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14 March 1980

USSR Report

MATERIALS SCIENCE AND METALLURGY

(FOUO 2/80)

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USSR REPORT

MATERIALS SCIENCE AND METALLURGY

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FERROUS METALLURGY

IMPROVED PLANNING AND INCENTIVES IN THE FERROUS METALS INDUSTRY

Moscow METALLURG in Russian No 12, Dec 79 pp 1-2

[Article by I. A. Vashchenko, chief of the economic planning administration of the USSR Ministry of Ferrous Metallurgy, entitled: "Improving Planning in Ferrous Metallurgy."]

[Text] The decree of the Central Committee CPSU and the USSR Council of Ministers "About the improvement of planning and the reinforcement of the influence of the economic mechanism on raising the efficiency of production and the quality of work" contains a comprehensive program for the further improvement of planning guidance by means of economics, for the development of democratic principles in the administration of production, and for raising the creative activity of personnel.

Measures are stipulated in the decree for further increasing the efficiency of production and the quality of work, for the achievement of high gross national production through an acceleration of scientific and technical progress and a growth in the productivity of labor, for improving the quality of production, and for assuring a steady lift to the economy of the country and with this, to the basic welfare of the Soviet people. Specific measures for improving planning were defined and ways were outlined for increasing the effectiveness of capital investments. The role of self-support, economic leverage, and incentives in the administration of production is being heightened.

The decree of the CC CPSU and the USSR Council of Ministers proceeds from the basic conclusions on the improvement of the administration of the national economy in the modern stage as determined by the 25th party congress, by the subsequent Plenums of the CC CPSU, and by the speeches of Comrade L. I. Brezhnev. The decree is a further development and realization of those conclusions. Accomplishment of the measures stipulated in the decree requires carrying out a sequence of systematic and organizational actions.

The administrations of the Ministry, the All-Union industrial associations, the enterprises, and the scientific research and planning institutes in ferrous metallurgy are faced with carrying out a great deal of important work in drafting new normative documents and revising existing industry documents (instructions, conditions, methodical directives and so on) about planning, capital construction, self-support, and economic incentive. The solution of the problems in raising the level of planning work and raising the quality of the planning goals being drafted, occupies the central place in this work.

For the past fifteen years important work has been done in the industry on improving planning, improving the analysis of enterprise production activity, and improving the methodology of planning estimates. However, the plans being drafted for the social and economic development of the industry, the All-Union industrial associations, and the enterprises still do not respond fully to today's demands. The plans are not always uniformly intensive for the months or quarters. Cases of incomplete coordination of planning goals occur. Enterprises and associations do insufficient work on the substantiation of the designs of the plans being submitted.

The development of planning goals still is not supported at all enterprises by the necessary organization for their fulfillment. As a result, the established quotas for consumption of raw materials, fuel, and metal are not observed. Also, the plans for intra-industry cooperation are not fulfilled which upsets planned balances and causes serious difficulties in the fulfillment of the approved production plan.

At the same time, the solution of the problems stipulated by the decree on the improvement of planning requires, at all levels from enterprise to the ministry, constant work on identifying the resources resulting from increased efficiency of production and on using them in drafting planning goals. Also, plan discipline must constantly be reinforced and the importance and role of planning goals must be heightened by all possible means.

For increasing the soundness of planning goals, the decree established that five-year and annual plans must be developed on the basis of economic and engineering estimates employing progressive technical and economic standards for the use of production capacities in conformity with the passport of an enterprise which contains the indexes needed for drafting plans.

In this connection, the administrations of the ministry and the institutes have begun work on the preparation of standard forms, and instructions for filling them out, that are applicable to all subdivisions of the ferrous metal industry. These forms must be completed with all indexes by all enterprises and associations in 1980. This is a very serious matter as the passport must be the basic technical and normative document in the drafting of plans. Therefore, to the extent that the indexes needed for the calculation of the plan will have been fully and correctly taken into account, and to the extent that they will have been correctly reported in the filling out of the passports, to an important degree will depend the quality of drafted planning goals and, consequently the success of each enterprise and the industry as a whole.

In recent years, gross value indexes have undergone sharp criticism in the press. The criticism is not without foundation. To eliminate the negative aspect of gross value indexes, the decree stipulates,first of all, an increase in the role of normative net production in planning the productivity of labor and wages. In a whole series of industries, especially in machine building, this index eliminates many of the shortcomings of gross or commodity production.

For ferrous metallurgy, as a raw material branch of industry, the index of normative net production does not eliminate the shortcomings of commodity production, but aggravates them.

At the same time that the application of normative net production does not eliminate the shortcomings of commodity production, it additionally requires labor-consuming work on the development of standards for working out wholesale prices, and it will double the volume of calculating work. Therefore it is stipulated that the necessary research and preparations be carried out in 1980, and, in 1981 at separate enterprises, that experimental tests be made of other indexes which could provide a more accurate reflection of the tempo of the growth of both the volume of production and the productivity of labor, and which could take into account most fully the specifics of ferrous metallurgy while at the same time reducing the negative aspects of gross or commodity production.

The solution of this problem is very important to the proper reflection of the results of the operations of the industry's enterprises, and especially for planning the growth of the productivity of labor and wage funds.

According to the decree, the change-over of scientific research and planning institutes and enterprises to the self-supporting system of managing operations for the creation, assimilation, and introduction of new technology on the basis of supply authorizations and contracts must be completed in 1980. So also must be completed the change-over to the financing from a single fund for science and technology of scientific research, experimental construction, technological work, and reimbursement for expenditures related to development and assimilation of new forms of production and technological processes. For accomplishment of this change-over, work already is going forward on the preparation of appropriate standards and conditions for the creation of the single fund for science and technology, and for the formation of a fund for economic incentives and others.

The decree of the CC CPSU and the USSR Council of Ministers stipulates that the measures for improvement of planning must clearly be supported by further development of self-support, by reinforcement of the role of economic incentives, and by raising the level of economic operations. In recent years, new indexes for planning and evaluating the activities of the structural subdivisions of an enterprise have been developed and introduced. New, improved systems have been introduced for accounting between shops on the quality of production, and for the delivery of supplies on schedule for maximum production and so on. New conditions are in effect on rewarding workers, engineers and technicians, and office workers which reinforce the role of material incentives in raising the efficiency of production. Thus, at the Kuznetsk metallurgical combine, and at the Krasnyy Oktyabr', Cherepovetsk, Azovstal', Novolipetsk, Nikopol'sk Yuzhnotrubnyy, Donetsk, and many other plants, self-support has become an effective factor in raising the labor activity of the working masses, in drawing them into production management and the economic structure, and, to an important degree, promoting the fulfillment of planning goals.

However, the system of interplant self-support is not everywhere effectively influencing the improvement of technical and economic indexes, and still, there is not at all enterprises a clearly developed system for analysis and review of the results of the economic activities of its own shops and services. Therefore, the necessary steps must be taken to reinforce the role of economic leverage (profits, prices, finances, and material incentive systems) so that the whole system of self-support of an enterprise is directed more fully toward combining the interests of each worker with the interests of the enterprise, and the interests of the enterprise with the interests of the state. In this way the economic interest of every worker is increased in lowering production costs, in conserving material, labor, and financial resources, in more fully using production funds, in delivering products of high quality, in assimilating new kinds of production, and in expanding the assortment of it.

By July 1980 the Ministry of Ferrous Metallurgy together with the institutes will develop the conditions for the management of the self-support of enterprises and of the associations which must help the enterprises. In the All-Union industrial associations work is being done on further improvement of self-supporting methods of work and on introducing them into the activities of the Ministry.

The decree stipulated an increase in the amount of the bonuses in wholesale prices for products having the state Mark of Quality,and a reduction of the wholesale price on the order of 50% for products in the second category of quality or not certified as to quality within the established periods. Thus, enterprises achieving improved quality in production, or increasing the output of products with the Mark of Quality receive the opportunity of increasing allotments to the funds for economic incentive.

Experience shows that the economic methods of influence make a substantial improvement in the quality of production and at the same time permit enterprises to increase the incentive funds significantly. However, the use of this means by the industry is still insufficient - there are some difficulties in agreement with the consumer about the price increase for products with the Mark of Quality. However, wherever all services of an enterprise are actively included in this work, there are well-defined results.

The industry's scientific research institutes have been entrusted with the preparation of a proposal for wide development of the brigade form of management and stimulation of labor. A review is planned of the standard conditions for rewarding workers, supervisors, engineers, technicians, and office workers to bring them into conformity with the requirements of the decree of the CC CPSU and the USSR Council of Ministers.

The institute of economics of TsNIIchermet [The Central Scientific Research Institute of Ferrous Metallurgy] is doing work on the analysis of the formation of economic incentive funds and, on this basis, proposals are being prepared on fund-forming indexes for enterprises, associations, and the Ministry as a whole for the 11th Five-year plan. Much remains to be done at the enterprises and in the associations on working out the economic foundations of the standards for working capital, and also on the measures for bringing the amounts of internal working capital up to the established standards.

For organizing the work in the industry to accomplish the measures stipulated by the decree, in October of this year the Ministry conducted a group meeting of workers from the economic services of the enterprises of the Central, Southern, and Eastern regions of the country at which appropriate recommendations were adopted.

Serious problems must be solved in raising the effectiveness of the capital investments chosen for the industry, in accelerating the placing into operation of production capacities, in reducing the number of buildings being started, in cutting down on uncompleted construction, and in improving the critical analysis of planning decisions. The most important measure for improving the management of capital construction is the change over to the new procedure of accounting between the client and the contractor.

For consideration of the questions of the effectiveness of capital investments, of the status and quality of planning drafts, and of conditions in capital construction, it is planned to conduct special meetings with the workers of industry planning institutes and organizations and the leaders of the associations and enterprises involved in capital construction. The institute of economics of TsNIIchermet and Gipromez [The State Union Institute on the Design of Metallurgical Plants] have made an analysis of the effectiveness of capital investments.

The solution of the problems posed by the decree of the CC CPSU and the USSR Council of Ministers requires from all units of administration and from each worker, great initiative and independence in the solution of economic problems. But this is possible only for economically trained personnel. Therefore, special attention must be given to the economic instruction of personnel to raise the level of qualification of every worker. Much work is being done in the industry on raising the qualifications of supervisors and engineering and technical workers at seminars, courses, and so on. But there remains the massive training to be done directly in the enterprises. This training must not be of a general character, but a specific one;that is, the principles in the documents being studied must be related to the problems of a shop, a section, or a plant and so forth. It is necessary to get each worker to know the basic questions of economics at his own station.

Simultaneously with the development of the methodical documents and conditions, and with the preparation of the system of indexes and standards, the enterprises must do much work on the identification and use of the resources resulting from the increased efficiency of production; for that is the aim of the decree in the first place. The personnel of the shops, sections, and shifts must participate in this work.

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NON-FERROUS METALLURGY

NON-FERROUS METAL MINING, EXTRACTION, PROCESSING GOALS DISCUSSED

Moscow TSVETNYYE METALLY in Russian No 12, Dec 79 pp 1-8

[Article by A.P. Snurnikov: "Speeding Technical Progress, Thorough Utilization of Raw Material and Intensification of Technological Processes--Key Factors in Improving Production Efficiency"*]

[Text] The 25th Congress of the Communist Party of the Soviet Union emphasized with new force the importance of scientific and technical progress as one of the major conditions for further improving the economic potential of our country. CPSU Central Committee General Secretary and President of the Presidium of the USSR Supreme Soviet Comrade L.I. Brezhnev in his summary report to the 25th Party Congress noted particularly that for the purpose of solving the key economic problems of the 10th and subsequent five-year plan periods there is only one route--the route of a rapid growth in labor productivity and of a drastic improvement in the efficiency of all social production.

The decree of the CPSU Central Committee "On Further Improvement of the Economic Machinery and the Objectives of Party and State Agencies" and the decree of the CPSU Central Committee and USSR Council of Ministers "On the Improvement of Planning and Strengthening of the Influence of the Economic Machinery on Improving Production Efficiency and Work Quality"** emphasize the growing importance of quality indicators for the purpose of improving the economic efficiency of production. Great emphasis is placed on the employment of intensive factors for developing the economy.

USSR Council of Ministers President A.N. Kosygin in his article*** devoted to improvement of planned management of the country's economy has also specified the necessity of refraining from outmoded management methods.

