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DEFORMATION OF ALUMINUM ALLOYS IN ISOTHERMAL CONDITIONS

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It has been scientifically proven that aluminum, more than other materials, meets the requirements of production, storage and processing of various foods. Therefore, the prospects for its use in the agro-industrial complex are quite high. At the same time, the process of developing such materials should be improved and promoted.

Aluminum alloys are widely used in the aviation industry, in mechanical engineering and in agricultural production, due to their properties and light metal consumption. Alloys are resistant to water, they are not afraid of corrosion, sunlight, easily disinfected.

All these properties are best suited for the use of aluminum in the storage of both cereals and livestock products. Moisture, dangerous molds, rodents and various insects are released and absorbed in storage. Aluminum has a high thermal conductivity and reflectivity, which reduce the risk of moisture condensation, which normalizes storage. The smoothness of this material suggests that the walls of aluminum structures collect much less dust.

The proposed isothermal method of hot deformation of aluminum alloys in the processing of metals by pressure, differs from traditional deformation, and the temperature of the heated workpiece and the deforming tool is kept constant, close to the upper limit of forging temperatures, throughout the process.

The deformation of the metal under isometric conditions and approximate deformations is characterized by an increase in ductility compared with ductility when machined in a cold tool. This is due to the lower rate of deformation, the lower limit of which is limited only by the productivity of the process. As a result, the "filling time" of defects that occur during metal deformation increases, the temperature stress in the workpiece volume decreases, the deformation becomes more uniform.

Key words: isothermal deformation, hot deformation, rolling of billets, aluminum alloys.

Fig. 2. Ref. 7.

1. Introduction

During deformation under conditions of isometric deformation, the forces are reduced and, accordingly, the amount of heat released as a result of deformation is reduced, which, due to the homogeneity of deformation, is distributed in the volume of the workpiece. This is especially important in the deformation of metals and alloys, the structure of which strongly depends on temperature changes. Uniform deformation of the workpiece in the absence of areas of difficult deformation provides good and comprehensive processing of the structure, high strength and plastic characteristics of the metal and reduces the scatter of properties in the workpiece volume. process at a temperature close to the upper limit of the temperature range for this alloy. For example, reducing the deformation temperature by 50–200 ° C for titanium alloys facilitates the deformation in the ($\alpha + \beta$) region and provides high quality parts, reduces the depth of the alpha layer.

2. Problem formulation

Review the technology of low-waste technological processes of rolling billets in isothermal deformation for implementation in mechanical engineering. Application of rolling of blanks in the conditions of isothermal deformation to make the most of its advantages. To make the review of the carried-out researches on temperature, speed of deformation, degree of deformation on technological parameters of rolling of preparations in the conditions of isothermal deformation.

3. A purpose of work

The purpose of this work is included in the development and implementation of low-waste technological processes of rolling billets of aluminum alloys under isothermal deformation, which provide: the use of force prevention and dimensions; increase labor productivity; use of labor intensity and consumption of aluminum alloys; improving the quality of stamped parts, the use of independent means of production of stamped parts and profiles.

4. Results of research

Creation of conditions of isothermal deformation allows to carry out stamping in the optimum thermomechanical mode, to use the phenomenon over plasticity and gives the chance to make stamped forgings of a difficult configuration (flanges, arms, levers, swings, etc.), with the minimum allowances for machining, the minimum, Fig. 1.



Fig. 1. Samples made by isothermal stamping

The accuracy of the parts obtained in the conditions of isometric deformation is significantly increased due to:

- reduction of elastic deformations of the equipment system - tool, as the resistance to deformation of the metal and processing effort decreases; , greater stability of the geometric dimensions of machined parts;
- reduction of residual stress in the volume of stamped steel, which reduces its leach during cooling and heat treatment, improves quality;
- reducing the thickness of the defective layer and improving surface quality parts (semi-finished product) as a result of less action of heated metal with the environment by reducing the deformation temperature and the use of effective protective and lubricating coatings.
- reduction of residual stress in the volume of stamped steel,

In [1] the analysis of results of studying over plasticity of metals and alloys is resulted, the basic features of processing of metal are allocated and the pressure in the state above the plasticity. It is noted that some of them provide significant advantages, which include:

- extremely high deformation capacity of materials in the state above plasticity (1 - 2 orders of magnitude more than in the normal plastic state);
- low resistance to deformation (5 - 10 times less than the same materials in the plastic state); isotropic mechanical properties throughout the volume;
- high relaxation capacity of materials in the state of over-plasticity, and, as a consequence, the absence of internal residual stress after deformation.

technologies for processing metals by pressure include:

- reducing the rate of deformation (2 - 4 orders of magnitude less than the speed of conventional processes of processing metals by pressure), limiting the productivity of the process; which requires the use of high heat resistance materials for the tool and the complexity of the tool design, associated with the need for heating and thermal insulation.



