5	8	8,3	8,2
M12	$18_{-0,2}$	$12,5^{+0,2}$	20			9	14,4	4	8	10,3	10,2
M16	$24_{-0,2}$	$14,5^{+0,2}$	25			11	16	3	10	12,3	12,2

a) Screw; b) Plunger used in the 2nd transitory operation; c) Plunger used inside hexagonal

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sions are attained.

The force required to exert the necessary pressure for shaping the nest of the

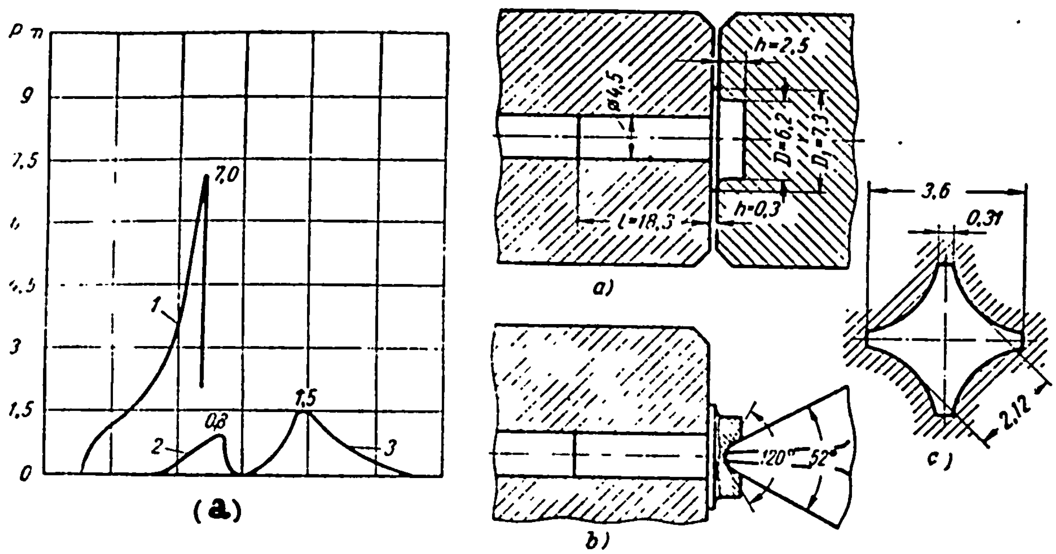

Fig.197 - Cross Shaping by the Open Method the Nest of Already Upset Head. Curves to left: 1 - Force required for upsetting the cylindrical head; 2 - Force for shaping nest; 3 - Ejecting force;

(a) Length of plunger stroke

head by the open method is:

$$P = \Delta \sigma'_T F \ \kappa q,$$

where Δ is coefficient equal to 5-6; F is the projected area of the cross-shaped nest in mm^2; σ'_T is the true resistance to the deformation of the material in kg/mm^2, corresponding to the threshold of strengthening (see Fig.186).

<u>Upsetting Hollow Rivets.</u> Two methods are available for the upsetting of hollow rivets. To upset by the first method, special automatic presses equipped with two matrixes, are used (Fig.199).

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The head is upset in the first matrix (with one or two strikes). Thereafter, the rivet is transferred by spring actuated pins to the axial line of the second

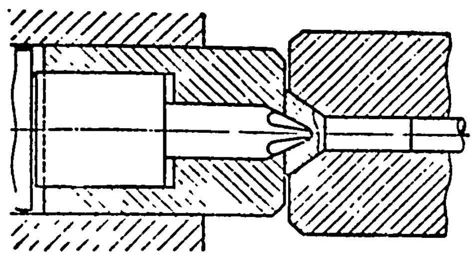


Fig.198 - Cross Shaping the Nest by the Closed Method Simultaneously with the Upsetting the Countersunk Head. Method by A.N.Gladkikh

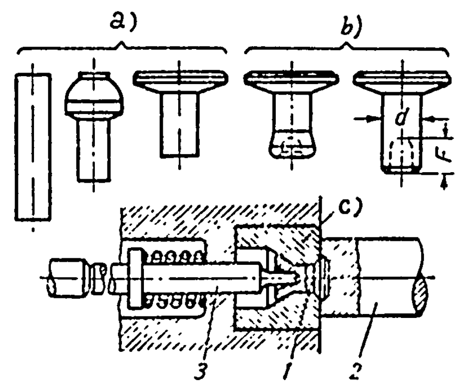


Fig.199

a) Transition to the upsetting matrix;
b) Transition to the punching matrix;
c) Punching matrix

matrix where the rivet stem (1) is acted upon by the punching die (3) to produce the initial hollowness. The punching die (3) also acts as an ejector.