*From an address at the industry's non-ferrous metallurgy conference (cf. information of p 94 of this journal).
**PRAVDA, 28 Jul 79.
***KOMMUNIST, No 12, 1979, p 16.

"The stagnation and adherence in some management teams to old approaches and methods of making economic decisions, when a quantitative growth in production has been given priority, can only hinder scientific and technical and economic and social progress, and cause unnecessary expenditures of public labor and the loss of what has already been produced. The surmounting of this approach is an indispensable condition for the fuller utilization of the advantages of advanced socialism."

Of course, the foundation for achieving high quality indicators is technical progress and the utilization of the latest achievements of science and technology. Therefore today, in fulfilling the decrees of the CPSU Central Committee and USSR Council of Ministers, it is necessary critically, on the basis of these decrees, to evaluate the results achieved in technical development of the industry and to subject to a detailed analysis the approaches and methods of planning, introducing and mastering new technology.

It is necessary in light of the decree to take a look at the level of the work of organizers in all teams for the management of technical progress, to give it a proper evaluation and to draw the appropriate conclusions from this.

Ore mining is the most labor intensive and expensive area of production in non-ferrous metallurgy. For example, of the total expenditures of labor and capital for producing one ton of heavy non-ferrous metals approximately 50 percent belongs to the share of mining operations.

The ministry has determined the key trend for improving the efficiency of ore mining to be the retooling of open-pit mines on the basis of high-unit-capacity mining transportation equipment, and of underground mines on the basis of combinations of high-efficiency self-propelled equipment.

At the present time the drilling of blast holes in the industry's pits is performed almost 80 percent by high-efficiency SBSh-250MN and SBSh-320 cutting machines with a bit diameter of 243 to 320 mm. In the immediate future the basic drilling machine at large pits (the Kal'makyrskiy, Kounradskiy, Sorsk, etc.) will be SBSh-320 machines and the high-power "Ruslan" unit with a drilling diameter of 350 to 400 mm, created by Gipronikel' [State Institute for the Planning of Nickel Industry Enterprises].

At ore pits (the Zhdanovskiy, Kal'makyrskiy, Zlatoust-Belovskiy, Kounradskiy, Sorsk, etc.) is being expanded the use of modern high-power excavators with a shovel capacity of 8 and 12.5 m^3, and in the exploitation of alluvial deposits, walking draglines with a shovel capacity of 10 and 15 m^3.

Removal of the ore mass from pits is performed basically (80 percent) by motor vehicle transportation. A considerable amount is done by dump trucks with a load capacity of 40 tons (40 percent). Dump trucks with load capacities of 75, 90, 120 and 150 tons are being adopted (the Zhdanovskiy, Gayskiy, and Mukulanskiy pits and the Yakutalmaz Association).

All this powerful equipment makes possible high efficiency and a savings only when it is completely utilized.

But at a number of enterprises the capabilities of this equipment are not being utilized sufficiently: It is not being furnished with the required operations front, is working one or two shifts per 24-h period, and is not being overhauled at the proper time. As a result, at some pits the utilization factor for drilling machines, excavators and dump trucks is not greater than 0.5.

Self-propelled equipment is being introduced extensively in underground mining operations. With its use 35 percent of the total amount of ore mined by the underground method is being produced.

Self-propelled equipment has made it possible to improve labor productivity both in stoping and in cutting mine workings by a factor of 1.5 to two and more. Especially high figures have been reached at mines of the Achisay, Dzhezkazgan, Tyrnyauz, Gayskiy and Almalyk combines.

But at some of them the utilization factor for the available inventory of machines in terms of time and capacity can be increased and with the present supply of enterprises with self-propelled equipment the volume of ore mining done by employing it can be increased 1.5-fold.

With the old equipment and technology the thorough organization of labor was strongly recommended. This was reasonable, since in this case the major percentage of the cost of mining ore was represented by wages (40 to 50 percent), which was explained by the relatively high cost of labor and the not too high cost of equipment.

With self-propelled equipment the picture has changed drastically. The main item of expenditure in the cost of mining ore has become outlays for amortization, overhauling and equipment servicing (50 percent) in view of the high cost of machinery, and the percentage of wages has been reduced drastically (to 20 percent) as a result of a considerable growth in labor productivity.

From this it follows that equipment should be utilized to the maximum degree. This is achieved by changing over to a labor specialization arrangement in conjunction with multi-face operation.

A typical example in this respect is the work experiment of V.N. Zhuravko's crew in the Dal'polimetall Association, which in April 1979 reached in cutting workings record labor productivity for a face worker--25.2 m^3 per man per shift.

Exerting a great influence on the economics of mining and concentration enterprises are losses and impoverishment of ore in mining. For the purpose of reducing them, systems of development have been extensively introduced at the industry's mines which include walling up the exhausted space, the percentage of which has become greater than 20 percent of the total amount of ore mining by the underground method.

This technology has been well mastered at mines of the Noril'sk, Gayskiy and Leninogorsk combines. Here high quantity and quality figures have been reached. A high degree of activity in introducing this advanced technology for thoroughly using lean ore has been manifested also by workers of the Achisay Combine, who together with Kazakh Polytechnical Institute have developed an efficient method of preparing walling-up mixtures. A great savings can be gained also by using binding materials based on slag with a low iron content.

Meanwhile, the managers of the Dzhezkazgan Combine and SUBR [Severoural'sk Bauxite Mines], where very precious ore is being mined, have underrated the new technology and have slowly made the changeover to systems which include walling up.

Great prospects for the fuller utilization of mineral resources and a reduction of losses and impoverishment are inherent in the introduction of radiometric methods of assaying, sorting and preconcentrating ore. A work experiment at the mines of the Pechenganikel' Combine, the Khrustal'nenskiy GOK [Mining and Concentration Combine] and Zyryanovskiy Combine has confirmed this. However, the introduction of this advanced technology has been delayed by a shortage of instruments and separators. Obviously it is necessary considerably to speed the performance of measures indicated by the ministry relating to arranging for the production of instruments and separators and to conducting extensive research.

Improvement of the utilization of expensive equipment, the reduction of losses and impoverishment of ore, and the expansion of the employment of advanced systems of developing deposits, for production-process assaying and sorting in the mining of ore even under conditions of a systematic lowering of the content of metals in ore will make it possible to improve the economic efficiency of mining production processes in the industry.

In connection with the worsening of the quality of ore in terms of metal content and mineralogical structure, concentration conversion has been considerably complicated. The amount of ore to be refined has increased and additional production operations have arisen. Under these conditions special attention should be paid to making the preparation of ore less expensive, to expanding the scale of employment of such processes as the self-crushing of ore and preconcentration of it in heavy media, as well as to the investigation of radiometric methods of concentrating ore.

The efficiency of the self-crushing process is determined by the fact that two operations are eliminated from the production cycle--medium and fine crushing--and expenditures for balls and rods have been eliminated. In addition, in a number of cases the changeover from ball crushing to the self-crushing of ore has reduced sliming and has improved flotation conditions.

The self-crushing of ore is being rapidly extended to the practice of concentrating diamond- and gold-containing ore. However, for ore of other non-ferrous metals (the Balkhashskiy, Zangezurskiy and Tyrnyauz combines) the adoption of this process is being carried out slowly.

On the whole the process of self-crushing of ore has proved itself and its technology has been mastered, but the quality of the equipment produced still remains low, as a result of which the advance ratio of mills has not exceeded 70 percent.

At plants of the non-ferrous metallurgy industry the method of preconcentrating ore by using heavy media and other physical methods of concentration has been mastered, and the amount of ore refined by this technology has reached tens of millions of tons per year.

These processes could produce a great savings at other enterprises also; for example, the Tyrnyauz deposit contains scarn marble and the yield of calcite from the process will make it possible to produce a more concentrated heavy fraction of ore and incidentally produce marble chips for construction purposes. Gipronikel' and Mekhanobr [All-Union Scientific Research and Planning Institute of the Mechanical Processing of Minerals] must speed up the plan development and the Soyuzredmet Association must solve the problem of introduction.

The ministry has systematically been following a general line toward the introduction of oxygen in technological processes for the production of non-ferrous metals.

A great number of non-ferrous metals are being produced annually by using oxygen. Oxygen has been most widely used in smelting copper and nickel, in roasting zinc concentrate and in producing lead.

When oxygen is used in metallurgy the process is intensified and the consumption of fuel is reduced. For example, shaft smelting using an oxygen blast results in savings of about a quarter of a million tons of metallurgical coke per year.

The economic efficiency of using oxygen is now widely recognized. All the oxygen plants constructed are being run at full capacity. However, there is one enterprise--the Severonikel' Combine--at which the 12,000-m^3/h-capacity oxygen plant built in 1976 has up to this time not found a customer for its products. As paradoxical as it is, at the Severonikel' Combine it is thought that when the plant is not operating it produces fewer losses than while it is being used.

The Gipronikel' Institute, which designed this plant, and the Severonikel' Combine must reconsider their incorrect position and find a solution for the intelligent utilization of oxygen in the combine's production.

Of especially great importance for improving the efficiency of the production of heavy non-ferrous metals is the introduction of new oxygen processes. This has been demonstrated by more than a decade of experience in the operation of a commercial furnace for the oxygen-jet smelting of copper concentrates at the Almalyk Combine. Energy costs for the production of unrefined copper by this method are 27 percent lower than when smelting in a reverberatory furnace.

An engineering project has been developed for total conversion of the Almalyk Mining and Metallurgical Combine to oxygen-jet smelting. After implementation of this project the extraction of sulfur from gases in the form of sulfuric acid at this enterprise will be increased to 96 percent and there will be an opportunity to increase the processing of gold-containing fluxes and to increase the extraction of precious metals from Kal'makyrskiy ore.

Since 1975 an industrial plant for the oxygen electrothermal smelting ("Kivtset") of copper-zinc concentrates has been in operation at the Irtyshsk Complex Ore Combine and the reconstruction is under way on this combine's copper smelting plant, based on the "Kivtset" technology. This technology makes possible the high extraction of precious components, considerably improves labor productivity and effectively solves the problem of protecting the environment.

Engineering projects are being carried out for reconstruction of lead production capacities according to the "Kivtset" technology at the Far East Mining and Metallurgical Combine and the Elektrotsink Plant. The construction of such a unit is under way at the Ust'-Kamenogorsk Lead and Zinc Combine.

The reconstruction of these enterprises will make it possible to extract from raw material an additional many thousand tons of zinc and copper, will produce about 100,000 tons of sulfuric acid per year, and will realize an additional annual profit of approximately nine million rubles.

Autogenous processes, in spite of their high efficiency, are being introduced so slowly that they to a considerable extent have become obsolete and are being replaced by new processes even before they are mastered. For example, a new autogenous process is being developed at the Noril'sk Mining and Metallurgical Combine as well as in a unit at the experimental Gintsvetmet Plant in Ryazan'.

The decree of the CPSU Central Committee and USSR Council of Ministers according to which the USSR Gosplan, ministries and departments must allocate capital investments primarily for the reconstruction and retooling of enterprises will make it possible for production subdivisions, as well as for construction organizations, to speed the introduction of high-efficiency autogenous processes in production, and there is reason to expect that the pace of introduction of this advanced technology will increase.

The thorough utilization of raw material has an enormous role in the improvement of the economic efficiency of production and is evidenced in a savings of labor and capital, i.e., in an increase in the productivity of social labor, acceleration in the growth of total product output, more efficient utilization of capital investments, a reduction in product cost, and in a number of other factors.

Improvement in the completeness of the extraction of metals and in the thoroughness of the utilization of raw ore has exerted a direct influence on the improvement of technical and economic indicators of production. For example, at the Ust'-Kamenogorsk Lead and Zinc Combine the profitability of the majority of types of byproducts has far surpassed the profitability of basic products. For example, the production of cadmium is 3.4 times and the production of sulfuric acid is 13 times more profitable than the production of zinc. The production of unrefined copper from raw lead ore is 5.8 times more profitable than the production of lead.

A considerable savings from improving the thoroughness of the utilization of raw material has been gained at the Balkhash Mining and Metallurgical Combine. As the result of a systematic increase in the output of byproducts, their share of the total of commodity products has exceeded 25 percent.