In [2, 3] described materials on the choice of parts to be manufactured by the method of isothermal stamping, development and implementation of the technological process, features of isothermal stamping of parts made of aluminum and magnesium alloys, equipment and facilities, recommended lubrication. The paper emphasizes that isothermal stamping of aluminum alloys can be used in combination with the processes of conventional forging and stamping. However, the temperature regimes of isothermal deformation must comply with the recommendations, and the allowable degree of isothermal deformation of billets of extruded and rolled bars of aluminum alloys in one pass at temperatures corresponding to the recommended temperature deformation intervals and deformation rates up to 5 mm/s are not limited. There are no recommendations on the use of preparatory and billet streams (CCD) and rolling of billets in the conditions of isothermal deformation and close to it. Stamping of details is provided in one transition.

The literature covers the hot deformation (stamping) of aluminum alloy blanks using the effect on ductility [4-7].

Technological recommendations [2] are intended for use in isothermal stamping of precision blade blanks of titanium alloys in closed dies. The main features of isothermal stamping in closed dies, technological process of stamping, applied protective - lubricating coverings are described in the work. To prepare precision blanks for stamping, the process involves a scheme of transverse settling of cylinder blanks in a closed die, which is characterized by the end of the metal along the spherical part of the cavity with a simultaneous set of metal in the locking part. Rolling of blanks in isothermal conditions is not used.

In [4], the authors in experiments to determine the plasticity of deformable aluminum alloys B96ts, thermally strengthened, B93, Ak6, 01420, Ak4-1 determined that despite the significant differences in chemical composition, the studied alloys have a similar structure and they equally reveal the mechanism of plastic deformation. In addition, the authors note that the use of the effect on ductility in processing has a positive effect on the complex of mechanical properties of aluminum alloys: increases their ductility, homogeneity of properties by volume, decreases the anisotropy of mechanical properties.

Work [7] when conducting experiments to determine the effect on the plastic deformation of titanium alloys W3-1, W9, W6. In addition, the authors note that a significant positive feature of isothermal stamping of titanium alloys is the reduction of the alpha layer due to reduced heat and increase the degree of deformation of the surface layer. The depth of the alpha layer is approximately 5 times less than with conventional stamping and is 50 - 100 μm .

Analyzing the application of plasticity in the processing of metals by pressure, it should be noted that this process is used to obtain parts of complex configuration few plastic and difficult to deform alloys. Due to the fact that such materials have a high cost, and their processing - a great complexity of numerous operations, it becomes obvious the prospects of pressure treatment of these materials in a state above plasticity.

Application of rolling of blanks in the conditions of isothermal deformation. stripping, heating, which significantly prolongs the production cycle of forgings and increases the complexity of their manufacture. The metal utilization factor is in the range of 0.15 to 0.3. The parts used in the products of the industry are structurally complex (the presence of thin high ribs; small radii; small stamping slopes and allowances for machining; thin canvases with closed sections and a deep cavity).

This determines the manufacturability in the process of stamping and the appearance of defects. Stamping of these forgings from not prepared preparations in advance strengthens technological process of reception of high-quality stamped forgings. A literature review to identify recommendations for the use of rolling billets of aluminum alloys in isothermal conditions, as one of the preparatory operations of CCD in the manufacture of stamped forgings showed that the recommendations for the use and design of CCD using rolling blanks in isothermal and other forms. alloys are absent.

The guide is devoted to the design and manufacture of forgings used in the aviation industry and meet modern production requirements, but information on the use of rolling workpieces in isothermal deformation and close to it in the PZR for the manufacture of stamped forgings from aluminum alloys is missing.

The work [2] is devoted to the rolling of aluminum alloys, but there are no recommendations for their rolling in the conditions of isothermal and approximate deformation.

Data on the materials obtained [3], products, tools, methods of forging after stamping. Tables and graphs characterizing the chemical compositions and mechanical properties of aluminum alloys, as well as the mechanical properties of the obtained products are given. There is no description of the application of rolling of aluminum alloy blanks in isothermal conditions and close to them. on hammers and presses in production conditions. The description of application of rolling of preparations from aluminum alloys in isothermal conditions and close to them is absent.



