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SCIENCE & TECHNOLOGY
USSR: MATERIALS SCIENCE

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Concept of Development of Die-Forging in USSR

907D0006A Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 8,
Aug 89 pp 2-4

[Article by A. I. Petrov, doctor of technical sciences, general director of the "ENIKmash" Scientific Production Association, I. M. Podrabinnik, department head, "ENIKmash" Production Association, candidate in technical sciences: "The Concept of the Development of Die-Forging in the USSR"; first three paragraphs are an editorial introduction printed in italic]

[Text] The lead article "Progressive Pressure Shaping Equipment for Domestic Machine Building" (issue No. 1, 1989) presented the results of an analysis by ENIKmash of the status of die-forging and press-forging building in this country.

The results of the analysis lead to the conclusion that die-forging and press-forging building in the USSR must be radically restructured.

The editorial board decided to publish (for purposes of discussion) articles prepared at ENIKmash: "The Concept of the Development of Die-Forging in the USSR (cf. below) and "The Concept of the Development of Press-Forging Building in the USSR" (in the next issue) and asks readers to voice their opinions on the issues raised by the authors.

In order to analyze the concept of the development of die-forging (DF) in the USSR, we will isolate the following from a large number of factors:

- the amount and breakdown of the materials to be processed;
- the specialization and concentration of DF;
- production of dies, press molds, and tools;
- the stock of forging equipment.

Status of the Problem

The Amount and Breakdown of Materials to be Processed

Worldwide ferrous metals production rose slightly in the last decade and even experienced a decline in individual branches in developed countries [1]. Steel production in the USSR continues to grow, and the USSR is the world leader in steel smelting.

As Academician N. S. Yenikopolov noted, "The increase in metal production here

is senseless. All developed countries understand that it is more advantageous to develop the production of plastics. They require less energy to manufacture and corrode much more slowly. Processing plastics into goods is much less labor-intensive than manufacturing them from metal. Means of transportation made wholly or partially from plastics require less fuel to move" [2].

In 1986 the USSR smelted 161 million tons of steel; the USA, 75 million tons; Japan, 98 million tons; and the FRG, Great Britain, and France together, 75 million tons. At the same time, the output of domestic machine building and metal processing goods was only 75-80 percent of that of the USA [3]. The metal content of the country's national income (metal product utilization per 1 million rubles of national income per year) exceeded that of the USA and other industrially developed capitalist countries by a factor of 1.2-3.

One of the main reasons for the high metal content of public production in the USSR are the shortcomings of the breakdown of the final product of ferrous metallurgy and of a corresponding breakdown for metal use.

Analysis of data on the amount of materials processed abroad on KPO [forging equipment] shows that the breakdown of materials processed in the USSR is not sufficiently balanced, and this is one of the reasons for large metal losses.

The production of hot stamped blanks and forgings in the USSR surpasses their production in industrially developed countries [4]. Instead of hot stamped blanks and forgings, these countries use parts produced by metal-saving processes such as cold extrusion, powder metallurgy, and plastic pressing and casting, and they also used bent rolled pieces and high-precision steel shapes.

The breakdown of rolled product in the USSR differs from that of industrially developed capitalist countries in its smaller share of rolled plate, tin plate, rolled product with different kinds of anti-corrosion coatings, cold-rolled plate, and other economical kinds of rolled product, as well as its much smaller number of shapes and shape dimensions.

In 1985 rolled plate represented 41.3 percent of the total rolled products in the USSR (66.9 percent in the USA in 1983).

Most of the bar in the USSR is processed on metal cutting stands without the pressure shaping that ensures the shape of the blank will be as close as possible to that of the finished products. Metal cutting with chip removal is still primary in metal processing.

At present 650,000 tons of fasteners are now produced by turning, with a metal utilization factor (KIM) of 0.3-0.4. When these products are made by hot heading the KIM reaches 0.87-0.09, and productivity increases 5-10 times [5].

Total metal consumption and the progressiveness of technology in machine building and metal processing depends greatly on the KIM. In the past 15 years, the KIM in machine building and metal processing has not changed much (0.78-0.79). In the USA the KIM is 0.865.

The KIM in press-forging has not risen in 15 years. It is about 0.79.

The USA has only half the waste chips. The "Metalloemkost" long-term comprehensive program to lower the metal content of national income noted that industry does not use metal products efficiently and that a large amount of waste is formed when it is being processed. The technical level of blank production remains low, and the percentage of low-waste and waste-free technologies used there is small. The specific metal content of many machines and equipment is dropping slowly.

Specialization and Concentration of Die Forging

The USSR State Committee for Statistics reports the results of the work of press forging shops to produce forgings from rolled stock, ingots, and hot-stamped blanks.

The analysis of data on the net cost of 1 ton of good blanks per worker shows that as the size of the enterprise increases, output of blanks per worker rises, while net cost declines.

If the productivity per worker in shops producing up to 100 tons of good forgings from rolled stock is set at one, then it will be 2.8 times larger in shops producing from 501 to 1,000 tons of forgings; 4.48 times higher in shops producing 3,001-5,000; and 42 times higher in shops producing more than 20,000 tons.

However, enterprises producing up to 3,001 tons of forgings from rolled stock account for 94.4 percent of the total.

At enterprises producing forgings from ingots, per-worker productivity in shops with a forging output of 501 to 1,000 tons is 4.45 times higher than in shops producing up to 100 tons; 9.2 times in shops with output above 20,000 tons.

Enterprises producing up to 3,001 tons of forgings from ingots account for about one-third of this group.

Production of hot-stamped blanks per worker in shops of similar size will be 2.6 and 8.36 times higher.

Enterprises producing up to 3,000 tons of hot-stamped blanks account for 76.2 percent of the total.

The net cost of good forgings varies as follows depending on the size of the enterprise. In shops with output to 100 tons the net cost per ton of forgings from rolled stock is 9.6 times higher than in shops with output above 20,000 tons; that of forgings from ingots, 4.41 times higher; that of hot-stamped blanks, 2.16 times higher.

These data show that large enterprises are more efficient than small ones.

Domestic and foreign experience does not support the trend toward the preferential development of large enterprises.

In the USSR the average manufacturing workforce at enterprises producing

forgings from rolled stock is 23; 140 at enterprises producing forgings from ingots; 101 at enterprises producing hot-stamped blanks; and 61 overall for press-forging.

In the USA forging is done primarily at small enterprises. The results of a survey show that a forging enterprise in the USA has an average of 86.6 people.

Enterprises in the USA are classified as follows by number of workers [6]:

Number of workers	Importance of enterprises, percent
1-25	36.9
25-50	22.3
51-100	15.9
101-250	16.6
More than 250	8.3

Almost 60 percent of the enterprises have a workforce up to 50; 91.7 percent up to 250 people.

It is not the level of concentration, but the level of specialization of die forging that is decisive.

This country's die forging industry has a low level of production specialization.

Specialized production facilities produce 3-5 percent of the forgings. According to the TsSU [Central Statistics Agency], 76 enterprises out of 100 manufacture stamped blanks with their own manpower, and 84 out of a 100 manufacture forgings in this way.

Domestic enterprises with a low level of die-forging specialization and concentration manufacture a wide variety of products, which retards the introduction of automated equipment.

The use of automated complexes and line is limited, since the primary condition for cost-effectiveness is a sufficient number of technologically similar products.

The introduction of new kinds of automated equipment, flexible manufacturing modules and systems in multiple-product manufacturing is not worthwhile unless the number of forgings and stamped blanks is sufficient.

The low level of production specialization limits the use of low-waste pressure shaping. High-precision processes presume the use of expensive equipment. It is more difficult and time-consuming to adjust these processes, and their use may be justified only for parts produced in large quantities.

The problem of specialization is directly related to that of rationalizing cooperative relations, product transportation, and the load on railroad transport.

The level of die-forging specialization in highly developed capitalist countries is now much higher than in the USSR. The USA, FRG, and England have

forges producing only one kind of product, e.g. stamping dies. In the USA there is a plant producing 32 million car engine connecting rods a year. There are companies supplying only one kind of forging (piston rings, pinion gears, crankshafts, etc.).

About 200 companies in the USA produce stamped forgings on order, and 45,000 people are employed at the plants of these companies. About 50 companies manufacture stamped forgings for related enterprises; 189 companies (2,800 facilities) specialize in the production of stamped blanks from plate; 550 companies in the USA and Canada are engaged in spring production.

Foreign experience supports the high efficiency of narrowly specialized enterprises producing items by pressure shaping. Companies joined in various associations, unions, and branches are specialized according to manufacturing processes, kinds of equipment used, the nature of the items produced, and other characteristics.

The UkSSR Academy of Sciences Institute for Casting Problems studied technical and economic aspects of increasing the level of specialization in press-forging at 11 production sites of large shops at heavy and transportation machine building enterprises in the Donetsk-Pridneprovsk region. It was determined that increasing the level of specialization through the optimum redistribution of products among production sites alone can result in an additional 24,800 tons of product, which is equivalent to the construction of one large forging shop. The increase in the capacities of these shops requires no extra capital investments for construction work.