A great influence on the industry's operating results with regard to the thorough utilization of raw materials has been exerted by the CPSU Central Committee's decree "On the Work of Party Organizations of the Ust'-Kamenogorsk Lead and Zinc and Balkhash Mining and Metallurgical Combines Relating to the Mobilization of Collectives for the Achievement of High Indicators for the Thorough Utilization of Raw Ore." Non-ferrous metallurgy enterprises and institutes have begun purposefully, actively and objectively work on improving the utilization of raw material. The advanced know-how of the Ust'-Kamenogorsk and Balkhash combines, approved by the CPSU Central Committee, has begun to be employed extensively at other enterprises of the industry.

Important results have been achieved by concentrators at Ural plants, e.g., in the concentration of copper and zinc ore at the Uchalinskiy, Sredneural'sk, Karabash and Kirovgrad plants on account of the introduction of multi-stage flotation systems, aeration and conditioning of pulp, and effective methods of refining unrefined concentrates.

In 1978 versus 1977 there has been an increase in extraction of copper of 3.6 percent and of zinc of 6.5 percent at the Karabash Plant, and of zinc of 2.4 percent at the Sredneural'sk Plant.

Because of further mastery of the technology of extracting secondary components, in the copper industry the yield of molybdenum concentrates has been increased by 20 percent, in the tin industry that of copper concentrates by 30 percent, and of zinc by 65 percent, and the production of a lead concentrate has been arranged for; in the tungsten and molybdenum subindustry the output of a bismuth product has been increased by 11 percent, and in the rare metals subindustry, that of mica concentrates by seven percent and of quartz molding sand by nine percent.

At the same time today it is necessary to direct special attention and effort to eliminating existing shortcomings. Still many concentration plants continue in 1979 to underfulfill the plan quotas for the extraction of metals. The greatest number of plants which do not fulfill their extraction quotas are under the direction of Kazmintsvetmet [Kazakh SSR Ministry of Non-Ferrous Metallurgy] and the Soyuzmed', Soyuzzoloto and Soyuzpolimetall all-Union industrial associations, among them the Tekeli, Kentau, Almalyk, Kirovgrad and Sredneural'sk concentration plants.

The positive results of the work of the majority of plants have been to a considerable degree depreciated for the national economy by the unsatisfactorily working enterprises.

Above-quota losses of metals are the result of poorly organized technological sampling of deposits, an uneven-paced delivery of ore to plants, and deviations from the planned chemical and material composition of ore to be refined. It is obviously necessary to plan and monitor the stable quality of ore being recovered. At a number of enterprises the preparation of production for the receipt of ore with a modified composition is being enacted more and more unsatisfactorily. The role of the crushing and pulverizing of ore is being underrated; production process discipline is being violated; and different grades of ore are being mixed unjustifiably. Reflected in extraction figures also are the unsatisfactory servicing of equipment and frequent unscheduled shutdowns of it.

The considerable potential of concentration plants in this regard is obvious and they must utilize it more rapidly.

In the current year the majority of metallurgical enterprises improved their figures for the extraction of metals. However, such combines as the Noril'sk Mining and Metallurgical, Pechenganikel', Severonikel', Yuzhuralnikel', Krasnoural'sk Copper Smelting and Ufaleyskiy Nickel, as well as the Sredneural'sk Copper Smelting, the Chimkent Lead, the Elektrotsink and the Nal'chik Hyrdometallurgical plants, have not fulfilled their quotas for the extraction of metals.

Of great importance for improvement of the thoroughness of the utilization of raw material is the more complete processing of production semiproducts and waste. The decree of the CPSU Central Committee and USSR Council of Ministers obliges ministries and departments to "develop and incorporate in the structure of five-year plans plans for the utilization of byproducts and secondary products, secondary materials and other resources."

Lead plants at the present time have accumulated a great amount of zinc-containing slag. The extent of its processing during the years of the five-year plan period increased almost twofold in 1978 as compared with 1975 and will increase in 1980 by even more than 30 percent. In the processing of slag in the fuming plant of the Ust'-Kamenogorsk Lead and Zinc Combine the cost of commodity zinc is approximately twofold lower than the cost of metal produced from concentrates. Labor productivity in the extraction of metals from slag is more than twofold higher than labor productivity in the recovery of metals from raw ore.

However, a number of quotas for the processing of zinc-containing slag are not being fulfilled, chiefly because of delays in the construction of a Waelz complex for processing cold slag and of a hydrometallurgical section for processing zinc cakes at the Leninogorsk Complex Ore Combine. The construction of the hydrometallurgical section at the Almalyk Mining and Metallurgical Combine is also being accomplished slowly. The entry into service of this section would make it possible for the combine to relieve the capacity of the Waelz section for processing slag from the Chimkent Lead Plant in an amount of up to 75,000 tons per year.

One great potential for improving the efficiency of production processes is the most complete utilization of ore deposits and expansion of the raw materials base by involving in processing unyielding and substandard ore which is hard to subject to concentration.

This is of especially important significance in the production of copper. The demand of the national economy for this metal has been increasing continuously, and the content of copper in mined and prospected ore is steadily decreasing. The price of copper on the world market has been steadily increasing and at the present time has reached $2000 per ton. In light of this it is not possible further to tolerate underrating of the method of compact and subterranean leaching of beyond-balance and so-called lost ore.

Already in operation in the industry are six plants for the compact leaching of copper. The cost of the metal produced by this method, with the exception of the Almalyk Combine (where the planned capacity of the unit has not yet been mastered), does not exceed the cost of copper in pyrometallurgical production. However this method of increasing the output of copper from inexpensive raw material has clearly been underrated by enterprises of Kazmintsvetmet and Soyuzmed'.

Having been unjustifiably dragged out is the construction in the 10th Five-Year Plan period of a plant for compact leaching of copper at the Balkhash GMK [Hydrometallurgical Combine], and work has been proceeding at a slow pace at the East Kazakhstan Copper Chemical and Krasnoural'sk Copper Smelting combines. Kazmintsvetmet and Soyuzmed' should take measures to develop the production of cement copper at these enterprises.

The non-ferrous metallurgy industry has at its disposal great opportunities for improving the utilization of non-ferrous metal scrap and waste and for involving in production waste slag, primarily that with a high metal content, and zinc cakes and other waste and semiproducts of production, as well as a potential for improving the utilization of exhaust gases and waste water.

In recent times much has been done to increase the extent of the preparation of non-ferrous metal scrap and waste and to improve their utilization. Involved in the area of preparation and production have been new kinds of waste, such as tungsten-containing, molybdenum, rhenium-containing and others which previously were not utilized. New technological processes have been developed for processing different kinds of waste. However, the figures for the extraction of secondary metals at the Soyuzvtortsvetmet Association are inadequate.

Having taken place are physical losses of aluminum in storage, oxidation of it in open areas, as well as heavy losses of metal along with slag. These causes are characteristic of many enterprises of Soyuzvtortsvetmet.

The work of the industry's VNIIPvtortsvetmet [All-Union Scientific Research Institute of Processing of Secondary Non-Ferrous Metals] Institute should be directed primarily, and the concentration of the Soyuzvtortsvetmet Association should be concentrated on elimination of the shortcomings in arrangements for the processing of secondary raw material in the non-ferrous metallurgy industry.

Copper secondary raw material is being processed chiefly at the Kirovgrad Copper Smelting Combine with high indicators. Furthermore, a number of valuable components are being utilized as byproducts.

However, here, too, there is a potential for a more complete and thorough utilization of raw material. It is necessary to speed construction of the experimental industrial plant for electrothermal processing of shaft furnace slag for the purpose of extracting from it zinc and tin, to arrange for the processing of the entire quantity of tin-containing converter slag, and to take a number of other measures.

The chief method of utilizing sulfur-containing gases at enterprises of the non-ferrous metallurgy industry is the production of sulfuric acid.

In 1978 the output of sulfuric acid from metallurgical exhaust gases increased almost 30 percent as compared with 1970.

Furthermore, the cost of one ton of sulfuric acid produced from metallurgical gases is 30 to 40 percent lower than that obtained in chemical plants from pyrite concentrates and more than 40 percent lower than that produced from elemental sulfur.

In the industry there is considerable potential for increasing the production of sulfuric acid. At the present time only 40 percent of the sulfur from metallurgical gases is being utilized.

One of the reasons for the unsatisfactory utilization of sulfur is the presence of large amounts of sulfur-containing gases with a low content of hydrogen sulfide. Radical improvement in the utilization of these gases involves the introduction of autogenous processes in the production of heavy non-ferrous metals.

At a number of enterprises capacities are not being fully utilized for increasing the processing of lean gases with the existing capacities of sulfuric acid sections. A complex, introduced in 1977, for the utilization of sintering gases at the Ust'-Kamenogorsk Lead and Zinc Combine, is still not in full operation. Not totally completed is the reconstruction of sulfur-trapping units which make it possible to increase the utilization of converter gases at the Sredneural'sk Copper Smelting Plant. Because of the low concentration of hydrogen sulfide, the utilization of sulfuric acid capacities at the Severonikel' Combine equals only 51 percent, and the oxygen plant at this enterprise, as already mentioned above, is not operating.

Improvement in the degree of utilization of sulfur is not only of economic, but also of ecological importance; therefore, great attention should be paid in 1980 and in the 11th Five-Year Plan period to questions relating to the utilization of sulfur gases.

A leading role in speeding technical progress and improving production efficiency belongs to planning and scientific research institutes, scientific development directors and chief project engineers. Their work should be evidenced not only in the high-quality execution of projects and in the introduction through their projects of advanced technology and equipment, but also in mastery of the planned capacities and technical and economic indicators at new and reconstructed enterprises at which their plans and developments are implemented. There are entirely sufficient opportunities for this at institutes (semi-industrial and industrial testing, the inventor's supervision, base laboratories, special teams, etc.).

However, the state of affairs is such that only by an underestimation of this most important job on the part of directors of planning and scientific organizations, directors of scientific research studies and chief project engineers can be explained the long overdue mastery of the planned capacity of the Kirovabad Aluminum Plant and the planned figures of the Krasnoyarsk Plant (VAMI [All-Union Institute of Aluminum and Magnesium]); of the building for the self-crushing of ore at the Tyrnyauz Combine and the Karagayly and Madneul'skaya concentration plants (Mekhanobr); of the capacity of the Mukulanskiy Pit, and of the new anodizing section of the Noril'sk Combine, and the metallurgical and chemical capacities of the Severonikel' Combine (Gipronikel'); of the large-scale sheet section at the "Krasnyy Vyborzhets" [Red Elector] LPO [Sheet Metal Production Association] and the Kamensk-Ural'skiy and Revda plants of OTsM [Society of Non-Ferrous Metallurgy] (Giprotsvetmetobrabotka [State Scientific Research and Planning Institute of Alloys and Processing of Non-Ferrous Metals]); and of the Mtsensk Secondary Non-Ferrous Metals Plant (VNIIPvtortsvetmet).

The ministry is quite strictly making directors of enterprises, institutes and scientific research work and chief project engineers answer for the non-high-quality execution of projects or sections of them and for the overdue mastery of newly introduced capacities. For the purpose of eradicating such cases in the work practice of institutes, an intolerant attitude must be created in teams toward people who unsatisfactorily perform work given them and who work without ingenuity and without fervor. Too great are the negative consequences of an irresponsible attitude toward work. It is necessary to increase the sense of responsibility of each associate.

The decree discussed, of the CPSU Central Committee and USSR Council of Ministers, obliges the ministry to change over in the 11th Five-Year Plan period industrial institutes to a new form of accounting for completely executed scientific developments.

On the basis of the requirements for the thorough planning of scientific research work, its completion will be considered the introduction of the results of the research in production with the achievement of all planned figures. Directors of institutes must very seriously prepare for this, since the changeover requires a radical restructuring of the organization of all work and a considerable improvement in the sense of responsibility of scientific associates for the results of their work.

Production efficiency is inextricably linked with the quality of the resulting product. In the 10th Five-Year Plan period in the industry a great amount of work has been done on the mastery of the production of new products of higher quality. The output of eversharp hard-alloy blades has been increased threefold, production has been begun on tungsten-free hard alloys, and more than 700 types of rolled and drawn products, electrodes with a protective coating, and new semiconductor materials have been mastered. All this has produced a considerable savings for the national economy.

At metallurgical enterprises, as a result of an improvement in technology, there has been an increase in the output of higher grades of nickel, copper, zinc, titanium and a number of other metals, and as a result of this enterprises have received additional profit. But the main result consists in supplying the national economy with high-quality metals and in improving the technical level of production in consuming branches of industry, in transportation and in agriculture.

