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THE ECONOMIC BASIS FOR AUTOMATIZATION OF INDUSTRIAL PROCESSES

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Under a socialist economy there are unlimited possibilities for automatization of industrial processes. However, all problems concerning the expediency of using combination machine tools and automatic transfer machine lines require careful economic analysis. Up to the present, these problems have not been worked out. The methodological approach, the basic data, and indexes are missing.

The economic expediency of applying automatization can be determined only by comparing planned machine tools and lines with either those presently in operation or with the more modern nonautomatic machining methods which have been used under specific conditions.

In this analysis it is not only necessary to take into consideration the increase in productivity, but also the expenditure of live and material labor. This may be achieved by comparing under various conditions the costs of machining a single part or the costs of making the part for a year by different methods.

In comparing the variants of automatic operations with the variants in nonautomatic methods, it is necessary to consider in each case what elements decrease the length of the production cycle. During the inoperative period of the machine tool, the cost of its operation is determined by the wages paid to the operator and the depreciation on the equipment. When the machine is idling, we add the cost of repairs and electric power consumed to the first two expenses. Finally, the cost of the cutting tool is to be added when the machine is actually working. Through this differentiated approach to the cost per unit of time we can avoid a number of inaccuracies that might emerge in such an economic analysis.

To simplify the analysis let us break down the operating cycle into two parts. First, let Z represent the time required for inserting and removing the work piece

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and let R stand for the machining time and time required for secondary operations. Now, the operating cycle on nonautomatic machine tools can be represented by Z-R. A semiautomatic machine will be represented by Z-AR and an automatic by AZ-AR.

Working a nonautomatic machine tool requires the undivided attention of one operator. An automatic machine tool requires the attention of an operator only during inserting and removal of the part, thus leaving him free to operate other machines during the remainder of the time. The extent of such free time depends on the ratio: $\frac{t_z}{t_o}$

where t_z equals time required for inserting and removing the part, and t_o equals total operating time. Thus, t_z plus t_r equals t_o, in which t_r equals actual working time (machining and secondary operations).

If the nature and order of the operations performed on an automatic machine tool remain constant, the t_o of the process will be constant. The t_o may increase due to time required to change tools (secondary losses, according to G. A. Shaumyan's terminology).

The automatic machine tool is more costly to manufacture and requires more time for repairs than a conventional machine tool. Despite the fact that shortened machining time cuts tool wear and power consumption, an automatic machine tool is more expensive to operate than a nonautomatic tool. The economic expediency of automatization lies in the wage saving which derives from one man's operating several machines.

Let us discuss the possible methods of automatizing conveyer lines of nonautomatic machine tools (see Line 0 appended chart).

The symbol T represents the nonautomatic cycle of interoperational transfer of work part. The symbol AT represents automatic transfer. In Column A are shown the variants of concentrations of operations on one machine tool. Column B shows the variants possible on automatic transfer machine lines.

Prof G. A. Shaumyan, Doctor of Technical Sciences has given us an analysis of the productivity of multiposition machine tools and transfer lines. He points out that the increase in productivity brought about by further combining of tools is not proportional to the increase in productivity brought about by the addition of work positions. The productivity decreases if the number of positions exceeds the calculated optimum. In other words, the length of the working cycle of a single nonautomatic operation t_r is in this case less than the length of the working cycle of an automatic machine, t_{ar}, or a line which has undergone further combination of tools. Sometimes, however, a decrease of operating time is achieved even when t_{ar} is greater than t_r as a result of a cut in the time for loading and unloading, and in interoperational transfer of the work part.

Under the systems of automatization shown in Columns I and II the time for manual operations and transfer is shortened, and the machining time frequently increased. The outlay for wages is decreased since several combination machine tools and other machine tools can be operated by a single person. Even more machines can be operated by one man under the variants I - 2 or II - 2 when loading operations are also made automatic. The economic expediency of using variants (Columns I and II) increases as the length of the single operations increases. It should be remembered that wage savings in this analysis must be balanced against substantial increases in operating costs of the equipment.