The final shaping of the hollow stem takes place when the rivet is pushed out from the punching matrix. The removal of the rivet from the punching die is effected by grippers when the upsetting die (2) returns to its original position.

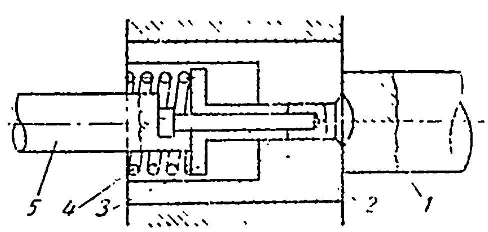
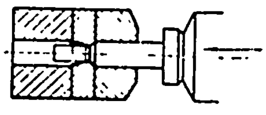
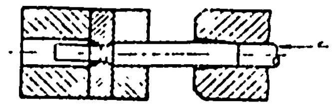
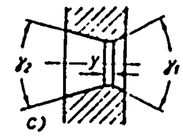
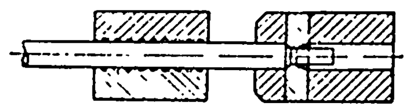


Fig.200

The second method of upsetting hollow rivets (Fig.200) is essentially as follows: the cylindrical piece which is cut off from the wire is transferred to the line of upsetting by the first movement of the slide bar; there, the upsetting die (1) places the rivet on the punching die (2) to make it hollow; the upsetting of the head (formation of a cone) takes place with the further movement of the

Table 52

Reducing Methods

Reducing Methods	Place to Install the Eye	Purpose of Reducing	"Squeeze" Intensity Required for the Reducing $\varepsilon = \frac{F_o - F}{F_o} 100\%$ *
 a)		 b)	 c)
Pushing stock into stationary eye (straight method); a - before facets are trimmed; b - before upset; c - shape of eye hole**	Matrix	1 Squeezing and calibrating for threading 2 Calibrating the smooth portion of bolt stem 3. Stem squeezing (a substitute for the 1st upsetting step); the stock is squeezed to the point where the head is to be shaped.	In a single-step operation, the "squeeze" intensity is $\varepsilon \leq 40\%$
			
Moving the eye on the immovable stock (the reversed method)	Plunger	1. Squeezing the ends of long stock to prepare them for threading. 2. Squeezing and calibrating a portion of the stem in a complex combined operation.	$\varepsilon = 50 - 60\%$ may be obtained with a double or triple squeeze

* F_o is the stem area before the reducing; F is the area of the stem after reducing

** $\gamma_1 \sim \gamma \sim 25 - 30°$; $y = 0.8 \quad 3$ mm

Remarks: The squeezing may cause the part being reduced to become bent; to avoid it, the eye is equipped with a guide when, $\gamma_2 = 0$, and y= the length of the guide

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slide bar until a point is reached when the butt end of the rivet leans against the projecting end of the removing device (3) which is activated by spring (4), the final shaping of the head is effected with the next (second) strike; after this, the finished rivet (still sitting on the punch die) is moved out from the upsetting matrix by the ejector (5) and is taken out by the remover (3). Certain special types of automatic presses have another additional remover having the shape of a hook.

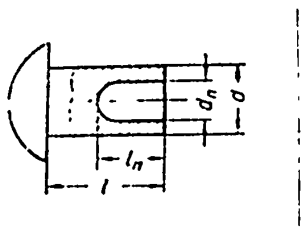

Fig.201

The relative dimensions of hollow rivets (Fig.201) obtained by cold upsetting are:

$$\frac{l}{d} = 0{,}8 \div .7; \quad \frac{l_n}{d} = 0{,}5 \div 1;$$
$$\frac{d_n}{d} = 0{,}5 \div 0{,}7.$$

The predominant shape of hollow rivets is semispherical, elliptical and countersunk.

The most common diameter of the hollow rivets is from 2 to 6 mm.

Optimum utilization of headed hollow rivets is obtained with nonferrous metals and alloys. The relative hollow depth obtained experimentally is:

$$l_n = (1 \div 1{,}2)d; \frac{l_n}{d_n} \leqslant 1{,}5.$$

The upsetting of steel holow rivets is still in the experimental stage.