On the other hand, with regard to the quality of some kinds of products the demand of the national economy is still not being satisfied totally. The most important objectives are to improve the quality of primary and secondary aluminum and of rolled non-ferrous metals, to develop a technology for producing electrolytic copper foil, and to expand the production of eversharp hard-alloy blades made of tungsten-free hard alloys and having wear-resistant coatings.

In 1979 agencies of Gosstandart [State Bureau of Standards] applied economic sanctions to a number of enterprises for producing products with the violation of standards and technical specifications. It is necessary to take measures to not tolerate the production of substandard products.

It is necessary to strengthen technological and production discipline at enterprises and to ensure the strict observance of technological rules and operating modes.

In the decisions of the 25th CPSU Congress and in the decree of the CPSU Central Committee and USSR Council of Ministers great importance has been attached to scientific and technical progress.

As USSR Gosplan President N.K. Baybakov correctly stated, "Both the production plan and the capital construction plan must be based on the plan for scientific and technical progress, must become an extension of it and its materialization in products and fixed capital."

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NUCLEAR SCIENCE AND TECHNOLOGY

ALLOYS FOR ATOMIC ENERGY

Moscow SPLAVY DLYA ATOMNOY ENERGETIKI in Russian 1979 signed to press 20 Sep 79 pp 3-4, 210-211

[Foreword and Table of Contents from book edited by Professor, Doctor of Chemical Sciences O. S. Ivanov and Candidate of Technical Sciences Z. M. Alekseyeva, Izdatel'stvo "Nauka," USSR Academy of Sciences, Institute of Metallurgy imeni A. A. Baykov, 1,000 copies, 215 pages]

[Text] Recent results of theoretical and experimental analysis of constitution diagrams of the phase composition, structure and properties, in the equilibrium and metastable states, of alloys of various systems that are important for the analysis and development of nuclear fuel and construction materials for atomic power reactors, are presented in this collection.

The first part contains a survey on the prospect of the thermodynamic method of calculating constitution diagrams of two- and multicomponent metallic systems with the aid of the electronic computer, which has undergone considerable development in the last decade. Works of this nature open great opportunities for the further development of the general theory of metallic alloys and for the construction of effective constitution diagrams of multicomponent systems, including systems with uranium, plutonium, thorium and zirconium.

The program of studies aimed at the construction of the constitution diagram of the quaternary system U-Pu-C-N by thermodynamic calculation marks the beginning of the analysis of the behavior of carbonitride uranium-plutonium fuel during exhaustive burnout.

The results of thermodynamic and analytical methods of the construction of constitution diagrams of multicomponent systems are presented in many articles. For example, calculations of the temperature dependences of the differences of Gibbs' thermodynamic potentials between competing uranium, thorium, plutonium and other phases are given; considerable attention is devoted to methodological aspects of the construction of constitution diagrams of multicomponent systems; a new analytical approach to such construction on the basis of familiar constitution diagrams of binary systems is set forth; the vectorial approach to the problem of the thermodynamic calculation of the constitution diagrams of multicomponent systems is described. The section includes articles that describe the results of an experimental construction of constitution diagrams, or of their elements, of the U-Cr-C, U-Pd-Ni, U-Th-Fe, Th-Pd systems. Interesting experimental data are presented on the stabilization of uranium monocarbide with excess carbon and with chromium and iron additives.

Diagrams of the metastable state are drawn for the development of the thermal processing of uranium alloys in concentration-temperature coordinates for alloys of several cross sections of the ternary U-Zr-Mo, U-Zr-Nb and U-Nb-Mo systems, in alloys of which the $\gamma \rightarrow \gamma^s \rightarrow \gamma^0 \rightarrow \alpha''_b \rightarrow \alpha'_b$ multistep martensite transformation takes place during hardening. X-ray diffraction analysis of U-Mo and U-Nb alloys with a third component established that the valence factor of the alloying metal exerts the strongest effect on the change of the crystal structure of the metastable α', α'', γ^0, γ^s phases.

The second part pertains to analyses of the concentration dependence of properties. The radiation strength of metallic alloys of uranium is analyzed systematically by way of example of many alloys; the principles of gas swelling as a function of composition and microstructure are disclosed; the results of an analysis of the physico-mechanical properties at high temperature of carbonitride materials that are important for atomic energy are reported. Articles in the book on the analysis of the corrosion resistance of zirconium alloys pertain to the presently most important range of elevated working temperatures. The articles in the collection are original and previously unpublished.

Editor-in-chief, Professor, Doctor of Chemical Sciences Oleg Sergeyevich Ivanov died unexpectedly during the preparation of the manuscript for press. O. S. Ivanov is the leading scientist in the field of the development of the physico-chemical principles of alloys for atomic energy. Analyses of the constitution diagrams, phase transformations and properties of alloys of the most important binary, ternary and quaternary systems based on uranium, thorium and zirconium, completed with his participation and under his supervision, are known widely both in the USSR and abroad. Being an experimenter, O. S. Ivanov foresaw that thermodynamic calculation would, in the future, come to the aid of the researcher, presently constructing constitution diagrams through experimental analysis of many alloys. His works in this field have already been realized for two-component and for some three-component systems. All studies conducted under the supervision of O. S. Ivanov in the laboratory of physico-chemical analysis of alloys of the Institute of Metallurgy imeni A. A. Baykov of the USSR Academy of Sciences, were dictated by practical problems of the search for new materials necessary for industry and the national economy. The results of most of these studies have found reflection in thematic symposia and monographs, in journal articles, in works of national and international conferences and in authors' descriptions and patents. This collection is the seventh thematic collection of works of the laboratory, which O. S. Ivanov headed for 25 years.

Contents

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REFRACTORY MATERIALS

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CORUNDUM CERAMICS REINFORCED WITH FILAMENTARY CRYSTALS OF MULLITE

Moscow OGNEUPORY in Russian No 12, 1979 pp 34-36

[Article by D. N. Karpinos, Ye. P. Mikhashchuk and V. M. Grosheva, Institute of Problems of Materials Science of the Ukrainian SSR Academy of Sciences, and V. I. Kalinichenko, Dnepropetrovsk State University]

[Text] Corundum ceramics, which have good physicomechanical properties, cannot be used under variable thermal conditions at high heating and cooling rates due to their low thermal stability.

It is known that one of the methods of increasing the thermal stability of ceramics is to reinforce them with metal fibers [1, 2], but the use of metal fibers as a reinforcing component leads to weakening of the composites at high temperatures due to oxidation of the metal.

We conducted investigations to develop a composite material based on aluminum oxide with high thermal stability. An aluminum oxide matrix (α-Al_2O_3) with grain size less than 2 microns was reinforced with 5, 10, 15 and 20 percent (by volume) of filamentary crystals of mullite ($3\ Al_2O_3 \cdot 2\ SiO_2$) [3], whose indices are presented below:

Refractive indices:	
N_q	1.654
N_p	1.642
Bifraction	0.012
Angle 2V, degree	52
Lattice constants, Å:	
a	7.55
b	7.69
c	5.77
Crystal size, microns:	
length	350-1,000
thickness	3-5
Density, g/cm^3	3.1
Melting point, °C	1,900±20
Tensile strength, MPa	1,700
Heat-transfer coefficient $\alpha \cdot 10^6$ in the range of 20-1,000°C, $°C^{-1}$	5.3

Filamentary crystals of mullite were produced by a technique developed at the Institute of Problems of Materials Science of the Ukrainian SSR Academy of Sciences [4].

The properties of reinforced ceramices are affected by the physicomechanical properties of filamentary crystals, the degree of their uniform distribution in the composite, the technology of manufacturing the articles and the number of filamentary crystals introduced.

The uniform distribution of filamentary crystals of mullite in the composite depends on the method of mixing the initial components. High dispersion of filamentary crystals of mullite causes nodulization of them during lixiviation from the melt, which considerably worsens uniform distribution of the composite fibers during preparation of the charge. Mullite accumulations weaken the products.

Pulverization of the mullite crystals, which occurs upon mixing of the initial components, also reduces the strength of the composite. The best distribution of mullite crystals in the charge is achieved during dross mixing of the components in a "mixer"-type stirrer. The moisture content of the dross is 42 percent and the length of mixing is 20 minutes. The billets dehydrated in gypsum molds were dried at 100°C to 2 moisture content of 2-5 percent and were placed after cooling in graphite molds for hot forming, which was accomplished on PSU-50 and PG-100 hydraulic presses with induction heating.

The main factors which affect the properties of the articles during hot molding are temperature, forming pressure and isothermal aging. Since graphite press-molds have comparatively low strength, molding pressure was assumed equal to 15 MPa; the molding temperature was 1,500°C [5]. The length of isothermal aging at 1,000°C was selected experimentally.

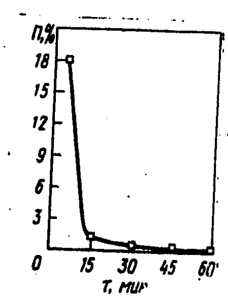

Figure 1. Dependence of Open Porosity of Composite P on Length of Isothermal Aging τ During Hot Forming. The filamentary crystal content in the specimen was 10 percent.

There is a finite density for each hot-forming temperature which essentially does not vary due to an increase of the length of isothermal aging.

The material is sintered mainly during the first 15 minutes of isothermal aging during hot forming (Figure 1). Recrystallization sintering under pressure, which also leads to a significant increase of thermal stability (Figure 2), occurs with a further increase of aging. The length of isothermal aging is determined in each specific case and depends on the shape, dimensions and mass of the product.

The content of filamentary crystals of mullite in corundum ceramics considerably affects its porosity and thermal stability. The optimum content of filamentary crystals of mullite in the composite (10 percent (by volume)) provides good indicators of the composite (see table).

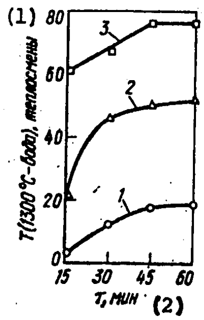

Figure 2. Dependence of Thermal Stability T on the Length of Isothermal Aging τ During Hot Forming: 1--Al_2O_3 specimens without additive; 2 and 3--composites with 5 (2) and 10 percent $3Al_2O_3 \cdot 2SiO_2$ (3)

Key:
1. T (1,300°C--water), thermal cycling
2. Minutes

An increase in the thermal stability of reinforced corundum ceramics is caused by blocking of crack propagation occurring during thermal impact by the fibers. Corundum reinforcement with filamentary crystals of mullite also increases the static (compressive and bending strength) and dynamic strength of the material (impact bending strength). However, an increase of strength is observed only with an increase of the mullite crystal content in the composite up to 10 percent; a further increase reduces ~~streng~~ strength, which is explained by an increase of the porosity of the composite.

The compressive strength is determined on cubic specimens with sides of 10 mm, bending strength is determined on bars 10 x 10 mm in cross-section and 60 mm long and impact bending strength is determined on specimens 10 x 10 mm in cross-section and 50 mm long.

The compressive, bending and impact bending strength are determined due to the effect of breaking stress parallel to the direction of the pressing force.

Physicomechanical Properties of Reinforced Corundum Ceramics*

Content, percent		Open Porosity, percent	Strength, MPa	
Corundum	Filamentary Crystals of $3Al_2O_3 \cdot 2SiO_2$		Compressive	Bending**
100	--	0.7	1,300	193 (0.4)
95	5	0.55	1,293	217 (0.51)
90	10	0.24	1,200	301.7 (1.03)
85	15	5.8	1,100	211.2
80	20	20.0	900	57.2

*The ceramics were produced by hot forming at 1,500°C with aging for 15 minutes.

**The impact bending strength, J/cm^2, is indicated in parentheses.

The microstructure of corundum reinforced by filamentary crystals of mullite was studied in transparent microsections obtained in the plane perpendicular to the direction of the pressing force (Figure 3).

Based on the results of the investigations, the design office of the institute manufactured components of an intersectional insulator which is subjected during operation to the effect of radiation and convective heat fluxes. The parts were manufactured by the hot forming method in the form of billets 100 mm high with outer diameter of 85 mm and inner diameter of 45 mm and were machined by diamond tools on metal-cutting machines.