These indicators can be achieved with basic equipment already in operation without increasing its operating time. The labor content of producing the total number of forgings drops 13.6 percent, and yield per worker rises 5.9 percent. The net cost of processing the total forgings output drops 11.5 percent [7].

Production of Dies, Press Molds, and Tools

The dies, press molds, and tools that are used vary widely in mass (from a few grams to several tens of tons), overall dimensions (from a few millimeters to 10-12 m long), and the geometry of their components.

The importance of dies in instrument building, for example, is demonstrated by the following data. Mass production of a second-class radio requires a set of processing equipment consisting of about 1,200 dies, 300 press molds, and 1,600 fixtures.

Series production of cars requires about 300 large, 900 medium, and 200 small dies.

The quality of tools for pressure shaping materials to a great extent governs the quality of the parts, as well as the continuity, reliability, and economy of production.

Tools account for an average of 5-8 percent of the net cost of forged blanks, in several cases 40 percent. The main components of the net cost of forgings weighing up to 25 kg are: metal, 45-55 percent; dies, 6-25 percent; wages, 4-

8 percent; the rest, equipment amortization and other expenses.

For this reason, proper organization of die equipment production is very important.

In the USSR a small portion of the dies, press forms, and tools is produced at inter-branch and intra-branch specialized production facilities; while most of them (about 80 percent) are produced by the enterprises' own manpower.

For this reason, the cost of processing equipment and tools in circulation (all kinds, including metal cutting) in several cases reaches 25-35 percent of the equipment's balance cost. At many machine building plants there are 15-20 tool makers for every 100 basic workers. Up to 12-15 percent of the total stock of equipment and up to 4-6 percent of all production area in machine building plants are concentrated in the tool shops.

At most machine building enterprises, tools are usually manufactured in multi-product low-capacity shops on all-purpose equipment using one-of-a-kind or small-quantity technology, often primitively, usually with high labor input and low tool resistance.

The low level of production specialization and concentration determines the fact that all-purpose adjustable dies are produced in small quantities, the automated die design system is almost not being introduced, and it takes a long time to assimilate new products.

The implementation of more progressive KPO [press forging equipment]--finish blanking presses, powder metallurgy, multi-position cold extrusion and heading, isothermal and several other kinds of forgings--is being delayed by problems in manufacturing highly resistant dies in semi-primitive production facilities.

The fact that forging equipment is under-equipped with dies, press molds, and tools and there is a lack of centralized production of these items is delaying the introduction of resource-saving manufacturing processes and the development of KPO export, is limiting the demand for and introduction of progressive automated KPO, and is lowering the productivity and efficiency of the equipment to be developed.

If dies and press molds are manufactured centrally at specialized plants, their production costs drops two- to threefold compared to their cost when they are manufactured at nonspecialized tool shops.

Specialized production facilities for die manufacture use shaping grinding and electro-erosion processing, which make it possible to automate the manufacture of basic die parts. This makes the problem of designing and retooling die production using automated programmable control all the more pressing. All this helps increase die resistance, reduces the frequency with which product must be updated, and increases the efficiency of die forging.

Literature mentions the high level of centralized production of die tooling in the USA. It is pointed out that only 20 percent of machine building plants manufacture tools and process equipment for their own needs.

In terms of prospective demand, the technical and economic significance of organizing centralized production of dies, press molds, and tools is increasing.

The Stock of Forging Equipment

The USSR has the world's largest stock of forging equipment. However, the equipment's productivity is not increasing, the stock is not fully supported by a workforce, and the equipment shift operation factor has not increased for many years.

The change in the amount of materials not process on KPO is slightly ahead of the growth of the equipment stock. Yield per unit of equipment in the stock has risen only 5.4 percent in 10 years. This means that the country's die forging is developing extensively.

The efficiency of equipment in the branches of the machine building complex is higher than that of equipment in non-machine building branches.

In addition, the distribution of equipment among branches in the USSR is less beneficial than in the USA.

The technological breakdown of the equipment stock in the USSR is less progressive than in the usa.

The age breakdown of the KPO stock in the USSR in 1985 deteriorated as compared to that of the stock in 1972, since old equipment is written off slowly.

The percentage of imported equipment is high.

The trend in equipment stock reproduction and in the development of the machine building technological base has changed substantially abroad in the past decade. This development is more and more based not on the quantitative growth of the stock, but in qualitative shifts in its structure and in technical level in the use of progressive technology and high-capacity machines.

This trend has not yet appeared in the USSR.

The progressiveness of the stock of metal processing equipment is evaluated by the importance of the KPO stock in the total stock.

Given the country's current stock of metal cutting equipment, it is incorrect to state the problem of enlarging the KPO stock to increase its shape of the metal processing equipment stock.

The Concept of Development

The concept of the development of die-forging involves the following:

- the stabilization and further decrease in the amounts of steel smelted, an increase in the percentage of plate and other economical kinds of rolled product, an increase in the quality of metal produced for pressure shaping;

- the expansion of the use of low-waste and waste-free hot-stamping technologies and equipment on automatic equipment and lines, cold forging, powder metallurgy, pressing and casting plastics to increase the metal utilization factor, the reduction in the metal content of the national income;
- specialization and concentration of die forging by regions and branches to improve equipment yield and lower the net cost of forgings and forged blanks;
- organization of centralized production of dies, press molds, and tools by region and branch to lower their cost, improve resistance, and create conditions for reducing the frequency of product updating;
- the stabilization and substantial reduction in the stock of forging equipment, improving its branch, technological, and age breakdown, increasing the percentage of progressive equipment in the stock to improve the efficiency with which it is used and to process the necessary amount of materials without additional manpower.

The solution to these problems lies in the sphere of the centralized state policy of USSR Gosplan and Gosstab and the initiative of the regions, branches, and enterprises. All new, modern ways to organize production-- family subcontracting, leasing, and cooperation--are appropriate.

Preliminary proposals for implementing the concept have been developed.

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Activities of Moscow Automotive Institute Described

907D0006B Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 8,
Aug 89 pp 4-7

[Article by A. D. Matveyev, G. A. Navrotskiy, doctors of technical sciences:
"On the Activity of the Institute's Metal Pressure Shaping Machines and
Technology Department"]

[Text] The Moscow Automotive Institute, founded in 1939, trains automobile building engineers in all specialties involved with the design and research of automobiles, engines, and control systems, as well as the technology for casting production, pressure shaping, and cutting. In the institute's early years, all manufacturing specializations, including metal pressure shaping, were combined under the Machine Building Process Department.

The Metal Pressure Shaping Machines and Technology Department was formed in 1943. Until recently it trained mechanical engineers (production and design engineers) under one specialization. Starting with the new school year, the faculty will train engineers in two specializations: "Pressure Shaping" and "Autobody Construction."

The first department head was Prof. A. A. Rybarzh, the well-known specialist in researching the mechanical properties of sheet steel that govern its stampability, formerly the chief metallurgist of the AMO plant and the All-Union Automotive Association.

The instructors' scientific activity is closely related to requests by the automobile manufacturing industry and press forge building. Two scientific areas were initially clearly defined:

- the theory and practice of hot stamping;
- research and calculation of crank presses for cold sheet and hot die forging.

In the 50s the scientific topics were expanded to cover four areas:

- the theory and practice of low-waste hot- and isothermal stamping;
- research on the theory, practice, and tools for cold forgings;
- the theory and practice of cold sheet stamping;
- research, testing, and design analyses on press forging machines, automatic machines, and automation devices.

The first area was established and developed by A. V. Rebelskiy and A. N. Bryukhanov and their students. As early as 1947 they published a book on hot stamping that was highly esteemed by specialists. The book correlates domestic and foreign experience on the process of hot stamping forgings on hammers, presses, horizontal forging machines, and other kinds of equipment and on tool calculation and design engineering. It also contained developments and certain results of the authors' research. It has been translated and published in 11 countries.

Efforts in this area were continued and expanded at the department by I. S. Polyakov, I. L. Akaro, V. I. Perfilov, A. S. Loginov, et al. A great deal of attention is being given to studying and correlating the experience of leading automobile building enterprises--VAZ [Volga Automotive Plant], KamAZ--which has been reflected in two monographs published with the active participation of I. L. Akaro.

The results of scientific research on the theory and practice of hot stamping have been put to use in industry. The process for low-waste stamping of round forgings in closed dies with counterpressure introduced at the auto plant imeni Leninskogo komsomola reduces metal consumption 20 percent and tool expenditures 7-10 percent. The technology based on this process, assimilated at several plants, was transferred to specialists in the Bulgarian People's Republic. The sigmoidal shape developed for the die basin for direct extrusion is being used at the Kuybyshev and Lugansk Automotive Valve Plants and at the Chelyabinsk Automotive Plant. The dies' durability improved by a factor of 1.6-2.5. Various units for automatic die lubrication developed at the faculty have been successfully assimilated at many plants. The cost-effectiveness of using one unit is 10,000-12,000 rubles. The results of research on hot stamping theory and practice have been published in 250 articles, six pamphlets, and two monographs.