Due to the fact that the existing technological processes of manufacturing stamped forgings with an elongated axis of aluminum alloys [4] from unprepared for stamping blanks enhance the technological processes of obtaining high-quality stamping and are characterized by high complexity, low productivity, high metal consumption, it is necessary to develop technological recommendations and typical technological processes for the manufacture of stamped forgings using the operation of rolling workpieces in the conditions of isothermal and close to it deformation.

The literature review provided an opportunity to get acquainted with the work on the study and implementation of the isothermal method of rolling metals and alloys. Methods of heating the electrical contact of the rolls, the induction method of heating the rolls and various structures and devices for implementing the method of isothermal rolling are proposed. For example, a device that allows precise temperature control in the deformation center and the rolling of thin-walled profiles of complex shape from materials that are difficult to deform.

Hot rolling of beryllium and tungsten with heated rolls was studied at the Battelov Institute (USA). Tests have shown that materials such as tungsten and beryllium, which are difficult to roll, the blanks of which are preheated to a temperature of 760 ° C, can be rolled with a compression of 43% in one pass when using lubricating glass (phosphate glass) and heating the rolls to 540 ° WITH. The paper describes the use of isothermal rolling in the United States. Molybdenum rollers (Fig. 2), forming the product, also serve as electrodes for heating the workpiece. Electric current, passing from one roll to another through the workpiece, heats the last and certain part of the rolls, creating a mobile hot zone. Rolling takes place under the combined action of compression force F and feed force $F - F$. The degree of deformation in one pass reaches 95%.

The possibility of rolling billets of compressor blades made of steels and titanium alloys in isothermal conditions, which were created by passing an electric current through the rolls and the workpiece during rolling, was investigated.

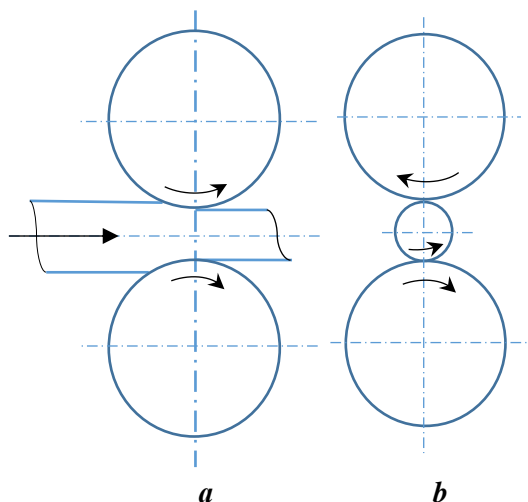


Fig. 2. Schematic diagram of thermal rolling: a – longitudinal rolling, b – cross rolling,

Studies of the temperature regime of the process according to the scheme of rolls-rolls allowed to develop a technological process of isothermal rolling of billets from alloy VT3 - 1 and steel EI787VD. The peculiarity of isothermal rolling of the blades is that it is carried out at a relatively low resistance to deformation. The resistance to deformation of the alloy VTZ-1 during isothermal rolling of the blades is described above. The research was carried out under conditions of isothermal deformation processes by the method of settling of cylinder samples with diameter and height of 15 mm without oil with different speeds and degrees of deformation on a universal testing machine UIM - 10TM with a force of 100 kN, equipped with high temperature muffle furnace with automatic temperature control. The test machine is equipped with an electronic force measuring device to record the force-deformation curve.

In this work, the authors used a rolling tool, which performed not only the functions of forming equipment, but also was used as an electrode for current supply.

Experimental studies have shown that on the curves of strain $\sigma = f(\varepsilon)$ hardening corresponding to low strain rates ($\varepsilon = 0,0015 - 0,15c^{-1}$), there are no strengthening branches, which indicates the predominance of dynamic softening over hardening in the specified speed range.



The authors recommend a formula for calculating the deformation force in the entire range of changes in the experiments of thermomechanical parameters (except $T = 750\text{ }^{\circ}\text{C}$, at $\varepsilon = 0,15\text{c}^{-1}$).