Semi-industrial tests showed the promise of using corundum ceramics reinforced with filamentary crystals of mullite under variable thermal load conditions.

Conclusions

The technology of producing highly heat-resistant dense corundum materials reinforced with filamentary crystals of mullite was developed. The optimum number of filamentary crystals of mullite in the composite was determined.

It was established that reinforcement of the ceramics with filamentary crystals of mullite permits an increase of its strength.

Figure 3. Microstructure of Corundum Ceramics Reinforced With Filamentary Crystals of Mullite. X120 Transmitted light. Without analyzer.

The promise of using reinforced corundum as a structural material operating under variable thermal load conditions was shown.

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MISCELLANEOUS

UDC: 669.2:338.9

EFFICIENT UTILIZATION OF RESOURCES URGED

Moscow TSVETNYYE METALLY in Russian No 11, Nov 79 pp 9-15

[Article by A. P. Snurnikov: "Efficient Utilization of Resources -- One of the Principal Tasks of the Scientific and Technical Community"]

> [Text] "No matter how the wealth of our society may grow, the strictest economy and thrift remain among the most important conditions for growth and development of the nation's economy and improving living standards of the people" (From speech by CPSU Central Committee General Secretary Comrade L. I. Brezhnev at the 25th CPSU Congress)

Following are the principal directions being taken in the area of efficient utilization of raw material and fuel-energy resources in nonferrous metallurgy: improvement in the level of comprehensiveness of raw materials utilization, development of waste-free industrial processes, conservation of fuel and electric power, and protection of equipment and structures against corrosion.

Guided by the CPSU Central Committee decree entitled "On the Work of the Party Organizations of the Ust'-Kamenogorsk Lead-Zinc and Balkhash Mining-Metallurgical Combines on Mobilization of Work Forces to Achieve High Performances in Comprehensive Utilization of Raw Ore," ferrous metallurgical enterprises and institutes are working systematically on improving utilization of raw materials and increasing extraction of metals.

In recent years the advanced know-how of the above-mentioned combines, approved by the CPSU Central Committee, has been disseminated throughout this branch of industry with the aid of scientific research institutes, primary organizations, republic and oblast Scientific and Technical Society boards. The scale of application of advanced industrial processes, which are boosting figures on comprehensive utilization of raw materials, has expanded.

In 1978 there was a 17% increase in volume of ore processing with employment of preliminary concentration in heavy media. This process is presently being set up at the ore concentration mills at the Tekeli Lead-Zinc and Leninogorsk Polymetal combines.

Volume of ore processing employing self-grinding and ore-pebble grinding has increased by several million tons. Layouts for selective flotation of combined hard-to-dress ores are being perfected.

Multistage arrangements for pulp flotation, aeration and conditioning have been adopted in concentrating copper-zinc ores at the Uchaly, Sredneural'sk, Karabash, and Kirovgrad concentration mills, as well as effective methods of final concentration of rough concentrates. As a result in 1978 there was a 3.6% increase in copper recovery and 6.5% increase in zinc recovery at the Karabash Mill, and a 2.4% increase in zinc recovery at the Sredneural'sk Mill.

Based on the experience of the Balkhash Mining and Metallurgical Combine, a process is being set up for final recovery of copper, molybdenum and precious metals from copper flotation tailings at the Sorsk Molybdenum Combine.

Work is continuing on incorporation of processes of final recovery of tin and rare metals from slimes, employing gravitation, flotation, as well as combined methods. Effectiveness of concentration of tin-containing slimes, however, remains poor due to the fact that beneficiation plants are insufficiently outfitted with high-productivity gravitation and grading equipment. As a result of improvement of industrial processes, adoption and utilization of high-efficiency equipment, and further incorporation of processes for recovering by-product components, comprehensiveness of utilization of raw materials has improved.

In the copper industry production of molybdenum concentrates has increased by 20%; in the tin subbranch -- copper concentrates by 31% and zinc by 65%; production of lead concentrate has been set up; in the tungsten-molybdenum subbranch -- bismuth product by 11%; in the rare-metals subbranch -- mica concentrates by 7% and quartz molding sand by 9%.

Today, however, we should concentrate our attention and efforts primarily on eliminating existing gaps and deficiencies, and we still have a considerable number of these. Almost 30% of all beneficiation plants are failing to reach 1979 plan-specified targets for recovery of metals. The largest number of plants which are failing to meet metal recovery indices are under Soyuzmed', Soyuzzoloto, and the Kazakh SSR Ministry of Nonferrous Metals. Considerably behind target in recovery of metals are the Tekeli, Kentau, Almalyk, Kirovgrad, and Sredneural'sk beneficiation plants.

Benefit to this branch produced by successfully operating beneficiation plants is being diminished to a substantial degree by the unsatisfactory performance of lagging enterprises, which are failing to meet plan-specified targets pertaining to recovery of metals.

The main reasons for above-target metal losses lie in poorly-organized sampling and testing of ore deposits, inadequately smoothly-scheduled movement of ore to the mills, and deviations from the plan-specified chemical and physical composition of the ores being processed. A number of enterprises are still unsatisfactorily readying the equipment to receive ores of variable composition; they are underrating the role of crushing and grinding the ore, and process discipline is being violated; different grades of ores are being wrongly mixed. Also reflecting on recovery figures are unsatisfactory equipment operation and unscheduled equipment stoppage.

There is considerable reserve potential available to increase comprehensiveness of utilization of the raw materials during ore beneficiation, and it must be immediately utilized. It is essential to arrange for smooth, uniform supply to the mills of ore of the plan-specified content; it is necessary to organize more thorough study of the composition of ores on the basis of advance sampling of the ore deposits, to ensure a stable composition of ores being processed, to prepare in advance process arrangements for multiple-grade processing of ores at the mills, to reduce the rate of equipment breakdown during operation, and to speed up development and adoption of optimal ore concentration process arrangements. Accelerated utilization of production internal reserve potential is an important current task of the scientific and technical community at nonferrous metallurgy enterprises and institutes.

Scientific and Technical Society organizations at scientific research institutes and enterprises should as soon as possible resolve local problems pertaining to increasing recovery of zinc and sulfur from Ural ores, lead and zinc from Zhayrem ores; development of an efficient process of concentration of the pyritic lead-zinc ores of the Ozernoye, Tekeli, and Filizchayskoye deposits; decrease in losses of copper, bismuth and other associeted metals when concentrating tungsten-containing and tin ores; development of a selective process of concentrating copper-nickel ores, especially when increasing the content of talc-containing ores on the Kola Peninsula.

This year the majority of metallurgical enterprises are meeting their metals recovery target. Some of the credit must go to the primary organizations of the Scientific and Technical Society. Such combines as Yuzhuralnikel' and Pechenganikel', however are failing to meet their nickel recovery targets, while the Pechenganikel' Combine in addition is not meeting its copper and cobalt targets. Apparently our Scientific and Technical Society organizations are also not working sufficiently persistently at the Ural enterprises as well, since the Sredneural'sk Copper Smelting Plant and the Krasnoural'sk Combine have not yet achieved targeted copper recovery into commodity output, while the Ufaleyskiy Combine is failing to meet its cobalt recovery target. The Elektrotsink Plant and the Chimkent Lead Plant are continuing to perform unsatisfactorily.

In February 1979 USSR Gosplan examined the question of measures to achieve further improvement in utilization of secondary material resources in the nation's economy and noted that secondary resources, production and consumption waste are in many instances still being utilized in insufficient quantities. A portion of these resources is lost, destroyed, dumped into the slag heap, and discharged into bodies of water.

Our branch of industry possesses great potential for improving utilization of nonferrous metal scrap and waste and for bringing into production waste slag, particularly slag with a high content of metals, zinc tailing cake and other production waste and by-products, as well as reserve potential to increase recovery of stack gases and effluents.

Considerable work has been done in recent years to increase procurement of nonferrous metal scrap and waste and to improve their utilization. New types of waste have been drawn into acquisition and production -- waste containing tungsten, molybdenum, rhenium, etc, which were not utilized in the past. New industrial processes were developed for processing various types of scrap and waste. Construction began on shops to process salt slags from reverberatory furnace melting of aluminum alloys in order to recover valuable components from them.

This has made it possible somewhat to reduce losses in storage and to increase recovery of aluminum. The figures on recovery of secondary metals at the Soyuzvtortsvetmet Association, however, still remain low.

The principal reasons for a low aluminum recovery figure are mechanical losses during storage, oxidation at open storage sites, lack of charge preparation, and considerable losses of metal with slags, processing of which has not yet been set up at a single Soyuzvtortsvetmet enterprise. As a result losses with reverberatory furnace melting salt slags comprise approximately 40-50% of all losses.

The bulk of copper secondary raw material is processed at the Kirovgrad Copper Smelting Combine, with a high degree of copper recovery, exceeding 98%, and with utilization of a number of valuable constituents. There is still potential here, however, for fuller and more comprehensive utilization of raw material. To achieve this it is necessary to speed up construction of an experimental commercial-scale installation for electrothermal processing of shaft furnace slags with the objective of recovering zinc and tin from these slags, to equip all converters with dust-trapping devices, to eliminate mixing of the smelting products of the ore and secondary branches, and to organize processing of the entire volume of tin-containing converter slags.

A large quantity of solid production waste, more than 300 million cubic meters per year, is generated at mining enterprises, beneficiation mills and metallurgical plants. In 1978, however, only 10 million cubic meters was utilized as building materials (crushed rock, gravel) and as mine backfill.

A large percentage of overburden and tailings is not utilized due to the fact that the USSR Ministry of Construction Materials Industry, in spite of repeated suggestions by the USSR Ministry of Nonferrous Metallurgy, is failing to show proper interest in this matter.

At the present time metallurgical enterprises have amassed a large quantity of lead plant zinc-containing slags, as well as red and belite sludges from alumina production. The volume of processing of zinc-containing slags has doubled during the five-year plan. A shop for hydrometallurgical processing of zinc cake is scheduled to go into operation in the very near future at the Almalyk Mining and Metallurgical Combine. This will free Waelz shop capacity for additional processing of Chimkent Lead Plant slags.

The previously-targeted processing volumes of zinc-containing slags are not being met, however, due to construction delays on a Waelz unit for processing cold slags and a hydrometallurgical plant for processing zinc cake at the Leninogorsk Polymetals Combine.

There will be a substantial increase in volume of processing belite sludge for cement in 1980 by movement on-stream of additional processing capacity at the Achinsk Alumina Combine.

Research is being conducted, jointly with the USSR Ministry of Ferrous Metallurgy and the USSR Ministry of Construction Materials Industry, on utilization of red sludges in ferrous metallurgy and production of building materials.

One of the main factors holding back further increase in volume of processing of production waste is a lack of capital financing and failure by construction organizations to complete the work volumes specified by the targets of the 10th Five-Year Plan.

Substantial quantities of noxious gaseous substances are generated at nonferrous metallurgical enterprises: sulfur dioxide, hydrogen chloride, hydrogen fluoride, chlorine, etc, which can be utilized as raw materials for chemical products -- sulfuric acid and fluorides.

At the present time "concentrated" sulfur-containing gases from roasting of copper and zinc concentrates and oxygen-jet smelting are most fully utilized in sulfuric acid production at enterprises of this branch. Other gases which are weaker in sulfur dioxide content -- converter, electric furnace, and sintering furnace gases -- are partially recovered.

Radical improvement in utilization of sulfur-containing gases involves adoption of autogenous processes in production of heavy nonferrous metals.

A number of enterprises are not yet fully utilizing capability to increase processing of sulfur-containing gases with existing sulfuric acid shop capacity. A unit for recovering sintering furnace gases, put on-stream in 1977 at the Ust'-Kamenogorsk Lead-Zinc Combine, is not yet operating at full capacity. Renovation has not yet been completed on waste-heat boilers on sulfur-combustion units (providing increased utilization of converter gases) at the Sredneural'sk Copper Smelting Plant.

The Principal Directions of Development of the USSR Economy in 1976-1980, ratified by the 25th CPSU Congress, stated the target of reorganization of industrial processes and methods with the objective of creating and adopting no-waste or little-waste production facilities with high technical-economic indices. Resolution of this problem will make it possible more fully to utilize raw materials and sharply to reduce harmful pollution of the environment.

The economic expediency and considerable social significance of a closed-cycle no-waste process is obvious from an economic point of view. In nonferrous metallurgy there is a realistic possibility of development and adoption in the future of a number of closed-cycle metallurgical processes with complete processing of intermediate products and production waste.