Research aimed at developing new isothermal stamping processes was begun at the department in 1968 by Yu. G. Kalpin.

Plastic working regimes have been developed, optimum technological parameters have been found, and a typical induction unit for isothermal strain has been developed for stamping piston forgings. Certain engineering approaches used in the unit are protected by author's certificates. Problems in the theory of semi-hot plastic strain are being developed. In particular, the criteria of the phenomenological theory of failure are being clarified. The Engines Department of the MAMI [Moscow Automotive Institute] has participated in starting up production of almost all pistons for automobile, motorcycle, and some tractor engines by this method. An isothermal stamping section has been set up at the VNIIMotoprom [All-Union Scientific Research Institute for the Motor Building Industry] in Serpukhov, which produces stamped pistons for sports motorcycles. The AZLK [Automotive Plant imeni Leninskogo komsomola], ZIL [Plant imeni Lenina, Gorkiy], KamAZ, and other enterprises are involved in producing stamped pistons in this country.

The country's only monograph on this problem was published in co-authorship with industry personnel, and more than 50 articles have appeared in scientific anthologies and journals.

Research on the theory, practice, and tools for cold forging (KhOSH) began at

the faculty in 1962 on the initiative of I. A. Noritsyn. V. Ya. Shekhter and V. A. Golovin made a great contribution to the development of this research (Technology of Machine Building Materials Department).

The materials from this research has been included into references and published in the form of articles and anthologies of scientific works and scientific-technical journals (about 170 articles).

New technological processes and engineering approaches are protected by author's certificates. The results served as the basis for developing and transferring to industrial application more than 50 new typical processes for cold and semi-hot stamping of blanks for parts with complicated shape made of carbon and alloyed steels and ferrous metal alloys in order to lower metal consumption by at least 3-5 times or more. The economic effect of the application is 1.3 million rubles per year.

Systematic work on the theory and practice of cold sheet stamping has been done at the department since 1953.

The following research topics were developed:

- the theory and improvement of axisymmetric drawing and local shaping;
- the improvement of body stamping processes, investigatory work on using aluminum sheet for body parts;
- studying bending processes and developing recommendations for calculating process parameters;
- studying phenomena limiting the possibilities of sheet shaping under tension;
- finding new methods for testing sheet metals to rate their stampability.

The work of I. A. Noritsyn, "Theoretical Basis of the Continuous Deep Drawing Process," completed as a doctoral dissertation, was a major contribution to the development of the theory of multi-operation axisymmetric drawing.

Later, I. A. Noritsyn's supervised research on the stability of the flanged portion of a blank during axisymmetric drawing on double-action presses. Recommendations were developed for selecting optimum clamping force. The effect of meridional and peripheral curvature on the limit drawing coefficient was studied.

The department began work on improving body stamping processes at the end of the 60s. At this time, at V. Ya. Shekhter's initiative research was done on the use of aluminum-based sheet metals in body stamping.

At the first stage of the work on improving body stamping processes, efforts were directed at researching and developing processes based on stretch forming instead of drawing. The new processes were used basically in the pressing facilities at AZLK and VAZ. The first such development for "Decorative Fender Plating for the 'Moskvich-412' Automobile" was introduced in 1974.

The work on improving body stamping processes was later widened. Together with the pressing facilities at AZLK, VAZ, and the NIITavtopromom [Scientific Research Institute for Automotive Industry Technology], field and laboratory experiments were performed to expand the technological capabilities and

increase the cost-effectiveness of operations to draw parts with complicated shapes and to find new approaches in tool technology and design to increase the form shaping limits so that stamped and welded body units could be replaced by single-piece welded parts.

The author's collective which included faculty members was awarded the 1986 USSR Council of Ministers Award for the work "The Development and Introduction of Advanced Low-Waste Sheet Stamping Processes for Manufacturing Parts for the VAZ Family of Automobiles." The economic effect of the work was 15 million rubles a year.

Work on the use of aluminum alloy sheet for stamping body parts was successfully completed. Exterior body parts (hood panels, door panels) and certain interior fitting parts were produced in field experiments. The basis for further research in this area was established.

The faculty has been systematically researching sheet and bar bending since 1980. The objective of the research is to develop recommendations on calculating manufacturing parameters for bending operations according to different patterns of blank and tool interaction.

The faculty is experimenting on single and multiple pure bending to a large curvature through bending moment along, bending to a complicated shape, which takes place when a sheet crosses the threshold labyrinth of the clamping device for drawing body parts, etc.

Theoretical research on bending uses analytical and numerical methods. Members of the MAMI's Theoretical Mechanics Department and of the USSR Academy of Sciences' NIISI are involved in solving bending problems by numerical methods.

Research on phenomena governing the ability to shape a sheet in tension began at the department in 1965. The focus was on strain localization. It was found that the strain gradient and boundary conditions have a considerable effect on localization development. In many operations (flanging, pipe expansion, etc.) the development of localization may be delayed to such an extent that metal failure takes place first.

The search for new methods of testing sheet metals to rate their stampability resulted from difficulties in determining strain at the point of failure when current testing methods (uniaxial tension, hydrostatic swelling) and from the lack of sign-variable loading methods (tension-compression, multi-directional shear) of sheet samples to evaluate Baushinger's effect. The possibilities of shear testing with tension in a sample plane in the form of a parallelogram and axisymmetric tensions tests on a flat sample while retaining its planarity were studied. The second type of tests has been used for many years in VAZ's pressing facility to evaluate limit deformation during bi-axial tension. It was found that this parameter is one of the major indicators of sheet stampability.

The department has been performing research, tests and design calculations on press forging machines, automated equipment, and automation devices in the following areas since it was organized:

1. Research and calculation of crank presses for hot forging and cold sheet stamping (stamping kinematics, dynamics, strength, rigidity, and precision; analysis of technical data).
2. Research and development of clutch, brake, and connection system calculation methods.
3. Research and development of methods for calculating sheet stamping presses and cold forging and spring-coiling machines and evaluation of their manufacturing application.
4. Research and development of new devices to automate press forging machines.

The department is performing research under items 1 and 2 above at the request of ZIL and AZLK, and the Voronezh and other press forge building plants. This research was initially done by A. A. Ignatov and his students. At the end of the 60s the work was significantly expanded by the efforts for V. I. Vlasov, V. G. Plyugachev, and A. F. Kaplin. The objects of research and development were the main, auxiliary, and transport actuators, power and friction elements in clutches and brakes, and connection system valves. In particular, a new procedure for calculating pressure and strain distribution on the eccentric shafts of heavy presses was developed, formulas were derived for determining the point of application of equivalent eccentric shaft support reactions, and the nature of the distribution of linear pressures on contact surfaces was established.

Recommendations were developed on the selection and calculation of friction and other parts of clutches and brakes, valves, and connection system parts.

At the end of the 70s V. G. Mesyats and other students of V. I. Vlasov studied the energy parameters of hot stamping presses with a five-piece crank-wedge drive with increased (by 20-30 percent) rigidity and high stamping precision indicators. The correlation of the resulting data showed that the use of a main actuator designed in a crank-wedge arrangement permits a 14-27 percent decrease in energy demand at the working stroke section and a 28-30 percent decrease in required torque.

The dynamics of crank presses with a round connecting rods were also studied. It was discovered that the high dynamic stability of the main actuator of these presses provides the basis for recommending its use in presses in which the main shaft turns at increased speed and the inertiality of the moving masses is reduced. Dynamic loads in actuator mechanisms and vertical crank presses and the conditions for their use in manufacturing during stamping division processes were analyzed.

Guidelines for design subdivisions of press forge building enterprises were developed on the basis of this work. They are also being used as a text for students, and V. I. Vlasov's monograph has been published.

After 1977 research on hot-stamping crank presses, particularly on their precision and rigidity, was done under the supervision of V. G. Plyugachev. Together with V. G. Mesyats and other department members, he developed a procedure for calculating hot-stamping presses under eccentric loading,

analyzed anticipated slide block positioning accuracy as a function of structural and rigidity parameters, and proposed the introduction of the concept of "the zone of permissible load shift to a slide block in terms of the accuracy factor." The theory of similitude and dimensionality was used in this analysis.

Research and development of methods for calculating sheet stamping presses and cold forging and spring-coiling machines begun in 1960 was aimed at solving problems of the manufacturing application of machines, kinematics, dynamics, productivity, rigidity, balance, serviceability, automated unit manufacturing quality, vibration elimination, and the improvement of performance properties.