The authors conducted experimental studies of rolled titanium alloys with simultaneous heating of the electrical contact. In the course of experimental studies, the metal pressure on the rolls was measured with the help of magnetoelastic mesodes, the roll speed with the help of a cam device, the current and heating voltage, the temperature at different points of the roll and the workpiece with chromel - alumel thermocouples. Billets with a cross section of 3 x 5 mm, 200 mm long from VT3-1 alloy were rolled according to the roll-roll system, and Ø18 mm billets, 1200 mm long from VT9 alloy and blanks with a cross section of 6 x 20, 400 mm long from OT4 alloy were rolled according to the contact-contact system. The obtained data on the results of experimental studies on the system of roll-roll on the distribution of the temperature field in the body of the roll and the workpiece. Thus, when the workpiece is heated to a rolled temperature of $950\text{ }^{\circ}\text{C}$, the temperature in the roll of the roll reaches significant values even at a depth of 15 mm. Analysis of the dependences of temperature changes over time for the heating system electrocontact contact-contact shows that for small values of the heating current density, the temperature of the heat balance is reached in a relatively long time. As the cross-sectional area increases, the temperature of the heat balance increases at the same density of the heating current. Different forms of blanks, with the same values of heat balance temperature, require different values of heating current density.

In this work[5], the authors conducted experimental studies when heating the bandage to $350\text{ }^{\circ}\text{C}$. There is no data on the behavior of these dependences when heating the bandage temperature above $350\text{ }^{\circ}\text{C}$. Studies of technological parameters of rolled products (expansion, advancement, etc.) have not been carried out.

One of the ways to combat the occurrence of defects, as the author notes, is to control the nature of the metal during the deformation of the forging and determine the rational temperature and speed of the process.

To achieve this goal in the process of work the following tasks:

- to determine the nature of the metal in the stamp, in isothermal stamping in the manufacture of aircraft parts with finned complex shape and in the presence of elements of asymmetry of the elementary section;
- to determine the necessary conditions and parameters of a scientifically sound technological process for the formation of a defect-free product with an asymmetric arrangement of ribs;
- to solve the problem of precise control of the process of isothermal stamping and automatic support of the set modes. recommended, the ratio of geometric shapes of caliber and rolled workpiece is not taken into account.

Data on the definition of the deformation [7] resistance are obtained by settling and stretching, and not in the conditions of rolling, where the deformation cell has a completely different shape and of course different deformation conditions. There is no data that would show the dependence of resistance on the heating temperature of the tool.

Due to the fact that currently published little work on the study of the possibilities of rolling workpieces in isothermal conditions or close to them, conducting research on the effect of temperature, strain rate, degree of deformation on the technological parameters of rolling workpieces in conditions isothermal deformation, is an urgent task, the solution of which will lead to improved ductility and reduced strain, improving the quality of semi-finished products.

In [2] the researches of technological parameters of rolling of blanks from aluminum alloy AK6 with the sizes of blanks Ø14 x 150 mm on the experimental installation for rolling of blanks in the conditions of isothermal and close to it deformation are described. The dependences of expansion, advance, metal pressure on the rolls on the degree of deformation, heating temperatures of rolling dies and workpieces during rolling in smooth rolls are determined. However, this is not enough to develop technological recommendations for the implementation of the technological process and terms of reference for the manufacture of industrial samples of equipment for rolling workpieces under isothermal deformation and close to it.

Will allow to use its advantages as the deformation of the heated preparations will be carried out by the tool heated to deformation temperatures (or close to it) that will allow to reduce deformation efforts due to increase of plasticity of the processed metal which occurs because of fuller course of strengthening processes. Uniform deformation of the workpiece, in the absence of areas of difficult deformation and local overheating, provides good processing of the structure, and, as a consequence, reduces the scatter of properties in the volume of the workpiece. Thus, for each alloy it is necessary to choose the thermomechanical parameters of deformation providing reception of a qualitative product, both on a geometrical form, and on mechanical properties and a macrostructure.



5. Conclusions

Introduction of low-waste technological processes of rolling of blanks in the conditions of isothermal deformation at the machine-building enterprises, is caused by considerable application in products of aluminum alloys, the increased expense of metal (coefficient of use of metal 0,15 - 0,3), high complexity, a long cycle of manufacturing of high-quality stamped details.(2-3 stamping with intermediate operations of heating, cutting of rounding, poisoning, stripping) and tasks on improvement of metal-saving technologies. deformation temperatures, which reduces the deformation force by increasing the ductility of the metal.

Uniform deformation of the workpiece, in the absence of areas of difficult deformation and local overheating, provides good processing of the structure. Carrying out of researches on influence of temperature, speed of deformation, degree of deformation on technological parameters of rolling of preparations in the conditions of isothermal deformation will lead to improvement of plasticity and decrease in efforts of deformation, increase of quality of semi-finished products, for the subsequent stamping.