Comprehensive processing of raw nepheline in the aluminum industry constitutes one such layout. Elaboration of this process is a top priority for the Soviet Union and has no counterpart elsewhere in the world. Future plans call for building new enterprises to produce silica of raw nepheline, and the technology of its total processing will be applied on a larger scale.

Operational costs to produce alumina, soda, potash, and cement from nepheline raw material are 10-15% lower than the cost of obtaining these products by other commercial methods.

One way to create a comprehensive no-waste raw material processing technology is to set up a combined metallurgical production operation which permits closed-cycle processes with full utilization of intermediate products both at the same enterprises and on a subbranch scale. The most promising enterprises in the lead and zinc industry for establishing no-waste production technology are the Ust'-Kamenogorsk Lead and Zinc Combine, the Leninogorsk Polymetals Combine, and the Elektrotsink Plant.

Various-composition dusts are obtained in lead and zinc production processes, dusts containing primarily lead, zinc, cadmium, arsenic and certain rare elements. Processing the dusts produces a zinc solution and lead residue. The first of these products, after cleaning, enters the zinc production cycle, while the second product is shipped to a lead plant. In both cases commodity output (zinc and lead) are obtained from them without the formation of secondary intermediate products.

Zinc-containing shaft furnace smelting slags are the final waste product of lead production. The Ust'-Kamenogorsk Lead and Zinc Combine has developed and tested a method of comprehensive processing of solid slags by rotary kilning, with utilization of all valuable constitutents. The lead-zinc sublimates are processed into a zinc solution and lead residue, while the magnetic and nonmagnetic slag fractions are utilized in metallurgical production and for producing building materials respectively, that is, also without generating slag heap materials.

If we consider existing capability to refine copper matte to blister copper, we can state that lead raw material and lead plant intermediate products can be completely processed into commodity output: lead, copper, zinc, cadmium, rare elements, trace elements, and building materials.

Copper plants will also be able to operate in the future employing no-waste technology if more economical methods are found for processing smelting furnace slags utilizing all their constituents. The most promising in this respect is the copper smelting operation at the Dzhezkazgan Mining and Metallurgical Combine.

There is no concentrate roasting process stage in the process employed at this enterprise, since the quantity of sulfur in the concentrates is insignificant, and in order to obtain mattes with a copper content not exceeding 60% it is necessary to place sulfur-containing addition agents (pyrite concentrate) in the charge. This fact not only simplifies the enterprise's operation but also eliminates the need to provide for processing roasting shop dust and flue gases.

The principal difficulty lies in organization of comprehensive processing of the waste slags from electric furnaces. As was indicated by studies performed by Gintsvetmet [State Scientific Research Institute of Nonferrous Metals] and VNIItsvetmet [All-Union Scientific Research Institute of Nonferrous Metallurgy], the adding of lime to an electric furnace charge will make it possible to reduce copper content in the slags, while the ratio of the basic slag-forming constituents silica and calcium oxide will be such that after cooling the slag will take on binding properties and will be able to replace low-grade cement to a certain degree. We discussed above utilization of the silicate part of slags for producing various construction products and building materials.

If one takes account of the great potential for development at the mines of the Dzhezkazgan Combine of systems of mining employing backfilling with hardening mixtures and the impending considerable expenditure of cement for these purposes, development of a no-waste process at a copper smelting plant becomes a task of immediate importance for the near future.

For this Gintsvetmet, VNIItsvetmet, Giprotsvetmet [State Institute for Designing Nonferrous Metallurgical Enterprises] and the Dzhezkazgan Combine must develop an appropriate process for smelting copper concentrates in electric furnaces, substantiate the economic necessity of comprehensive utilization of slags as one of the constituents of backfill mixtures, test this method on a commercial production scale, design and build an installation for processing slags.

The incorporation of recycled process water is of great importance for developing no-waste production operations. Water recycling to one degree or another has been adopted at 140 nonferrous metallurgical enterprises in this country. Discharge of effluents has been practically eliminated at 22 enterprises.

The rate of adoption of water recycling and reduction of consumption of fresh water and discharge of polluted effluents is still insufficient, however. For example, process water recycling at nonferrous metallurgical enterprises in Armenia comprises only 8% of total water consumption, and the enterprises of Soyuztsvetmetobrabotka (56%) and Soyuzpolimetall (65%) are insufficiently committed to incorporation of water recycling. There is no water recycling whatsoever at a number of enterprises in this branch.

Conditioning of recycled water makes it possible to recover metals lost with effluents -- copper, lead, zinc, gold, etc. Thus the incorporation of water recycling produces not only an important social effect but also represents millions of rubles saved by the economy.

As a result of technical and organizational measures to improve power facilities and automate industrial processes, savings for the branch as a whole in 1978, as compared with ratified standard figures, exceed 150,000 tons of standard fuel, comprise approximately 1,200,000 gigacalories of thermal energy, and 300 million kilowatt hours of electricity.

At many nonferrous metallurgical enterprises economical utilization of fuel and electricity are continuous concerns of the work force.

These include the Berezniki Titanium-Magnesium Combine, the Krasnoyarsk Nonferrous Metals Plant, the Noril'sk Mining and Metallurgical Combine, the Dneprovskiy Aluminum Plant, the Zyryanovsk Lead Combine, the Yuzhural-nikel' Combine, the Chelyabinsk Electrolytic Zinc Plant, and the Kirgiz Mining and Metallurgical Combine.

One of the most important problems in nonferrous metallurgy is that of finding ways to conserve energy resources in the production of nonferrous metals. In spite of positive energy utilization results in this branch, however, the level of work being done is still inadequate. Not all enterprises and organizations devote adequate attention to matters of economical consumption of fuel and all types of energy. There is a wide field for action here for the scientific and technical community and all production specialists.

It is necessary to look into the reasons why there occurred a considerable overconsumption of fuel-energy resources in 1978 at the Krasnoyarsk, Bogoslovskiy and Ural aluminum plants, the Sredne-Ural'sk Copper Smelting Plant and the Almalyk Mining and Metallurgical Combine, and concrete measures must be specified to achieve improvement in the performance of these enterprises in the area of economy of raw materials and fuel-energy resources.

Nonferrous metallurgy is one of the most energy-intensive branches of the nation's economy; energy outlays comprise approximately 55% of the prime cost of some products. Total electric power consumption in the branch breaks down into the following percentages: 60% for electrolysis of nonferrous metals; 16% for metallurgy; 12% for mining and ore beneficiation; 7% for electrothermics; approximately 5% for auxiliary production operations.

In order to achieve savings in electric power it is essential to improve the design of presently-operating electrolyzers, to expand utilization of calcined anodes, to optimize industrial process conditions, etc.

There is considerable reserve potential for achieving savings in electric power in the electrothermal production of nonferrous metals. Principal ways to utilize this reserve potential involve improving the design of furnaces and their operating parameters. In particular, in the titanium-magnesium and rare-metals industry -- by renovating electrolyzers presently in operation and by putting on-line ore roasting furnaces operating in closed and semi-closed conditions.

Reduction in energy resource consumption is promoted by comprehensive utilization of resources, the most extensive drawing of secondary energy resources into production, accelerated development and adoption of totally new energy technology complexes in metallurgical production, all-out increase in the efficiency of industrial process and power equipment, plus other measures.

In our country much importance is attached to the problem of combatting corrosion. It is a well-known fact that each year approximately one and a half percent of the total mass of metal in use in the industrially developed countries is destroyed by corrosion, and this is a very large figure.

Definite efforts are being made in this branch to protect metals against corrosion damage; a number of new industrial processes are being adopted which eliminate the effect of corrosion on structural members and equipment. Corrosion-resistant and wear-resistant materials (plastics, alloys) are employed in the manufacture and protection of process equipment, pipe, and gas lines. New chemically stable paints are employed, and products of polymer concretes are being extensively adopted.

A vigorous campaign is in progress to combat corrosion at the Noril'sk Mining and Metallurgical Combine, the Pobedit Plant, the Zaporozh'ye Titanium-Magnesium Combine, the Verkhnedneprovsk Mining and Metallurgical Combine, the Ust'-Kamenogorsk Lead-Zinc Combine, the Uzbek Refractory and Heat-Resistant Materials Combine, plus other enterprises. Scientific and technological achievements and advance technology are extensively employed in chemical protection at enterprises. Reinforced polymer contrete baths for electrolyzers went into production in 1977-1978; the durability of these is greater than that of similar baths of reinforced concrete and makes it possible to reduce consumption of metal, reinforced concrete, rigid PVC, and other materials.

A number of repair trusts have established protective coatings construction laboratories. The chief power engineer administration has established a specialized enterprise, Tsvetmetspetsenergoremont, to restore anticorrosion coatings on power equipment, chimneys and cooling towers.

The All-Union Institute of Aluminum and Magnesium, Gintsvetmet, Giprotsvetmet, and the Kazmekhanobr Institute conducted a number of research studies and design projects on preventing corrosion of metals and expanded use of polymeric materials at metallurgical enterprises.

Alongside positive examples of solving problems of protecting metals against corrosion, we still have unsolved problems. Many enterprises fail to attach proper importance to protection of metals against corrosion, there are too few specialists in protective coating, chemical protection sections are not being established, and not everywhere have studies been conducted and programs elaborated for protecting equipment and structural members.

Active participation by specialists at enterprises, design and scientific research institutes, as well as the entire nonferrous metallurgy scientific and technical community in work on efficient utilization of material and fuel-energy resources will help improve technical-economic indices in nonferrous metals mining and production.
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TWO STAGES IN THE PROCESS OF CLEAVAGE FAILURE

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[Text] The process of failure (cleavage) which takes place in the interaction of counter rarefaction waves is characterized by short times ($\lesssim 10^{-6}$ s) and high, severalfold higher than the tensile strength of the material tested, maximum negative stress (cleavage strength). In spite of this, cleavage is analogous to the process of quasi-static failure in the respect that it begins with the appearance of nucleus defects [1] and ends with the growth of micro- and macrocracks [2]. It is known that in quasi-static failure the origin and spreading of a crack are different processes, and the process of failure is considered separately for the subcritical, critical and supercritical states [3]. The differentiation of the process of cleavage into stages is generally accepted [1,2,4,5], but the question of the number of stages and, consequently, of their characteristics and the conditions for transition from one stage to another remains open. In addition, the existing time diagrams of cleavage do not permit correlation of cleavage and quasi-static strength [2].

In this paper the process of cleavage is differentiated into stages (in the sense of the definition in [3]) and with steel as an example a description is offered of the subcritical stage of cleavage which agrees with the results of quasi-static investigations of strength.

Let us consider cleavage which takes place as the result of the interaction of one-dimensional plane rarefaction waves propagated perpendicularly to the free surface of the specimen. An investigation of specimens kept after cleavage [2,4] has revealed in them a great number of cracks of different sizes. However, in many cases separation of the specimen in cleavage takes place in a fairly thin layer. This provides an opportunity to consider the process of cleavage in this layer alone. Let us define the cleavage plane as a layer with a thickness of δ, whose center lies at a distance of ℓ from the free surface, whereby $\ell \gg \delta$, and abutting the boundaries of this layer is a material which remains monolithic throughout the entire process. The boundary of the layer facing the free surface we will designate as δ_+ and the opposite boundary as δ_-. With sufficient triviality of δ, the stresses in δ_+ and δ_- differ little from one another. Therefore by the stress in the cleavage plane we will mean the stress at boundary δ_+ with the required triviality of δ. Since the boundaries pertain to a monolithic material, then the stresses at the boundaries are related to their velocities by the equation of state of a monolithic material, regardless of the processes occurring inside the layer. In the scheme adopted, the description of cleavage boils down to determining the law of expansion of the failing layer. In failure the law for the change in stress over time at boundary δ_+ will determine the change in velocity of the free surface.