Work is usually done together with plants: the Serpukhov Press Forge Plant, the Azov and Odessa Press Forge Plants, the Barnaul Mechanical Press Plant, the Belebeyev "Avtonormal" Plant; with the Central Planning and Design Office for Press Forge Building (TsBKM) and with the Azov Special Design Office for Press Forge Equipment and Automatic Lines (CKBKO).

The first comprehensive research on the dynamics of a nail-making machine involved the study of stresses that develop in a complicated ribbed bed was performed using modeling theory at the Serpukhov Press Forge Equipment Plant. An operating model of the machine with a acrylic plastic bed was developed and produced. The results were applied at the plant as well as at the Cherepovets Steel Rolling Mill and other hardware enterprises.

A method for calculating torque on the main shaft and other theoretical problems related to an double-impact cold-heading machine with single-piece die were developed together with plants producing press forges and the TsBKM.

The cutting mechanism of the AB1919 multi-position cold-heading machine was studied together with the Azov Press Forge Plant with the participation of TsBKM associates.

The work of Yu. A. Miropolskiy was devoted to the theoretical bases and methods of designing high-speed cold-heading machines and to calculating and building cam actuators. He researched the factors that increase machine productivity. Sound procedures were developed for designing cold forging machines, equations were proposed for calculated the maximum permissible main actuator slide block speed and cold forging machine capacity, and the basis for plotting cyclograms was established.

Equations were derived for calculating the mechanical and dynamic parameters of the laws of motion with different acceleration and braking phases. It was established that cam mechanism accelerations must be optimum and mechanisms must be designed with regard for dynamic forces in order to ensure stable operation and specified mechanism speed. New main actuators for multi-position machines with increased rigidity were developed, researched, and tested. Several studies of crank-elbow cold forging presses, coining presses, and multi-position plate stamping presses were performed together with leading specialists of the Barnaul Plant. A great deal of attention was given to analyzing and synthesizing six-piece crank-elbow actuators. Power regimes and technological capabilities of multi-position machines, as well as the dynamics of actuators and cyclograms of the interaction of working members were studied, and a procedure for plotting an optimum cyclogram were developed.

The technological capabilities of automated spring-coiling machines and their structural features were studied, a classification and diagram of spring coiling methods were developed, the necessary power regimes were defined, a procedure for calculating delivery force was developed, a justification of the number of feed roller pairs was given, and recommendations on machine adjustment were prepared together with the Belebeyev "Avtonormal" Plant.

Research and development of new automation devices for press-forge machines began at the department in the 60s on the initiative and under the supervision of I. A. Noritsyn, and it was performed together with MAMI's Theoretical Mechanics Department. V. I. Vlasov, V. G. Plyugachev, and V. Ya. Shekhter studied this topic.

A theoretical analysis and experimental research were performed on roll, clamshell, and revolver material and blank feed mechanisms. Recommendations were developed on their design and calculation, and their accuracy and applications were evaluated.

The department has published more than 450 works in the area of research on press-forge machines, automated machines, and automated devices, including 18 monographs and handbooks; more than 60 author's certificates for inventions have been obtained.

Research on this topic has been applied in industry. The economic effect of this application exceeded 10 million rubles.

The department's laboratory is equipped with modern equipment, testing machines, devices for researching machines and technologies, and computers. Facilities for training engineers in the specialization of "Autobody Construction" are being created.

Under assignments from the USSR State Committee on Science and Technology, department members have for many years been participating in the work of the State Commission on Testing and Acceptance of New Models of Press-Forge Machines and Automatic Machines.

The department has trained 92 scientists, many of whom now head departments and scientific collectives.

Department members have published about 25 books.

The department collective continues to train engineers and scientific personnel with regard for new requirements of science and production technology and to improve the quality and reliability of automobiles and agricultural equipment produced by enterprises in this branch of machine building.

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New Process for Multi-Pass Cold Forging of Parts With Eccentric Head

907D0006C Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 8,
Aug 89 pp 7-9

[Article by Yu. A. Miropolskiy, candidate in technical sciences, Ye. V. Koloskov under the heading "Forging and Die Forging Technology": "A New Process for Multi-Pass Cold Forging of Parts with an Eccentric Head"]

[Text] Parts like bolts with heads shifted relative to their stems and different kinds of cams are now produced either by cutting with a low metal utilization factor or by multi-pass cold die forging, including cutting the cam according to a contour in the final stage, also with significant metal waste and, at the same time, with unsatisfactory trimming die durability.

The Moscow Automotive Institute has developed and studied a new process for multi-pass cold die forging of diesel engine fuel pump drive cams, including the following passes: upsetting the cut blank and direct extrusion of the cavity; preliminary heading of the head shifted relative to the axis of the hollow cavity with a sloped bottom plane, final heading of the eccentric head and extrusion in its recess, and broaching of the hole.

This stamping alternative was chosen because when a cam with a bottom plane parallel to the top one is being headed, a closed cavity forms with air and friction develops, which keeps the metal from flowing into the cavity so that this corner is not filled with metal. Corner filling is satisfactory with stamping according to the metal developed.

A design diagram was developed to calculate the energy parameters of the process and to determine the slope of the bottom plane of the eccentric head in the second forging pass, and the power balance method was used. This method uses the mechanically permissible field of rates at the strain source which can approximate the active introduction of minimizing parameters. When the problem is being solved, it is assumed that the circumferential rate constituent is zero, while the head remains cylindrical.

The mechanically permissible rate field can be described by the following functions:

- the radial rate constituent u_ρ

$$u_\rho = (v \cos \alpha \rho) / 2(h_0 \cos \alpha + \rho \cos \phi \sin \alpha);$$

- the axial rate constituent u_z

$$u_z = (-v \cos \alpha)(2h_0 \cos \alpha + \rho \cos \alpha \sin \alpha)(z)/2(h_0 \cos \alpha + \rho \cos \phi \sin \alpha)^2,$$

where α is the slope of the die's bottom plane; ρ , z , ϕ are running coordinates; h_0 is the height of the head at the center of the metal flow; v , strain rate.

It can be shown that the selected rate field satisfies all boundary conditions and the condition of constant volume. Let us use these relations to calculate the components of the strain rate tensor and then their intensity.

The power of plastic strain at the center equals

$$N_i = \int_0^{2\pi} \int_0^R \int_0^h \sigma_i \epsilon_i \rho \, d\phi \, d\rho \, dz,$$

where σ_i is the stress of metal flow at the subject point, determined according to the strength curve for the specified material; h , the current height of the head; ρ , ϕ , the coordinates of the point at the strain center;

$R = a \cos \phi + \sqrt{a^2 + \cos^2 \phi - a^2 + r^2}$; a is the shift of the center of metal flow relative to the center of the head; r , the radius of the blank.

Metal hardening is taken into account with the well-known hardening curve equation

$$\sigma_i = \sigma_B + A \epsilon_i^n,$$

according to the average accumulated strain

$$\epsilon_i = |\ln h/h_0|.$$

The power of shear forces on the boundary between the head and the stem and contact friction on the boundary between the head and the die

$$N_M = \int_0^{2\pi} \left[\int_0^{R_3} (\theta_i/\sqrt{3}) \cos \beta (u_\rho + u_z \operatorname{tg} \beta) \rho \, d\rho \, d\phi + \int_{R_3}^R \mu \sigma_i \cos \beta (u_\rho + u_z \operatorname{tg} \beta) \rho \, d\rho \, d\phi \right],$$

where u_z is set at $z=h$; $\beta = \arctg(\cos \phi \operatorname{tg} \alpha)$;

$$R_3 = (a-b)^2 \cos \phi + \sqrt{(a-b)^2 \cos^2 \phi - (a-b)^2 + r^2}.$$

The power of contact friction forces on the boundary between the head and the punch is determined with the equation

$$N_p = \int_0^{2\pi} \int_0^R \mu \sigma_i u_{\rho\rho} \rho \, d\rho \, d\phi.$$

On the assumption that total strain power equals the sum, i.e.

$$N = N_i + N_M + N_p,$$

stamping force equals

$$P = N/v.$$

Power was calculated numerically on a YeS 1045 computer. The value of a corresponding to the minimum total strain power was calculated. Integrals were calculated by trapezoidal method. The process was repeated with an interval of $\Delta h = S/10$ (where S is the total punch stroke during heading). After each interval the maximum R^+ (at $\phi=0$), minimum R^- (at $\phi=\pi$), and average $R_{av} = (R^+ + R^-)/2$, the radius of the head, were found. Calculations were repeated, and the results were used to plot curves relating strain force to punch stroke at different die bottom plane slopes at the second stamping pass. These curves show that strain power and force increase as the slope of the die diminishes, but as calculations and experiments show, this increase is negligible. The graph [not reproduced] presents the curves relating the increase in head eccentricity relative to the blank axis as a function of punch stroke at different die bottom plane slopes. If the slope is greater than 12° , as the experiment shows, eccentricity no longer increases, but there is a vertical head shear, and shrinkage cavities form at the top of the cylindrical cavity. A further increase in the slope of the die's bottom plane therefore makes no sense.