Reducing (Squeezing) of Stems. The stem reducing process, in most cases, is effected simultaneously with the cold upsetting or with the trimming, or as an operation by itself. Various methods of the reducing process are shown in Table 52.

TRIMMING THE UPSET PARTS TO PRODUCE REQUIRED CONTOUR

As a rule, hexagonal and square bolt-heads are upset cylindrically and the

STAT

trimming, to produce the needed contour, is done on automatic trimming presses.

There are two methods of trimming:

1) Pushing the stock into an immovable matrix with the stem in front.

2) Pushing the stock into an immovable matrix with the head in front.

The first method is more widely used.

This method is shown in Fig.202. Here the part after the upset in a cold-upsetting automatic press and after its delivery from the bunker to the trimming axial line is, first, pushed by the butt end of a movable matrix (1) into a immovable matrix (2) and the trimming is then effected at the end of the slide bar movement. After this, the part moves from the immovable matrix through the hole of the movable matrix and through the hollow inside of the slide bar and is pushed out by rod (3) into a box for finished parts. The portion of the metal squeezed between the two matrixes and trimmed to the shape of a crown (4) falls down into another box. If reducing, in addition to trimming, is required, it is effected by introducing an eye into matrix (2).

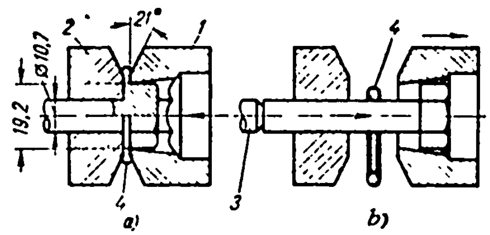

Fig.202 - Trimming Bolt Facets

a - Facet trimming; b - Ejecting the bolt and removing the crown

The force required to trim cylindrical heads is:

$$P \approx \alpha' \cdot p \cdot \sigma_v,$$

where α' is a coefficient equal to 0.035 - 0.045; σ_v is the minimum tensile strength of the material in kg/mm^2, taken from Tables prepared GOST; p is the perimeter of the trimmed part in cm.

The shearing force for bolts M6 is $P_{sdv} \approx (0.2 - 0.25)P_{obr}$; and for bolts M12 it is $P_{sdv} \approx (0.3 - 0.35)P_{obr}$. ($P_{sdv}$ is the shearing force and P_{obr} is the trimming force.)

SHAPING HEXAGONAL BOLT HEADS WITHOUT TRIMMING THE FACETS

The use of shape-changing only (in the production of hexagonal bolts) makes it possible to reduce the time and efforts by 20-25%, to reduce metal consumption by 3 - 7% and to improve the quality of the finished product.

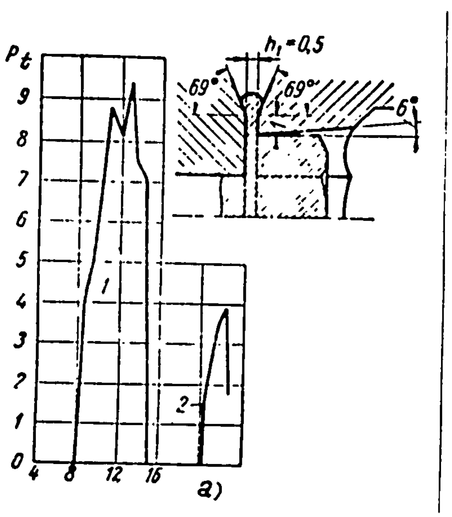

Fig.203 - The Plotted Curves Show the Changes in the Force Required to Trim and Shear the Crown and to Trim the Facets of the Head of a Bolt M12. The bolt is made from Grade-15 steel

1 - Trimming of the head; 2 - Shearing of the crown and ejecting the head

a) Length of stroke of the matrix

The technological process (worked out by V.A.Popov) for shaping bolts in two operations is effected in an ordinary two-strike cold-upsetting automatic machine with a plunger having a sliding core (Fig.204).

The first strike gives the head the shape of a cone, the final hexagonal shape is produced in a closed space by the second strike, as follows: the head (1) with its butt plane leans against the matrix and remains stationary while the core (2) moving forward changes the cone into a hexagon.

A three-step method of producing bolts (worked out by K.K.Preobrajenskiy of the "Red Etna" plant) is effected in a two-strike cold-upsetting automatic machine. By this method, the cylindrical shape of the head is produced in ordinary manner; the final shape is produced as a repeat operation in an automatic press

STAT

(see Fig.205).