In this study, by the method of a capacitive sensing element [6] a recording was made of the velocity of the free surface, $W(t)$, over time t during cleavage in low-carbon steel st. 3. Three series of experiments were conducted with substantially different forms of the stress profile in the forward compression wave. Fig. 1 shows a section of the profile of $W(t)$ from the second series. From experimental profiles of $W(t)$ were determined the following magnitudes (cf. Fig.1): the maximum velocity at moment t_A, W_A, the minimum velocity at moment t_B, W_B, acceleration in the left neighborhood of t_B, W'_-, acceleration in the right neighborhood of t_B, W'_+, the times between the closest velocity minima, t_2, t_3, t_4, ..., and time $t_1 = t_B - t_A$. The cleavage strength in the first and second series was determined from the equation $\sigma^* = 0.5\rho_0 C_0 \Delta W^*$ [7] with a correction for the elastoplastic behavior of the material, $\Delta W^* = W_A - (W_B - |W'_-|\Delta t_B)$ [8], where $\Delta t_B = 0.5t_2(C_\ell/C_0 - 1)$ [8,9]. In these equations for σ^*, in steel st. 3, $\rho_0 = 7.86$ g/cm is the density of the material, $C_0 = 4.64$ km/s is the volumetric speed of sound, and $C_\ell = 5.95$ km/s is the longitudinal speed of sound [9]. Oscillations in the free surface following after point t_B with a period of t_2 testify to the fact that within the specimen at a distance of $\ell = 0.5t_2C_\ell$ from the free surface has appeared a second free surface or a region with low dynamic stiffness.

The experiments demonstrated that the acceleration of the free surface determined by the slope of $W(t)$ (Fig. 1) changed sign in the slight vicinity ($\lesssim 0.1t_2$) of t_B thereby changing by $W'_+ - W'_- = (2 \text{ to } 8)\cdot 10^8$ m/s^2, i.e., acceleration at point t_B practically underwent a jump. Consequently at a certain moment of time prior to this boundary δ_+ experienced a jump in acceleration of the same order of magnitude. Thus, at a certain instant begins especially sudden (intensive) expansion (failure) of layer δ. In addition, in spite of the fact that the cleavage strength in the first series is 1.5-fold lower than in the second, for example, and times t_1 and t_2 are threefold longer, the time ratio t_1/t_2 is constant in each series and equals with an accuracy of six percent a value of $0.5\cdot(1 + C_\ell/C_0)$. This means that intensive failure begins practically immediately after passage through the cleavage plane of the last perturbation, C_-, of the elastoplastic rarefaction wave, Y_-, from the free surface.

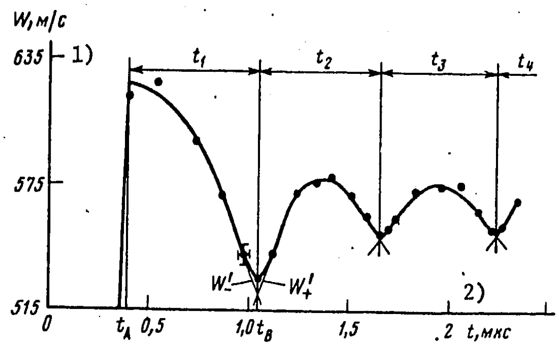

Figure 1. Profile of W(t). The starting point for reading the time is the instant the elastic forerunner reaches the free surface. Errors are indicated by a cross.

Key:

1. m/s
2. μs

Let us plot the profile, of σ(t), of the stress, σ, versus time, t, in the cleavage plane (Fig.2). For the purpose of plotting σ(t) prior to the beginning of intensive failure, let us use the method in [10], but let us take into account the fact that the negative stress in the cleavage plane arises not instantaneously, but with a certain speed determined by the rates of change of the stress in wave Y_- and in the forward rarefaction wave, Y_+. The profile of the stress in the Y_- wave in the cleavage plane is of a complex form, which will bear information on the interaction of the elastoplastic compression wave with the free surface. However it is important that the difference $\tau^* - \tau_1 = \ell/C_0^* - \ell/C_1$ in the time of arrival of the first perturbation of wave Y_-, having a velocity of $C_1 \gtrsim C_\ell$, and in the time of arrival of C_-, having a velocity of $C_0^* \lesssim C_0$, depends on distance ℓ. Accordingly, assuming that $C_1 = C_\ell$ and $C_0^* = C_0$, let us replace the breaking front of the negative pulse discussed in [10] with a straight line with a slope of $Y'_- = -\sigma_0/\ell(1/C_0 - 1/C_\ell)$, where $\sigma_0 = 0.5W_A\rho_0C_0$. At the same time the rate of change of σ in wave Y_+ will equal $Y'_+ = 0.5\rho_0C_0W'_-$. Summing algebraically the values of σ in wave Y_+ with the value of σ in wave Y_- at each moment of time, we arrive at σ(t) in the cleavage plane prior to the start of intensive failure. This profile is indicated in Fig.2 by the solid line prior to moment τ*; at moment τ_0^* there occurs $\sigma(\tau_0^*) = 0$. The rate of change in stress, dσ/dt, over period of time $\tau_0^* \le t \le \tau^*$ will be determined by the sum $Y'_- + Y'_+$. In keeping with [1], the profile of negative stress in the cleavage plane has the form of the envelope of the hatched section in Fig.2. The novelty in the plotting of $\sigma(t)$ as compared with the similar plotting in [1] consists in the fact that time $\tau^* - \tau_0^*$ is regarded as dependent on the coordinate.

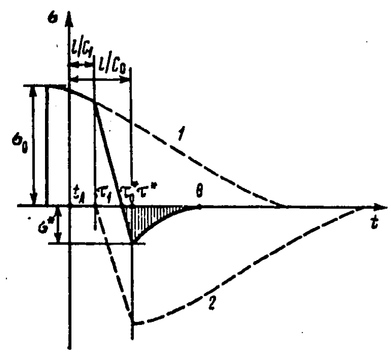

Figure 2. Profile of $\sigma(t)$ in the Cleavage Plane. The starting point for reading time is the arrival of the last perturbation of the elastoplastic rarefaction wave from the free surface. 1--forward pulse; 2--negative pulse reflected from free surface.

Let us link the beginning of the subcritical stage of cleavage with instant τ_0^* (cf. Fig.2), the critical state characterized by cleavage strength, $\sigma^* = \sigma(\tau^*)$, with instant τ^* , the beginning of the supercritical stage of cleavage with the beginning of intensive failure, and separation of the specimen with moment θ , $\sigma(\theta) = 0$.

Let us consider the subcritical stage. For the purpose of describing it we will utilize the impairment function, ϕ , and the law of growth from [11]:

$$d\varphi/dt = A(\sigma)^{m-1}, \qquad (1)$$

where σ is the negative stress; A and m are constants; t is the time; and ϕ is a scalar quantity equal to zero at the beginning of the subcritical stage and to one at the end of it. Let us assume (cf. Fig.2) in equation (1) that $\sigma = \sigma(t)$ is a positive stress as used here and below with $\tau_0^* \le t \le \tau^*$, $\phi(\sigma(\tau_0^*)) = 0$ and $\phi(\sigma(\tau_0^*)) = 1$. In addition, taking into account the fact that the material for the duration of the entire subcritical stage obeys the equation of state of a monolithic material, we will write:

$$d\sigma/dt = \rho_0 C_0^2 \dot{\varepsilon} = \text{const} = |\,\dot{Y}_1' + \dot{Y}_2'\,|, \qquad (2)$$

where $\dot{\varepsilon}$ is the rate of straining, and σ and t are the same as in equation (1). Dividing (1) into (2) and integrating the expression arrived at in terms of σ, and then taking the logarithm of the result of integration, we get the conditions for the critical state of cleavage:

$$\lg \sigma^* = m^{-1} \lg \dot{\varepsilon} + m^{-1} \lg(\rho_0 C_0^2 m/A). \qquad (3)$$

In Fig. 3, in keeping with equation (3), are given the results of experiments of the first and second series.

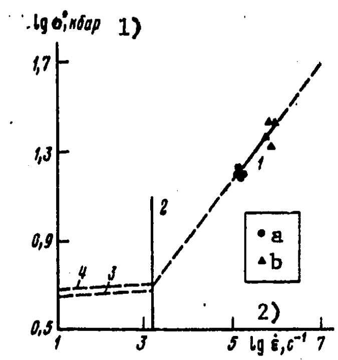

Figure 3. Correlation of Cleavage and Quasi-Static Strength of Low-Carbon Steel. a and b--experimental data of the first and second series respectively; straight line 1 plotted by the method of least squares; 3 and 4--strength of commercial iron; 2--boundary of quasi-static region

Key:
1. kbar
2. s^{-1}

Dependence (3) can be regarded as an analog of the dependence of the long-term strength, σ_s, on the rate of steady-state creep, $\dot{v}$ [12]. In Fig. 3 in coordinates of $\log \dot{v} = \log \dot{\varepsilon}$ and $\log \sigma_s = \log \sigma^*$ is given an extrapolation of data on the time dependence of the strength of commercial iron from [13] with a test temperature of $T_1 = 233°K$ (curve 3) and with $T_2 = 198°K$ (curve 4). Conversion of the dependence of durability, $\tau(\sigma_s, T)$, into the dependence $\dot{v}(\sigma_s, T)$ was accomplished by utilizing the relationship $\tau\dot{v} = v_0 = \text{const}$ [12] with $v_0 = 10^{-2 \cdot 2}$ for iron from [14]. Since experiments with quasi-static loading are performed with the condition that $\tau \gg d/C$, where usually $d \sim 2 \cdot 10^{-2}$ m is the length of the working section of the specimen, $C \simeq 10^3$ m/s is the velocity of elastic waves in bars (for iron $C = 5.25$ km/s), and $\tau \geq 10^{-3}$ s [12], then extrapolation of these experimental data for the boundary of $\tau_\gamma = d/C$ or for a rate of straining of $\dot{v}_g = C_g/d$, generally speaking, is inadmissible. In Fig. 3 the boundary of $\log \dot{v}^0 = \text{const}$ for iron is indicated by straight line 2. However, the cleavage data must be correlated with the quasi-static in the neighborhood of $\log \dot{v}_g$, in which the quasi-static data are certainly valid.

From Fig. 3 it is obvious that extrapolation of dependences of cleavage and quasi-static strength for boundary $\log \dot{v}_g$ will result in reasonable agreement of both dependences. With a time for the subcritical stage of $\Delta\tau_T$ close to the time for the establishment of a steady-state rate of movement of dislocations in metals of $\Delta\tau = 7 \cdot 10^{-12}$ s [15], there should be realized a cleavage strength, σ_T^*, of a nearly flawless material, i.e., comparable with the theoretical strength. Estimating the rate of straining with this as $\dot{\varepsilon}_T = \sigma_T^*/\rho_0 C_0^2 \Delta\tau_T$ (where $\Delta\tau_T$ is chosen at one order of magnitude higher than $\Delta\tau$), we get by means of equation (3) with the coefficients found $\sigma_T^* = 193$ kbar. This value of σ_T^* is close to the estimate of the theoretical strength according to the equation $\sigma_T = 0.1E$ [11]; $E \simeq 2000$ kbar is Young's modulus for steel.

Thus, the suggested interpretation of the subcritical stage of cleavage makes it possible to coordinate data on cleavage strength with one another and with results of investigations of the time dependence of strength under quasi-static conditions.

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DIFFUSION MECHANISMS OF VARIATION OF THE ABSORPTIVITY OF METALS DURING LASER HEATING IN THE AIR

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[Article by V. I. Boyko, corresponding member of the USSR Academy of Sciences F. V. Bunkin, N. A. Kirichenko, B. S. Puk'yanchuk]

[Text] During laser heating of a metal target in air, an oxide film is formed on its surface. This leads to significant variation of the absorption characteristics of the targets during heating of them by infrared radiation, which is connected both with the natural absorption of radiation in the oxide layer [1, 2] and light interference in the layered oxide-metal system during growth of the oxide film [3, 4].

The variation of the absorptivity of the metal targets can be connected not only with growth of the oxide film. First, there is a temperature dependence of the absorption coefficient of the metal. Secondly, in a number of cases diffusion phenomena are observed which lead to variation of the absorptivity A_0 of the metal itself. Thus, for example, the effect of a decrease in A_0 connected with annealing of the target and removal of micro impurities from it is known, that is, the effect connected with laser cleaning of the surface [5]. In [3], the proposition was stated that one of the most long-term processes making its contribution to the cleaning effect is diffusion of the micro impurities in metal in depth exceeding the thickness of the skin layer. In some metals (for example, in titanium) the inverse effect can be observed where as a result of oxygen diffusion from the air (or from the growing oxide) into the skin layer, intensification of the impurity scattering of the electrons and a decrease in their mobility take place [6]. As a result, there can be noticeable increase in absorptivity A_0.