Figures 5 and 6 [not reproduced] show eccentricity as a function of the slope of the die for different friction coefficients and as a function of the friction coefficient at different bottom plane slopes.

The optimum value of the slope of the head's bottom plane is determined on the assumption that the volume of the metal in the second and third stamping passes to the left of the plane passing through the center line is equal. The experiment shows that this plane remains almost in the same place.

Let us write the equality of volumes:

$$V_1 = V_2;$$

$$V_1 = F_{sec} H_K; \quad V_2 = f(b);$$

$$h = h_0 = x \operatorname{tg} \alpha; \quad y^2 + (x-b)^2 = R_1^2;$$

$$2 \int_0^{(b+R_1)} \int_0^{\sqrt{R_1^2 - (x-b)^2}} \int_0^{h_0 + x \operatorname{tg} \alpha} dx \, dy \, dz = F_{sec} h_{con}.$$

By solving this equation relative to α , we obtain the optimum slope of the bottom plane of the die, which equals about 7° provided that strain power is

minimum and head eccentricity is maximum.

The process was tested experimentally on a 1,000-kN hydraulic testing machine and a 4,000-kN cold extrusion machine. The blank material was steel 20Kh.

The first process pass was the most loaded from the standpoint of pressures on the tool. Pressures during blank upsetting and direct cavity extrusion are 1,800 MPa, which is far below permissible (2,500 MPa) for hardened tool steels. Pressures in the remaining passes do not exceed 700-750 MPa, which indicates the stability of the process and the rather high durability of the tool.

The process has been developed for a multi-position vertical cold extrusion press designed by the Barnaul Mechanical Press Plant. It is being introduced at the Yaroslavl Diesel Equipment Plant.

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Possibility of Improving Laser Hardening Efficiency by Additional Plastic Strain

907D0004A Kishinev ELEKTRONNAYA OBRABOTKA MATERIALOV in Russian, Vol 55 No 3, May-Jun 89 pp 16-18

[Article by G. I. Brover, V. N. Varavka, Rostov-na-Donu: "The Possibility of Improving Laser Hardening Efficiency by Additional Plastic Strain"]

[Text] Since in most cases traditional heat treatment methods, including heating and cooling operations, do not provide the required set of properties in the materials, the interest in combined methods of thermomechanical treatment (TMT), which combine heat treatment operations with the effects of external factors, is unquestionable.

The objective of this work is to explore the possibility of increasing the efficiency of laser hardening of tool steels U10, U12, Kh12M, R6M5 using surface plastic strain (SPS). Two procedures were used: laser hardening of the steels following by vibropercussive treatment following by high-temperature laser heating in the TMP cycle.

Vibration treatment was performed on a UVCh 4 x 10 unit, the working media were hardened steel balls 8 mm in diameter. Laser hardening was done out on a Kvant-16 industrial laser, and the metal's microstructure was analyzed using a Neofot-21 microscope. Hardness was measured on a PMT-3 instrument with a load of 0.49 N. Radiographic studies were performed with a DRON-0.5 diffractometer. Exposures were taken in $F_{k\alpha}$ radiation.

Studies of the structure and properties of steels subjected to laser hardening and vibropercussive treatment showed that the hardness of the metal's surface layers is 10-15 percent higher than that in a laser-hardened state. One of the unique features of the process is that when this treatment procedure is used, solid solutions which form as a results of high-speed laser processing and are supersaturated with carbon and alloying elements are strained. The increase in hardness is attributable to the partial conversion of austenite into martensite, as well as by the fact that when solid solutions are cold-work hardened, the martensite breaks down, as a result of which dispersed, evenly distributed carbides particles are released [1]. The increased density of defects introduced into the martensite and austenite structures during SPS help accelerate these processes. In radiographic studies, these structural changes are seen in the shift in austenite reflexes toward small angles of reflection, which is related to the transformation of low-carbon austenite

into martensite and in the narrowing of diffraction line (211) M, and in its shift toward high angles of reflections (table) because of the partial disintegration of the martensite and the release of carbides.

Results of Radiographic Analysis of Steel U12 after Various Hardening Methods

Processing conditions	Angle of reflection, 2θ , deg	Width of diffraction line (211)M, deg
Volume hardening and tempering	111.5	37
Vibropercussive treatment	111.65	14
Laser hardening	110.85	46
Laser hardening and vibropercussive treatment	111.15	34
Vibropercussive treatment and laser hardening, (TMP)	110.85	42

If the steel hardening process, i.e. laser hardening of pre-strained specimens, is carried out in the TMT cycle, there is a further increase in metal hardness to 12-13.5 GPa, which is 15-20 percent higher than for laser hardened steel with out SPS. The level of hardening achieved with this processing procedure is apparently attributable to the following:

- High density of defects in the crystal structure of the basic phases because the austenite inherits a defective α -phase structure produced during SPS at high heating rates [1, 2];
- The presence of dispersed carbides released during preliminary plastic strain;
- The beneficial combination of matrix saturation by carbon and alloying elements and the uneven concentration which develops during partial carbide dissolution during laser heating;
- The formation of a finer-grained austenite because of the increased number of phase centers, which are structural imperfections retained by the beginning of phase transformations.

Thus the basic steel hardening mechanisms in this case are dislocation, solid solution, dispersion, and grain boundary. The result is a structural state with high strength and an acceptable level of metal ductility indicators, which is expressed in a significant reduction in crack formation in irradiated spaces.

One of the advantages of carrying out the tool steel hardening process in the TMT cycle is that the hardened layer is 1.2-1.3 times deeper than that after laser hardening without SPS. The drop in the temperature of the α - γ transformation in high-speed hardening of plastically strained steels promotes this [2, 3].

In addition to achieving a deep hardened layer and higher metal hardness, combined processing of tool steels increases the resistance of primary phases to loss of strength during heating above that for laser hardened metal at 50-70°C, as well as to greater wear resistance thanks to the presence of a large amount of solid dispersed carbides and a reduction in the friction coefficient of the hardened surfaces [4]. This is because the metal hardened from a

molten state is highly textured, which is expressed during radiographic structural studies in the anomalous growth in the intensity of reflex (200) A for steels U12 and Kh12M or reflex (200) M for steel R65M. It was determined that the direction of crystallization is oriented advantageously in relation to the friction plane. Multiple release of dispersed carbides in the surface layers of the irradiated steel during additional tempering or during use of a heating tool also helps lower the friction coefficient.

Thus the use of these procedures for combined hardening of tool steels permits the improvement of their basic performance properties, which is attributable to positive structural changes in the processed metal, increased defect density in the crystal structure of the basic phases, the presence of a large number of dispersed, evenly distributed carbides, and the development of texture in the surface layers of the metal during laser hardening from a molten state. These effects are most clearly seen in processing tool steels in a TMT cycle with laser heating.

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Laser Treatment of High-Speed Steel R6M5

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[Article by T. P. Chuprova, A. M. Barnshteyn, M. N. Kryanina, V. P. Polukhin,
Moscow: "Laser Treatment of High-Speed Steel R6M5"]

[Text] Research on laser surface hardening of high-speed steels is an important part of work dedicated to the hardening of tools using concentrated energy sources [1-3]. This is because standard (volume) heat treatment now used often does not ensure the required tool properties [3]. The effect of a laser pulse on the structure and properties of high speed steels, as a result of which the material's hardness, rust-resistance, and wear resistance increased, has been studied [1, 2]. It is natural to expect changes in the nature of steel hardening during continuous laser treatment as compared to pulse treatment, if only because, in addition to other factors, the interaction of the steel's surface layer and the laser beam changes 10-100 times. The goal of this article is to select the material's initial state and laser treatment conditions that ensure maximum surface hardening and tool life.

Research Material and Method. Samples of steel R6M5 measuring $6 \times 6 \times 25 \text{ mm}^3$ and $10 \times 10 \times 55 \text{ mm}^3$ were studied after different heat treatments: 1) annealing ($840-860^\circ\text{C}$, cooling to $720-750^\circ\text{C}$, 4 hr, air cooling); 2) annealing + hardening ($1220-1230^\circ\text{C}$ (heating to $800-850^\circ\text{C}$, 5 min, in oil); 3 - annealing + hardening + tempering ($540-560^\circ\text{C}$, 1 hr, 3 times or once at 350°C , 1 hr). The R6M5 steel was laser processed using an LT continuous CO_2 laser in air with individual tracks at a laser energy density of $14-50 \text{ MJ/m}^2$. A light-absorbing coating (TU-6-10-1308-78) was applied to the samples' surfaces. Heat treatment after the laser treatment consisted of tempering at $560-630^\circ\text{C}$ 1-3 times.

The phase composition of the steel was studied by radiography with a DRON-1.5 diffractometer ($\text{Fe}_{\text{K}\alpha}$ -radiation) and metallographically with "Neofot-21," "Epikvant," and Kvantimet-720" units. Hardness was measured on TK2M and PMT-3 instruments. The steel's wear resistance before and after laser treatment was determined according to Brinell in tests on abrasive wear in a "B" machine [4]. The results of measurements were processed on an SM-4 computer using mathematical statistics methods.