Particularly favorable results may be achieved by paralled combinations (Column III), when either one part is machined simultaneously by several tools or the same operations are simultaneously performed on several parts. Under these conditions the work path for one part is sharply reduced in comparison with nonautomatic machines (Line 0).

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Lines of combination machine tools have all the virtues and disadvantages of any serial or parallel operation. Excessive lengthening of the line can rapidly lower productivity as a result of increased length of idling time during tool changing, spot breakdowns, repairs, etc. It has been found advisable where small parts are being machined to break the automatic line down into separate sections with automatic feed hoppers in between. From the point of view of design complexities and economy effected, the automatizing of loading and interoperational transfer of small parts is not usually justified. The introduction of automatizing loading and transfer of large, complex parts requires careful preliminary analysis of design and economy problems, since the wage saving does not always warrant the increase in operating expenses, particularly repair and depreciation, which complex loading and transfer mechanisms incur. Automatic electric and hydraulic mechanisms are particularly complex and extremely sensitive sections of a machine line; they are frequently responsible for long periods of idleness [when they break down]. With a longer work cycle and the use of more simple means of transfer, such as roller conveyers, pneumatic lifts and others, the attending personnel can perform the transfer and loading functions without particular effort. The advantages of using automatic loading and transfer require considerable economic analysis.

To take a simple example: A large multigraduated shaft undergoes rough machining and finishing on a lathe. The total operating time Σt_o is 34 minutes, including machining time Σt_m which equals to 26 minutes. By machining this shaft on two multicut semiautomatic machines (Model 118), the length of rough and finishing operations Σt_o is 2 x 5.2 minutes, during which the time for loading and unloading is Σt_v equals 2 x 0.9 minutes. From the equation $\frac{\Sigma t_m}{\Sigma t_z}$ equals $\frac{5.2 - 0.9}{0.9}$, we find that one worker can operate at least 4.8 machine tools. With the output of 40,000 parts per year when one worker operates two Model 118 semiautomatic machines, the expense of acquiring, delivering, and installing two such machines to do the work of six model D62 lathes is clearly justified.

If the two semiautomatic machines discussed above were to be equipped with special devices for loading, unloading, and transferring the work part, the time for secondary operations could be cut by 2 x 0.4 minutes. This would increase the annual output to 43,000 pieces. One third-class worker can operate the two machine tools. The saving on wages, including the expenditures for social insurance and paid vacations, amounts to about 400 rubles per year. The increase of output from 40,000 to 43,000 parts permits us to decrease the relative depreciation allowance by 600 rubles. The yearly saving, then, would be about 1,000 rubles. This is obviously not worth it unless the cost of installing the automatic devices were very low.

The above example of economic analysis reveals that with the obvious expediency of automaticizing the cycle according to the formula [Z-AR]-T-[Z-AR], complete automatization of the process according to the formula [AZ-AR]-AT-[AZ-AR] cannot be justified economically.

This is the sort of analysis that must be made of all machine-tool combinations and lines before decisions on the extent of automatization are made.

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METHODS OF AUTOMATIZING PRODUCTIVE PROCESSES

	A Single Operations	B Groups of Operations				
		Original Methods				
0	[Z-R]	[Z-R]- T -[Z-R]- T -[Z-R]				
		Forms of Combined Operations				
		I	II	III	IV	V
1	[Z-AR]	[Z-AR-AR]	[Z-AR]- AT -[AR]- AT...	Z — AR / AR / AR	Z < AR-AR... / AR-AR	Z < AR / AR -AT- AR / AR ...
2	[AZ-AR]	[AZ-AR-AR]	[AZ-AR]- AT -[AR]- AT...	AZ — AR / AR / AR	AZ < AR-AR... / AR-AR	AZ < AR / AR -AT- AR / AR ...
		Examples				
1	Multicutter semiautomat	Multispindle semiautomat	--	--	Multiposition combination machine tool	Automatic machine transfer line of combination machine tools for machining blocks
2	Single-spindle automat	Multispindle automatic for series machining	Inochkin's automatic transfer line	Rotating automat for parallel machining	Multispindle automat for combined machining	--

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