In this method, in case of necessity, the bolts are annealed before the shape is changed into an hexagon. A repeat operation may be effected in an ordinary automatic press which will trim the facets, after which all that is necessary is to change the cam position of the ejector.

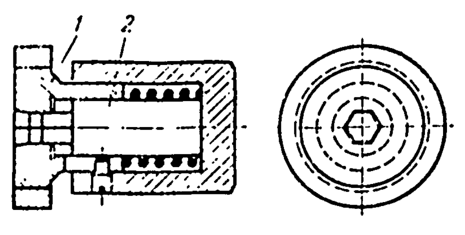

Fig.204 - Plunger with Sliding Core. Designed by V.A. Popov

The advantage of the first method is that an automatic press for trimming the facets and for the repeat operation is not needed. The advantages of the second method are: tools are held firmly in place, stability of the process and ease with which it may be applied in any enterprise possessing trimming automatic machines.

Hexagonal bolts with recessed heads may be produced in a two-strike cold-upsetting automatic press, as shown in Fig.206.

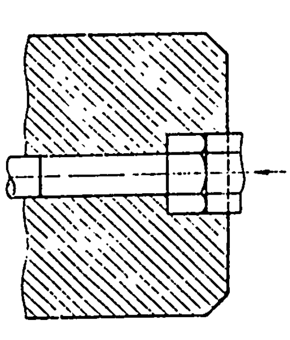

Fig.205

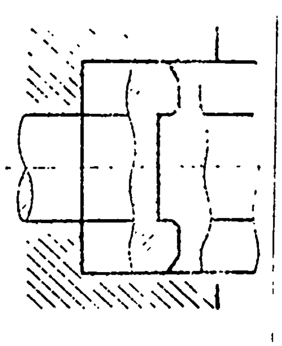

Fig.206

VOLUME STAMPING OF COMPLEX PARTS

The stamping of technologically complex parts is effected either in multioperational automatic presses with the application of the principle of parallel-consecutive method of operation, or by the method of stamping consecutively in several ordinary presses (using cold or electrically heated parts), or by combining different stamping operations with cutting or trimming operations.

A multioperational press is used for the production of such parts as hexagonal

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nuts, bolts, multistage pins and many others.

Cold shaping of nuts from a round rod is effected in five or six steps, including the cutting off the part from the stock.

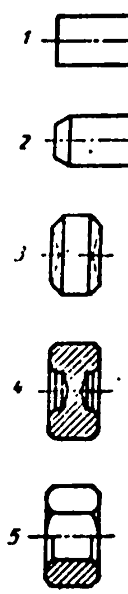

Fig.207

Dimensionally, nuts that may be produced by stamping are limited to sizes M6 up to M27.

The productivity of automatic presses (theoretical productivity) is 100 pieces per minute.

Steps in operation (Fig.207): 1 - cutting off from stock; 2 - formation of a facet on one side; 3 - upsetting (forming a barrel shape tapered at the ends); 4 - shaping the hexagon with plungers pressing from both sides; 5 - punching out the hole.

Nuts produced by this method have facets on the inside and on the outside with a 5 - 6 class of cleanliness.

After the shaping of the nut it is threaded, inspected, and treated against corrosion.

Chill-castings from hollow bars, at present, are prepared only as hexahedron nuts, with square notches in strips.

Multioperational stamping of bolts (Fig.208) may also be effected by a nut-producing automatic machine with a few changes in its design (method by V.M.Misozhnikov).

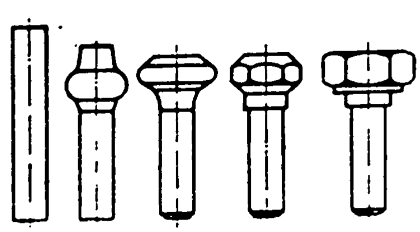

Fig.208

The horizontal section of the tool portion of a multioperational automat for the production of multistage cams is shown in Fig.209 where the plungers are drawn in their moving forward position.