Results of the Experiment and Discussion. Over the entire range of energy

densities used, laser treatment led to the melting of the steel R6M5 surface layer (table 1). The melted zone and the heated zone in the solid state above temperature A_c are characterized by high hardness; the rest of the laser-affected zone, which had withstood heating to temperatures corresponding to high tempering, is characterized by reduced etchability compared to the rest of the material. Laser treatment of samples with initially hardened structure in all cases led to the formation of cracks running perpendicular to the direction of beam travel, which is explained by the high level and unfavorable distribution of hardening stresses. This form of treatment was later disregarded. No other initial states exhibited crack formation upon exposure to the laser.

Table 1. The Effect of Laser Treatment (LT) on the Geometric Parameters and Hardness of the Laser-Affected Zone (LAZ) and the Laser-hardened Zone (LHZ)

Initial state	LO	Energy density, MJ/m ²	Depth		LHZ width, mm, (± 0.5)	Hardness HRC, after LT
			LAZ	LHZ		
Annealing, HRC=16.8	mlt*	33 \pm 0.7	1	0.4	4	39
	smf**	17 \pm 1	0.55	0.25	2	57
Hardening+ annealing 350°C, HRC=63	mlt	22 \pm 0.5	1.8	0.8	6	64
	smf	11 \pm 0.7	1	0.57	3	67
Hardening+ annealing 560°C, HRC=63.4	mlt	27 \pm 0.6	1.6	0.9	5	64
	smf	17 \pm 1	0.5	0.2	2	67

*mlt, treatment with surface melting;

**smf, treatment with surface micro-melting

The increase in the laser energy density naturally led to an increase in the depth of the laser-hardened zone (cf. table 1). The dimensions of the LHZ are maximum in samples pre-hardened and tempered at 350-360°C; the laser-hardened zone in samples in an initial annealed state was much smaller. Laser treatment in all cases increases the steel's hardness (cf. table 1), but the hardness produced in pre-annealed samples was far lower than that corresponding to the material's hardened state.

Laser treatment of steel R6M5 in an optimum initial state developed as a result of hardening and tempering at 350-360°C for 1 hr at an energy density of 14-50 MJ/m² increases hardness within the laser-hardened zone compared to the initial state. Furthermore, there is a "dip" in hardness in the tempering zone. Optimum laser exposure, 34 \pm 3 MJ/m² produced maximum hardness and maximum laser-hardened zone depth with a minimum "dip" in hardness in the tempering zone.

The structure of steel R6M5 after optimum heat treatment (hardening and tempering) consisted of martensite, residual austenite, and carbides (table 2). The bands of carbides formed basically from large ($>4 \mu$) Me₆C lebedurite (primary) carbides whose dimensions and location along the boundaries and at the interfaces of grains impairs tools' technological properties [3]. Carbide

particles in the laser-hardened zone exposed to laser radiation and heated to temperatures above $A_{c3}-T_m$ dissolved, alloying the solid solution (table 2), whose subsequent rapid hardened ensures steel hardening. The dissolution of most of the carbides in the laser-hardened zone and the increase in the percentage of austenite stable at room temperature (table 2) justifies tempering to break down the residual austenite and age-harden the martensite, although laser-hardened itself increases hardness compared to volume hardening (table 1).

Table 2. The Effect of Laser Treatment on the Phase Composition of Steel R6M5.

Phase composition, wt.%	After volume hardening and tempering 560°C, 1 hr 3 times	After laser treatment with energy density				
		51	34	25	21	17
Martensite	82	49	58	60	79	72
Residual austenite	3	45	39	33	20	25
Carbides	25	6	3	7	1	3

After laser-hardened samples were tempered three times for 1 hr at 540-630°C, they had a hardness 2-5 HRC higher than after conventional (standard) heat treatment. The fact that hardness remained elevated (>60 HRC) to 600°C indicates that the laser-hardened layer has a heat resistance 40-50°C higher than in volume hardening.

Thus laser treatment of high-speed steel R6M5 hardened and tempered at 350-560°C at energy densities of $34 \pm 3 \text{ MJ/m}^2$ increases red hardness and hardness and simultaneously eliminates large embrittling carbide particles.

Rapid abrasive wear tests in rigorous dry friction conditions using boron carbide powder (HV-53 GPa) as the abrasive showed a 20-25 percent increase in wear resistance as a result of laser treatment compared to traditional thermal hardening. One might naturally expect greater differences in the wear resistance of laser- and volume-hardened high-speed steel R6M5 during "metal-against-metal" dry friction tests simulating the use of a cutting tool.

Analysis of operating failures along the cutting edges of an edge-planer at the Khartsyzck Tube Mill led to the conclusion that the basic causes of tool breakdown are random impacts which cause edge failure, as well as the overheating, softening, and increased wear on the working edge of the cutter. Treating edge-planer cutting surfaces at an energy density of $32 \pm 1 \text{ MJ/m}^2$ led to the formation of a laser-hardened zone about 500 μ deep and caused a complicated change in the surface macrorelief (when the cutting edge was at a distance equal to no more than 20 percent of the depth of the laser-hardened layer). Field tests of a lot of cutters hardened according to this procedure shows a 2.5-time increase in the tool's resistances compared to the current technology. The increase in the heat resistance of steel R6M5 as a result of laser hardening provides certain room for increasing cutting speed in beveling the edges of plates for large-diameter gas pipes. Higher edge-plane productivity will make it possible to increase output and improve the quality

of gas piping.

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Development of Manufacturing Processes, Machine Designs for Multi-Position Cold Forging

907D0006D Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 8, Aug 89 pp 32-34

[Article by Yu. A. Miropolskiy, candidate in technical sciences: "Development of Manufacturing Processes and Machine Designs for Multi-Position Cold Forging"]

[Text] Since the constantly growing scale of machine, machine tool, and instrument production and the increasing requirements for their strength and reliability are highly dependent on the scale of production and the strength and reliability of fasteners, it is single- and multi-position cold forging machines that are designed to satisfy the country's demand for these parts. The unique features of fastener production processes and the level of development of parameters govern the quality of machine designs.

At the same time, domestic and foreign experience shows that these machines can be also used to produce semi-finished products and finished products for machine building, which helps increase the metal utilization factor and labor productivity.

When developing and improving cold forging technology and the parameters and design of machines, one must therefore keep in mind their use to manufacture parts for general machine building purposes.

The basic requirements for appearance, the degree of precision, and the mechanical properties of hex-head bolts and Allen head screws were established by standards according to which shanked fasteners must have well formed hexagonal edges, an even face, and a bevel at the end of the shank. They must also have guaranteed mechanical properties ($\sigma_B \geq 300-1,400$ MPa depending on the class strength from 3.6 to 14.9). The most widely used are shank parts in strength classes from 6.6 to 6.9 ($\sigma_B = 600-800$ MPa) and 8.8 ($\sigma_B = 800-1,000$ MPa). To meet these requirements when traditional processes including single and double shank extrusion are used, the stamped items are usually hardened by heat treatment.

The use of new four-pass stamping processes offers greater prospects for the manufacture of both types of items. To obtain an item with equivalent strength over the cross section that is ready for use without additional heat treatment, to increase shank strength and reduce head hardening and, consequently, to reduce loads on punches and increase their durability, a

blank diameter close that of the head of the finished item is used, while the shank and the head are formed by triple extrusion with internal hexahedron drifting or trimming along the contour of the outer hexahedron. Studies showed that this process results in products with equivalent head and shank strength (the difference is no more than 3 percent) and makes it possible to simultaneously decrease head cold working and, consequently, to increase tool durability at the final die forging position. Medium-carbon annealed and calibrated coiled steel wire was die forged on a four-position machine [1]. The hardness of the resulting Allen head screws is 21-23 HRC_e, $\sigma_B=829-927$ MPa, which corresponds to a strength class of 8.8 (without additional hardening heat treatment). The durability of punches for extruding the hexagonal clearance increases substantially. This increase is promoted not only by less cold working but to a great extent by the more uniform (almost double) distribution of forces over the die forging positions, which reduces slide block skew in the guides and increases die forging accuracy.

By analogy to this process, a similar process was developed to manufacture hex-head bolts. Total strain during the shaping of the shank to cut the thread is $e=0.58$, which corresponds to the true stress of 868 MPa; during heading, it is $e=0.53$, which corresponds to a stress of 832 MPa. Consequently, the resulting bolt of almost equivalent strength corresponds to strength class 8.8 and does not require additional hardening heat treatment.

A four-position process has been developed to produce spindles of brass annealed wire on a multi-position equipment. This process includes upsetting a cut blank and formation of a bevel on both faces, double direct extrusion of the shank and heading of the flange, extrusion of the square, upsetting of the shank and heading of the flange with extrusion of the groove and heading of the end square.