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ПРОТІКАННЯ ДЕФОРМАЦІЯ АЛЮМІНІЄВИХ СПЛАВІВ В ІЗОТЕРМІЧНИХ УМОВАХ

Науково доведено, що алюміній більше, ніж інші матеріали, відповідає вимогам виробництва, зберігання і переробки різних харчових продуктів. Тому перспективи його використання в агропромисловому комплексі досить високі. У той же час процес розробки подібних матеріалів слід удосконалювати і просувати.

Алюмінієві сплави широка застосовуються в авіаційній промисловості, в машинобудування та в сільськогосподарському виробництві, завдяки їх властивостям та полегшеній металоємності. Сплави стійкі до впливів води, їм не страшна корозія, сонячне світло, легко піддаються дезінфекції.

Всі ці властивості як не можна краще підходять для використання алюмінію при зберіганні, як зернових культур, так і продукції тваринницького походження. У сховищах виділяється і поглинається волога, небезпечні цвілеві грибки, гризуни і різні комахи. Алюміній володіє високою теплопровідністю і відбивною здатністю, яка призводять до зменшення небезпеки конденсації вологи, що нормалізує режим зберігання. Гладкість цього матеріалу дозволяє говорити про те, що на стінах алюмінієвих конструкцій збирається набагато менше пилу.

Запропонований ізотермічний метод гарячої деформації алюмінієвих сплавів в обробці металів тиском, від традиційних відрізняється тим, що формозмінення нагрітої заготовки здійснюють в інструменті нагрітому до температури деформації, а температура нагрітої заготовки і деформуючого інструменту витримується постійною, близькою до верхньої межі кувальних температур, протягом всього процесу.

Деформація металу в умовах ізометричного і наближених до нього деформації характеризується збільшенням пластичності в порівнянні з пластичністю при обробці в холодному інструменті. Це



пояснюється нижчою швидкістю деформації, нижня межа якої обмежена тільки продуктивністю процесу. В результаті збільшується час «заповнення дефектів», що виникають при деформації металу, зменшується температурна напруга в об'ємі заготовки, деформація стає більш рівномірною.

Ключові слова: ізотермічна деформація, гаряча деформація, вальцювання заготовок, алюмінієві сплави.

Рис. 2. Літ. 7.

ПРОТЕКАНИЯ ДЕФОРМАЦИЯ АЛЮМИНИЕВЫХ СПЛАВОВ В ИЗОТЕРМИЧЕСКИХ УСЛОВИЯХ

Научно доказано, что алюминий более, чем другие материалы, соответствует требованиям производства, хранения и переработки разных пищевых продуктов. Поэтому перспективы его использование в агропромышленном комплексе достаточно высокие. В тоже время процесс разработки подобных материалов следует совершенствовать и продвигать.

Алюминиевые сплавы широко применяются в авиационной промышленности, в машиностроение и в сельскохозяйственном производстве, благодаря их свойствам и облегченной металлоемкости. Сплавы устойчивы к влиянию воды, им не страшна коррозия, солнечный свет, легко поддаются дезинфекции.

Все эти свойства как нельзя лучше подходят для использования алюминия при хранении, как зерновых культур, так и продукции животного происхождения. В хранилищах выделяется и поглощается влага, опасные плесневые грибки, грызуны и различные насекомые. Алюминий обладает высокой теплопроводностью и отражательной способностью, приводят к уменьшению опасности конденсации влаги, нормализует режим хранения. Гладкость этого материала позволяет говорить о том, что на стенках алюминиевых конструкций собирается гораздо меньше пыли.

Предложенный изотермический метод горячей деформации алюминиевых сплаве в обработке металлов давлением, от традиционного отличается тем, что формоизменения нагретой заготовки осуществляются в инструменте нагретом до температуры деформации, а температура нагретой заготовки и деформирующего инструмента выдерживается постоянной, близкой к верхней границе ковочных температур в течение всего процесса.

Деформация металла в условиях изометрического и приближенных к нему деформации характеризуется увеличением пластичности по сравнению с пластичностью при обработке в холодном инструменте. Это объясняется меньшей скоростью деформации, нижняя граница которого ограничена только производительностью процесса. В результате увеличивается время «заполнения дефектов», возникающие при деформации металла, уменьшается температурные напряжения в объеме заготовки, деформация становится более равномерной.

Ключевые слова: изотермическая деформация, горячая деформация, вальцовка заготовок, алюминиевые сплавы.

Рис. 2. Літ. 7.

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