The stock, cut off by cutter (1) and

STAT

carried to the first stamping line, is pushed into eye (2) built-in matrix (3). With the pushing also takes place the first reducing of the stock ends with a pressure intensity equal to

$$\varepsilon = \frac{9.2^2 - 6.9^2}{9.2^2} 100 = 43\%.$$

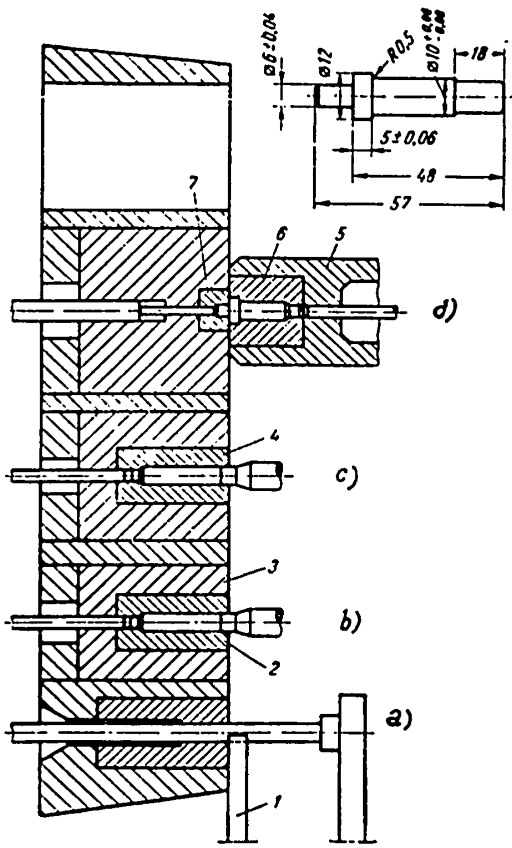

Fig.209

a) Feeding line; b) 1st stamping line; c) 2nd stamping line; d) 3rd stamping line

When the slide block with its plungers move back, then at the right moment, the part is pushed out from the eye, is grabbed by the transporting devices and transferred from the first line to the second stamping line.

In the second line, the front end of the part is pushed into the eye (4) (with a diameter of 6 ± 0.012 mm) is subjected to the final reducing with a pressure intensity $\varepsilon = 24\%$ and the remaining portion of the stem is upset to a diameter of 10 mm.

Next, the part is pushed out and transported to the third stamping line, which is the last stamping operation.

Here, the hard-alloyed plunger (5) with its eye (6) push the part into insert (7) where the shaping of the tail-facet (6 mm in diameter) takes place, and at the same time is effected, the upsetting of the shoulder (12 mm in diameter) and the reducing of the other end of the rod (to 9 mm in diameter) ($\varepsilon = 19\%$). Each movement of the slide block produces one finished part.

For parts with a greater complexity in configuration and with a higher degree

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of deformation and of relatively larger dimensions, the process of upsetting plus electric preheating may be applied. In this process of stamping the length of the precipitated particles of the bar h_o, after one stroke of the punch, is increased to 30 - 40 diameters.

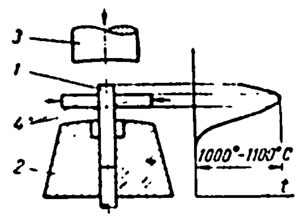

Fig.210 - Schematic Diagram of the Electric Heating Method in the Upsetting Operation and the Type of Temperature Distribution
1 - Stock; 2 - Matrix;
3 - Plunger; 4 - Contacts

The electro upsetting may be effected in vertical crank-type presses with turret stands equipped with an electric heating device.

To make the electro upsetting more effective, it is best to operate with a specific pressure $k = 10 \div 15$ kg/mm^2 and make the deforming plunger move with a velocity v from 2 to 4 mm/sec.

Such parts as auto-steering wheel levers, the axis for bicycle pedals, valve-tappet bolts for the M-20 and GAZ-51 cars, etc., are produced by the electro-upsetting method in the Molotov auto plant. In the Stalin auto plant, tappets are also produced by the electro-upsetting method.

A schematic diagram of the electric heating for accurate upsetting and the nature of the temperature distribution are shown in Fig.210.

THREAD ROLLING

Threading is effected by the use of flat threading dies and round rollers.

Threads resulting from the use of rollers have fibers which do not cross each other but arrange themselves to follow the cutting profile and, in this case, there is almost a two times increase in the microhardness of the material, a considerable increase in the yield point and in the resistance to fatigue by 20 - 25%.

The average square height of thread uneveness is: $N_{ck} = 0.4 - 1$ mk, when

STAT

threaded with round threading dies, and $N_{ck} = 1.5 - 4$ mk, when treaded with flat threading dies having the profile of a milling cutter.

The productivity, when threading to the 2nd class of precision with roller and flat dies, exceeds by 3 to 8 times the productivity of ordinary bolt threading machines.

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