Ferrous metal shank parts with a deep (to 10 d) cavity are usually manufactured by cutting with a large amount (to 60 percent) of metal waste to chips. However, extrusion may also be successfully used [3].

Short items suitable for processing on multi-position machines from wire or bar or from individual blanks are also of interest. These are item of relatively complicated, "unconventional" geometric shape. Because of the presence of an acute-angled two-sided truncated cone, automotive parts such as a brass or steel cone clutch were until recently made by cutting. They are stamped in two stages in four passes on a multi-position press: First a cylindrical semi-finished product with a two-sided conical cavity and a connecting piece are formed, then the connecting piece is removed; in the second stage the outer surface of the semi-finished product is reformed and holes are expanded. Shaping force is applied to the faces of the product; end force is applied from the hole. The blank is swaged and the connecting piece is simultaneously broken through.

To produce similar parts in individual cases, the semi-finished product is annealed between operations, which predetermines the need to equip the machines with a charge hopper.

Different machine building and metal processing branches make extensive use of parts with hollow and solid shanks and elongated non-round flanges, e.g. a steel "section housing." The process for die forging this part has the

following unique features.

A truncated cone with angle α at the apex is formed from a hollow cylindrical blank at position I [figure not reproduced]. The conical section of the blank is divided into two parts to depth h_3 at position II. Angle β between the divided symmetrical sections ensures proper metal flow in both directions. Radius R is provided to prevent creasing on the blank in the tool. The flange is pre-formed at position III by combining the upsetting and bending processes. The material, undergoing plastic strain, flows in both directions and forms two symmetric flange tags of length L , height h_4 , and width B_2 . $h_4 < h_3$. In final pass IV, an elongated flange of length L_2 , height $h_5 < h_4$, and width B_3 is finally formed.

A five-pass process has been developed to cold-forged a diesel engine pump piston with a complicated geometric shape. It is performed on calibrated steel wire or bar. The blank is cut by a knife, and in the forging pass it is calibrated to make its faces parallel and to obtain a bevel on both sides. Because it is relatively thin-walled, the semi-finished product is annealed after the third pass, and then it is further shaped.

The development of cold forging processes requires that the parameters and design of horizontal multi-position machines and vertical presses and the methodology by which they are calculated and designed be improved.

From this standpoint, the experience of leading companies in the USA, FRG, Switzerland, and Japan is interesting. The goals adopted by domestic plants and foreign companies to improve the parameters of technical data and the designs of machines in general can be stated as follows.

One of the basic goals is to develop base models of machines of different dimensional series according to a single mechanical diagram with a bed and other base parts. This approach would permit installation of machinery and additional devices with different structural treatments and purposes depending on the purpose of the machines. This approach also makes it possible not only to satisfy user requirements, but also to develop machine modifications equipped according to the user's requirements with devices for facing and chamfering shank parts, to cut threading, knurling, oil grooves, etc.: charge hoppers and oscillating conveyors to die forge parts with intermediate treatment of the semi-finished item (annealing, heating; mechanisms transferring the product between forging positions for items of different length and configurations turning them to the required angle (90 and 180°) or without turning, etc. The machines' actual output can be substantially increased by reducing and eliminating downtime during operation (downtime often exceeds 25-30 percent of operating time). To do this, the machines are equipped, for example, with a rapid tool adjustment system including several working tool kits to forge parts of different dimensional series, diagnostic systems and systems monitoring product length, manufacturing forces and ejection force, moments of opening and closing of the transfer mechanism grips. The machinery's mechanical parameters are monitored and adjusted, and sound-optical systems are used to indicate the cause for machine stoppage when the safety devices installed in almost all machine mechanisms are triggered.

The use of devices equipped with robots to replace tools is an efficient way to make economical use of machines in small-series production.

Working conditions and safety are improved by device for dynamic balancing of moving masses which reduce machine vibrations and increase mechanism operating reliability. The use of noise-absorbing housings and cabins which lower the noise level to permissible health norms is effective. When manufacturing operations are performed, heated oil vapors and air are removed by special collectors and electrostatic oil separators built into the machines.

A comprehensive approach to the development of machines which meet modern technical requirements determines the need to improve not only structures, but also the parameters of the machines and the methodology by which they are calculated and designed.

In selecting the diameter of the blank and the rated force of the machine, one should be guided not by data from the best foreign companies, which are often contradictory ($400 \leq \sigma_B \leq 750$ MPa) regardless of the efficiency of machine design, but by the requirements for the strength of the most common products and typical processes which ensure that these requirements will be met with minimum labor costs. When establishing the mechanical properties and diameter of the initial blank, one may use the function $\sigma_B \leq \sigma_s^* / (1 + 1.6e)$, where σ_B , σ_s^* are the ultimate rupture strength of the initial calibrated blank and the ultimate tensile strength of the finished product; e , the total relative strain in the blank when the product is die forged. When $\sigma_s^* m$, which depends on the strength class, and e , which corresponds to the cost-effectiveness of the tool's durability, are known, it is easy to find the σ_B of the initial calibrated metal.

Noting the benefits of developing and using devices for dynamic balancing of moving masses, one must first decrease the influences of sources of increased machine vibration and primarily reduce the mass of the moving parts of the main actuator and impact loads when spaces in the kinematic pairs of this mechanism are redistributed. Consequently one must eliminate sources of vibration as much as possible and then develop ways to prevent them. One must take into account that the portion of the mass of the slide block in kinetic energy accumulated by the mechanism by the beginning of the working stroke is insignificantly small. By minimizing the mass of the slide block and the required length of its stroke and fitting the mechanism with a device to select clearances, one can considerably diminish vibration sources--inertial and pulse forces--and, as a result, decrease overall dimensions, simplify design, and increase the effectiveness of the dynamic balancing device. The minimum required slide block stroke may be calculated according to the relation

$$S \geq l_{pr} + 2A/3$$

(l_{pr} is the length of the product's shank; A , the distance between the shaping dies).

An important parameter of machines, the rigidity of the main actuator power system, influences not only the precision of the products' height, but also other indicators of machine operating reliability: vibration resistance, tool durability, energy expenditures, etc. Recommendations on standardizing the upper and lower rigidity limits must be provided not only for automatic machines, but also for other types of crank press forging machines. The lower

limit (minimum) should be increased by 15-20 percent, not only to ensure the specified product precision, but also to affect the residual layer of lubricating material in kinematic pairs, which is not removed during operation at the specified speed. The upper rigidity limit should also be restricted, since a high upper rigidity limit leads to unjustified metal expenditures.

One may make the following conclusions about the development of processes and the design of multi-pass cold forging machines:

- complication of the geometric form of the items to be forged and the increase in strength and precision requirements, the expansion of the variety of metals and alloys that can be processed by annealing blanks at the initial and intermediate stages of die forging;
- scientifically valid choice of basic parameters for machines according to requirements for finished products and for processes given an increase in requirements for documentation defining the rigidity of the power system, vibrations, and noise level and their precise calculation at the machine design stage. Special attention should be given to diminishing the influence of sources of increased vibration, noise, etc. as well as additional devices to eliminate them;
- the use of modular design principles to develop machines according to a unified mechanical design with identical base parts (bed and main shaft) which make it possible to develop and improve mechanism design with regard for the changing requirements of technology while reducing the design's complexity and labor content;
- the production of machine models equipped according to user requirements with diagnostics and monitoring devices and with programmable tool replacement using robots and manipulators, as well as devices to remove heated oil vapors and sound-insulating cabins and housings;
- to manufacture cold forging parts with initial or intermediate blank annealing, multi-position specialized and special machines equipped not only with blank cutting and handling mechanisms, but also with charge hoppers with blank delivery distributed to the forging positions.

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Automatic Cold Upsetting Lines for Bolts, Nuts

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[Article by L. S. Kokhan, A. G. Navrotskiy, candidates in technical sciences:
"Automatic Cold Upsetting Lines for Bolts and Nuts"]

[Text] Shops manufacturing fasteners are equipped with automatic lines based on: all-purpose press forges, machine tools, and special assemblies; single-position upsetting machines; multi- and single-position upsetting machines; and multi-position upsetting machines and combined machines.

We now have experience operating rotary automatic complexes or single- or multi-product lines, and complexes based on automatic presses or presses and industrial robots have been developed.

Depending to purpose, automatic lines are divided into lines for production of bolts, screws, wood screws, studs, nuts, etc.

When automatic lines and complexes are developed, fastener production divisions are created: blanking, shaping, dividing, and roll-threading equipment; thermal and other equipment used to give fasteners certain properties depending on technical requirements; bolt-nut and screw-washer assembly devices; rust treatment, weighing and packaging devices, etc. to give the goods a marketable appearance and facilitate transportation.

However, sometimes buyer requirements can be satisfied by creating automatic lines with an incomplete cycle: lines consisting of blanking, shaping, dividing, and roll-threading equipment and special units for rust treatment and packaging. These lines are used to manufacture fasteners which are not usually heat treated.