In this paper a theoretical model is proposed for considering the diffusion mechanisms of the variation of the absorptivity in the process of laser heating of the metals in the air.

The solution of the electrodynamic problem defining the absorption coefficient of the metal A_0 essentially depends on the concentration distribution of the micro impurities N(z, t) near the surface of the metal. During laser heating diffusion of the impurities from the surface of the layer into the depth of the metal takes place. This process is described by the diffusion equation

$$(1)\quad \frac{\partial N}{\partial t}=D(T)\frac{\partial^2 N}{\partial z^2},\quad N=N(z,t),\quad z>0;\quad D(T)=D_0\exp\left(-\frac{T_0}{T}\right).$$

Here the diffusion coefficient of the impurity atoms D in (1) depends on the temperature T of the surface layer. This function is determined primarily by the exponential term [7]. Inasmuch as during the process of laser heating the target temperature varies with time T=T(t), equation (1) must be solved for an arbitrary time function of the diffusion coefficient D=D(t).

It is necessary to add the boundary and initial conditions defined by the statement of the problem to the system of equations (1). In the problem of laser cleaning we shall consider that the initial distribution of the impurities in the surface layer of the metal is described by the normal law

$$(2)\quad N(z,t)\big|_{t=0}=N_0\exp(-z^2/z_0^2),\quad \frac{\partial N}{\partial z}\Big|_{z=0}=0,\quad N\big|_{z=\infty}=0.$$

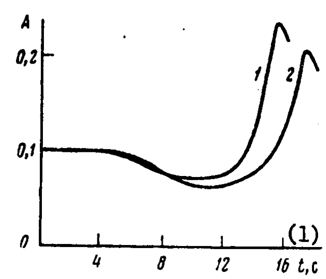

Figure 1. Experimental (1) and theoretical (2) dependence of the variation of the absorptivity A(t). The calculation was performed for the parameters of a specific experiment in [13]: P=15.8 watts, m=87.13 mg, s=0.3 cm^2, A_{01}=0.05, A_{02}=0.1, n=1.5, k=0.019, $\eta=2.22\times10^{-3}$ watts/$cm^2\cdot$°C, $\bar{\sigma}_0$=0.415, T_d=11000°K, $d_0=3\cdot10^{-3}$ cm^2/sec, T_0=10000K; $4D/z_0^2=10^6$-sec^{-1}.

Key:

1. t, sec

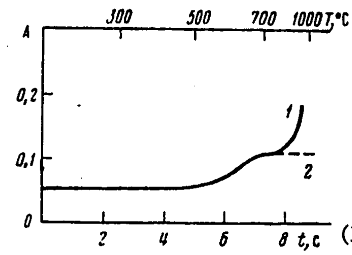

Figure 2. Theoretical dependence of the variation of the absorptivity of a thermally thin plate of titanium during its heating in the air by the emission of a CO_2-laser. The calculation was performed for the following values of the parameters: P=20 watts, m=50 mg, s=0.3 cm^2, A_{01}=0.05, A_{02}=0.1, n=2.6, k=0.045, T_d=33000K, d_0=10^4 cm^2/sec, T_0=18000K, D_0=$3 \cdot 10^{-3}$ cm^2/sec

Key:
1. t, sec

The solution of equations (1), (2) has the form [8]

$$(3)\quad N(z,t)=\frac{N_0}{\sqrt{1+\varphi}}\exp\left[-\frac{z^2}{z_0^2(1+\varphi)}\right],\quad \varphi=\frac{4D_0}{z_0^2}\int_0^t \exp\left(-\frac{T_0}{T(\tau)}\right)d\tau.$$

For the problem of saturation of the metal surface with oxygen of the air, the initial and boundary conditions for equation (1) have the form

$$(4)\quad N(z,t)\Big|_{t=0}^{z>0}=0,\quad N(z,t)\Big|_{z=0}=N_0,\quad N(z,t)\Big|_{z=\infty}=0.$$

Solving equations (1) with condition (4), we obtain [8]

$$(5)\quad N(z,t)=N_0\left[1-\Phi\left(\frac{z}{2\sqrt{\theta}}\right)\right],\quad \theta=D_0\int_0^t \exp\left(-\frac{T_0}{T(\tau)}\right)d\tau,$$

$\Phi(x)$ is the probability integral [9].

Let us first consider the absorption of the radiation by the metal surface in the case of a normal skin effect. On satisfaction of the condition $\omega\tau<<1$ (ω is the radiation frequency, τ is the relaxation time of the electrons of the metal) the absorptivity of the metal A_0 is defined by the expression [10]

$$(6)\quad A_0=\sqrt{\frac{2\omega}{\pi\sigma}},\quad \sigma=\frac{\sigma_0}{1+\gamma^n/\gamma^f},\quad \gamma^n=Nav_F,$$

where σ is the conductivity of the metal, σ_0 is the conductivity of the pure metal, γ^{ef} is the frequency of the electron-phonon collisions, γ^n is the frequency of the electron collisions with the impurities, N is the concentration of the impurity atoms, v_F is the velocity of the conduction electrons on a Fermi surface, a is the scattering cross section of the electrons on the impurities.

Formula (6) describes the absorptivity of the metal when N=const within the limits of the thickness of the skin layer which is not satisfied for the investigated class of problems. For determination of A_0 in this case it is necessary to calculate the surface impedance of the metal Z for the given impurity distribution N=N(z) (formulas (3), (5)).

Let us consider the important special case $\delta_0/z_0 \ll 1$, $\gamma^n/\gamma^{ef} \ll 1$. In this approximation by the ordinary method [11] from formulas (3), (6) we obtain the following expression for the impedance

$$(7) \quad Z = \frac{1+i}{\sigma_0 z_0}\left(1 + \frac{N_0 v_F a}{2\gamma^{ef}\sqrt{1+\varphi}}\right), \quad \delta_0 = \frac{c}{\sqrt{2\pi\sigma_0\omega}}.$$

Hence, for absorptivity of the metal target we have

$$(8) \quad A_0(t) = A_{01} + (A_{02} - A_{01})\left(1 + \frac{4D_0}{z_0^2}\int_0^t \exp\left(-\frac{T_0}{T(\tau)}\right)d\tau\right)^{-1/2},$$

where A_{01} and A_{02} are the absorptivities of the cleaned metal and the metal contaminated with impurities, respectively, where

$$(9) \quad A_{01} = \frac{c}{\pi\sigma_0\delta_0}, \quad \frac{A_{02} - A_{01}}{A_{01}} = \frac{N_0 v_F a}{\gamma^{ef}}.$$

In the investigated approximation $\delta_0 \ll z_0$, $\gamma^n \ll \gamma^{ef}$ the same result can be obtained, substituting the value of the impurity concentration (3) with respect to the thickness of the skin layer δ in (6),

$$(10) \quad \langle N \rangle = \frac{1}{\delta(\langle N \rangle)}\int_0^{\delta(\langle N \rangle)} N(z,t)\,dz.$$

In the middle infrared range for the majority of metals there is a weak anomalous skin effect [12]. Here instead of formula (6) for the absorptivity of the target it is necessary to use the expression [10, 6]

$$(11) \quad A_0 = A_2 + \frac{2(\gamma^{ef} + \gamma^n)}{\omega_p},$$

where ω_p is the plasma frequency.

Using (3), (10), (11), it is possible to see that for $\delta_0 << z_0$ for the absorptivity the expression is obtained which coincides with respect to form with (8) in which, however, the coefficients A_{01} and A_{02} are related to the microscopic characteristics of the metal differently than by (9). Here, it is not necessary for the condition $\gamma^n << \gamma^{ef}$ to be satisfied, that is, formula (8) in the case of an anomalous skin effect has a broader range of applicability than in the case of the normal skin effect.

Analogously, it is possible to consider the variation of the absorptivity of the target on solution of oxygen in the pure metal. Here, from (5), (10), (11) we obtain the awkward expression which is easy to write in the form of the following interpolation formula:

$$A(t)=\begin{cases} A_{01}+(A_{02}-A_{01})y; & 0\leqslant y\leqslant \frac{\sqrt{\pi}-1}{\sqrt{\pi}}; \\ A_{02}-\frac{A_{02}-A_{01}}{\pi(y+(2-\sqrt{\pi})/\sqrt{\pi})}; & y\geqslant \frac{\sqrt{\pi}-1}{\sqrt{\pi}}; \end{cases} \qquad y=\frac{1}{\delta_0}\sqrt{\frac{\theta}{\pi}}, \tag{12}$$

and the value of θ is presented in (5).

The coefficients A_{01} and A_{02} in formulas (8), (12) essentially depend on the condition of the surface [6]; therefore their theoretical determination is connected with significant difficulties. For our purposes these coefficients can be determined experimentally.

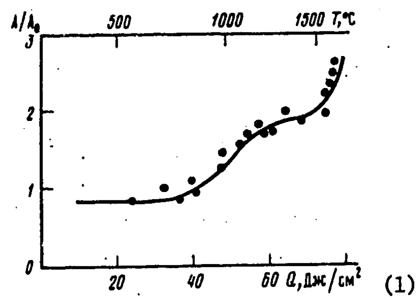

Figure 3. Experimental dependence of the variation of the absorptivity A/A_0 on a wave length of 10.6 microns when heating titanium foil 50 microns thick in the air by the radiation of a neodymium laser (λ=1.06 microns) [6]

Key:

1. joules/cm^2

The described processes of variation of the absorptivity of the metal target can be manifested on heating it in a vacuum (the cleaning effect) or in an inert gas environment (cleaning and saturation). The picture is complicated significantly for laser heating of metals in the air when both diffusion processes which change A_0 and the processes connected with the formation of the oxide film take place simultaneously on the surface of the metal.

The system of equations describing the dynamics of the temperature variation of a thermally thin metal target during laser heating in the air considering oxidation and diffusion phenomena have the form

$$mc_0 \frac{dT}{dt} = PA(x) - P_{\text{пот}}(T), \quad P_{\text{nom}}(T) = s\,[\eta(T - T_{\text{н}}) + \bar{\sigma}\bar{\sigma}_0(T^4 - T_{\text{н}}^4)],$$

$$(13) \quad A(x) = 1 - |R|^2, \quad R = \frac{r_{12}e^{-2i\psi} + r_{23}}{e^{-2i\psi} + r_{12}r_{23}}, \quad r_{23} = \frac{r_{12} - r_{13}}{r_{12}r_{13} - 1}, \quad \psi = \frac{2\pi x}{\lambda}\sqrt{\epsilon},$$

$$\sqrt{\epsilon} = n + i\kappa, \quad r_{12} = \frac{1 - \sqrt{\epsilon}}{1 + \sqrt{\epsilon}}, \quad r_{13} = -1 + \frac{A_0(t)}{2}(1 - i); \quad \frac{dx}{dt} = \frac{d_0}{x} e^{-T_d/T}.$$

In (13) the same notation is used as in references [3, 4].

As $A_0(t)$ in the case of cleaning expression (8) was used, and in the case of saturation, (12). The system of equations (8), (13), and also (12), (13) was solved numerically on a computer. The results of the calculations are presented in Figures 1, 2.

In Fig. 1 we see the absorptivity of a copper target as a function of time when heating it by the emission of a 15.8-watt CO_2-laser. Curve 1 corresponds to the experimental data of [13], and curve 2 was constructed on the basis of solving the system of equations (8), (13).

Fig. 2 shows the theoretical dependence of the variation with time of the absorptivity of a titanium target when heating it in the air by the emission of a 20-watt CO_2-laser. The dotted line gives curve 2 caused only by the absorption mechanism, and curve 1 is calculated considering the growth of the oxide film. Here 1 describes the absorptivity of the titanium considering the diffusion and oxidizing mechanisms, 2 describes only the diffusion mechanism of the variation of the absorptivity.

Fig. 3 shows the relation obtained experimentally in [6] for the variation of the absorptivity of the titanium foil with temperature in the laser heating process. However, the experimental conditions in [6] were such that it is appropriate to talk only about a qualitative comparison of the nature of the relations in Figures 2 and 3.

On the whole, from the comparison of the theoretical and experimental results it is possible to conclude that the model proposed in the article for calculating the diffusion mechanisms of the variation of absorptivity of the metal is applicable for the description of such complex processes as the heating of metal targets in an oxidizing medium.

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