The basic types of automatic line layout are: linear, L-, and U-shaped. The most common is linear, i.e. line equipment is laid out in series. This line occupies the least production space, is easy to adjust, readjust, service, and repair, and best adheres to safety regulations.

In an L-shaped layout, the line is less stretched out, several machines can be serviced at once, but access to the remaining assemblies is difficult.

In a U-shaped arrangement, it is difficult to adhere to safety regulations since pieces of equipment are close to one another.

All automatic lines are either serial or parallel depending on the blank handling method. Serial automatic lines are in turn divided into lines with rigid relationships between operations with a supply of blanks between operations and without it. Parallel automatic lines are linked by flexible relationships and have a supply of blanks between operations. Modern automatic hardware lines are basically serial, with individual sections having identical equipment arranged in parallel. This combination of connections is explained by the discrepancies between the capacities of individual machines in the automatic lines and sometimes by differences in tool durability.

Statistical research reveals that the area occupied by a piece of manufacturing equipment which is not part of an automated line, together with aisles, is 8-12 m² for nail shops. For bolt, screw, stud, and nut shops, the area per piece of manufacturing equipment depends on the size of the fastener: for M8, 8-12 m²; for M10-M16, 20 m²; for M20-M30, 25-40 m².

Areas per unit of manufacturing equipment included into automatic lines increases and is: for fasteners to M6, 20 m²; to M20, 40 m²; for larger fasteners, above 50 m².

The makeup of an automatic bolt production line depends on the product material and the method of manufacture. The "Krasnaya Etna" Plant (Gorkiy) uses a line consisting of two uncoilers, two three-position 13VOA-14F machines, two-scraper chain conveyors and one AR-12F threading machine. The automatic line produces M8 and M10 flanged bolts. The shank is extruded on upsetting lines after the blank is cut, then the hexagonal head is pre-formed and finally headed and the shank is reduced for threading. A tapered recess is also extruded at the second position for optimum head formation. The manufacturing process for the M8 bolt includes cutting, direct shank extrusion, formation of a tapered preliminary head, and shaping of the flanged head at the last position. The headed blank goes to the scraper conveyor and then to the AR-12F threader.

Technical data on the AR-12F Machine

Maximum thread length, mm	15
Thread diameter, mm	M10-M14
Machine capacity, pc/min	
with single-pass cam	98
with double-pass cam	196
Electric motor power, kW	9.05
Overall dimensions (L x W x H), mm	1,850x880x1,670
Machine weight, kg	1,800

The AR-12F can machine blanks coming simultaneously from two cold-upsetting machines, which explains the line's capacity--174 pc/min. Because of waste-free hexahedron manufacture, metal savings are 6-8 percent. Since a trimming machine is not required with this bolt manufacturing process, the line is 30 percent shorter than a bolt production line with trimming, and production area is 40 percent smaller. However, the strength of the flanged head is somewhat lower because the head is weakened by the indentation. The Magnitogorsk Metallurgical Hardware Plant produces M8 bolts on AV-1919 machines. The automatic line consists of a feed coil, a multi-function machine, a scraper

conveyor, and a threading machine with a hopper. One worker attends two lines. In a three-shift operation, the line's annual per-shift output is 1,513 tons. Automatic lines for producing M10 and M12 bolts are similarly arranged. Automatic lines for producing M16 and M20 bolts include a PZU-1 uncoiling, straightening, and feeding device, a multi-position machine, a chain hopper, and threading machine. The lines' capacity is about 55-60 pc/min, and a line is attended by two operators. The PZU must be used, since special mechanisms are used to straighten thick coiled rod. The PZU also cuts off the defective front end of the rod. The PZU-1 and PZU-2 straighten and feed rod 16-20 and 32 mm in diameter.

Technical Data

	PZU-1	PZU-2
Coil diameter, mm:		
outside	1200-1400	1000-1400
inside	200-500	600-1200
Coil weight, kg	100-500	100-500
Unwinding speed, m/min	9	6.6
Motor power, kW	5.2	-
Weight, kg	2800	4028
Manufacturer	KPO Plant (Odessa)	Press Machine Plant (Chimkent)

Figure 2 [not reproduced] shows a general view of the PZU-1.

A crane places the coil on the main support. The coil is centered by rollers moved by flywheels in grooves. The coil's horizontal position is limited by vertical rollers. The leading end is fed between rollers that bend the end of the rod to set it in the straightener, which consists of pressure drive rollers and rollers which distribute the ends of the bar. The rollers are adjusted vertically with screws to ensure the required radius of curvature for straightening. The straightener drive consists of a DC electric motor, worm reduction gear, chain transmission, and open toothed pair. To load the bars, the top of the housing is hinged by the top roller to the bottom of the housing, which holds the bottom roller. Hydraulic cylinder 6 does the loading. The rod passes through the straightener to idle guide rolls, then to the clamping mechanism, which consists of two slide bars with clamping prisms. The defective end of the bar is clamped manually (PZU-1) or with a pneumatic cylinder (PZU-2). Clamping prisms are aligned in common guides from the rocking lever system. A head which moves axially and sideways at the defective rod cuts the end and chamfers it. The head is turned by the electric motor through a V-belt transmission. An abrasive disk is placed on the head shaft. When the head is tilted by the transverse feed lever, the defective end of the rod is cut off. The chamfer on the feed end is faced by two cutters located at the abrasive disk axis and turned by the common drive. The head is moved axially by a carriage from the longitudinal feed lever. The bar prepared in this way is fed to the machine. The control panel is mounted on a hinged lever and is on the working side of the machine.

The Magnitogorsk Metallurgical Hardware Plant has a large number of automatic nut production lines. An A1617 nut machine and a VS-41 threading machine are used to make M5 nuts.

After deformation operations on the machine, the discharger takes the blank from the die and puts it on an inclined (scraper) conveyor.

The blank travels along the conveyor to the hopper of the Ve-41 machine and then to the threading mechanism.

A typical M8 nut production line consists of an uncoiler, AV1818 cold upsetting machine, a nut distributor, and three A2082 nut threaders. The line is a serial-parallel line with flexible connection from the upsetting machine to the nut threaders because of the use of hoppers. The overall dimensions of the line in plan view are 6500 x 4800 mm, height above floor level is 2830 mm. In a two-shift operation, line output is 254 tons a year. Two workers attend the line.

The automatic lines operated at the Cherepovets Steel Rolling Mill (ChSPZ) are intended for production M6-M12 bolts and M6-M12 nuts. Figure 3 [not reproduced] shows an automatic line in a three-shift operation. The line occupies about 220 m³ of production space. It consists of a VKA-3 multi-position machine, an AA2522 (or AA253) threader, a dispenser, and conveyors.

To correct defects on the front end of the coil, it is manually trimmed with shears. The rod passes through an expanded conical drawing plate to a mixed hard-alloy blade which is driven by an eccentric shaft mounted in bearings in the shears housing. Rigid guide blades are used to reliably hold the cutting blade against the shearing bush, and a handle is used to create high moment. The blade cuts off a rod up to 13 mm in diameter. Maximum force on the handle is 0.4 kN, while cutting forces are 3 kN.

At the Belebeyev "Avtonormal" Plant, M8 nuts are upset on a four-position machine, and the ready blank is transferred by conveyor to the hopper of an A2062 nut threading machine. The total area occupied by the line is about 45 m²; annual output in single-shift operation is about 120 tons.

At Odessa's "Stankonormal" Plant, the makeup of bolt manufacturing lines varies and depends on the manufacturing process. In one version, it is recommended that blank trimming be followed by two shank extrusions, setup of the preliminary head, and trimming of the hexahedron at the last position. In this case the four-position machine is equipped with facing, chamfering, and threading devices. Between these devices are transfer conveyors and hoppers. In another manufacturing process shearing, shank extrusion, and cylindrical head production are followed by heading of a large chamfer on the bolt shank and edge trimming. Good chamfer quality facilitates the mechanization of assembly jobs.

Special automatic lines are created to package and assemble fasteners. The line set up at the Magnitogorsk Metallurgical Hardware Plant consists of a step conveyor, two weighing devices, a turntable, a nail-driving machine, and tilting and turning devices. The line operates as follows. A crane pours bolts and nuts into the weighing device hopper. Then the items from the hopper go to the adjustable-speed inclined apron conveyor and from it to a tray. Under the tray are electromagnetic coils whose pulses move the fasteners into containers mounted on the step conveyor. The container goes to the weighing devices in the step conveyor's operating zone. At first two-thirds of the entire weight of the fasteners are poured from the container

into trays, then the rate at which the fasteners are poured into the trays decreases sharply until the container is full. The weight sensors are activated and the step conveyor moves the container to the section where the lid is nailed on by the nail-driving machine. Then the step conveyor moves the container to the unloading section, from which a crane takes the boxes to the finished product warehouse.

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