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THEORETICAL ANALYSIS OF ROTARY DRAWING PROCESSES FOR TUBE BILLETS USING DIFFERENT METHODS

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Annotation. The article deals with methods of theoretical analysis of rotary drawing processes from tube billets, which are widely used in modern industry to obtain parts with high accuracy and improved mechanical properties. Rotary drawing is a process in which tube billets are deformed under the action of a rotating tool, which leads to their drawing and geometry change.

Various methods of theoretical analysis are used to investigate this process, including analytical solutions, numerical modeling and finite element methods. Analytical methods provide simplified solutions to estimate the basic process parameters such as deformation forces, stress and strain distribution in the workpiece. Numerical methods, including finite element methods, provide a more detailed and accurate analysis, allowing complex workpiece shapes and multilayer materials to be considered, as well as predicting residual stress distributions.

The paper focuses on the influence of key parameters of the rotary drawing process, such as tool speed, clamping force, process temperature and material properties of the workpiece. Possibilities of increasing the accuracy and efficiency of the process, as well as improving the mechanical characteristics of the finished product are considered.

Keywords: rotary drawing, tube billets, process, deformation, part, tool, efficiency.

Introduction

Thin-walled cylindrical parts have found extensive use in various sectors of mechanical engineering, and therefore recently there has been a need for the production of thin-walled cylindrical parts (more than one meter) of complex design for special purpose machinery, which have the highest requirements in terms of design parameters and mechanical qualities.

Production of this kind of parts by classical methods is characterized by high labor costs and is associated with the use of a large number of large expensive pressing, chemical and thermal equipment. Whereas rotary drawing makes it possible to produce such thin-walled cylindrical parts on high production special machines with relatively small dimensions, weight and power: the amount of force in rotary drawing is much smaller compared to deep drawing, which directly depends on the creation of a local deformation zone.

Nowadays, when writing technological processes of rotary drawing, dependencies from all kinds of reference sources are used, obtained experimentally, including the results of theoretical research works, which do not take into account in sufficient quantity the local character of forming and mechanical characteristics of the part material.

The process of rotary drawing with strain division, which promises great discoveries in the direction of application of internal strain reserves, reduction of force loads and increase of properties of developed thin-walled parts, has not been investigated at all.

In view of this fact, there appeared an urgent task to increase the efficiency of manufacturing of thin-walled cylindrical parts for special equipment by rotary drawing on special machines by means of improving the theory of plastic forming, improving the capabilities of these processes, increasing their financial efficiency, operational parameters, establishing the relationship of deformation factors with ensuring geometric accuracy and the formation of mechanical properties of the material of the workpiece.

Materials and methods

Rotary drawing is the process of forming flat or hollow rotating workpieces along the profile of a mandrel by means of a shifting deforming force. The processing method is characterized by the presence of a local deformation zone resulting from the influence of a compressive element (roller) on the workpiece.

The drawing of cylindrical billets with wall thinning can be performed by reverse or direct methods, differing in the direction of metal flow in relation to the direction of the working feed of the compression roller.

The Soviet engineers and researchers made a significant contribution to the formation of the theoretical and practical part of the rotary drawing process: V. Barkoya, K.N. Bogoyavlinsky, A.I. Valder, V.V. Smernov, I.P. Rene, I.I. Kazakkevich, V.G. Kaparovich, V.I. Korolkov, N.I. Mogilny, E.A. Popov, A.S. Chumadin, and L.G. Yudin [1-11].

Also, foreign scientists S. Koboyashi, SO. Kolpakceoglu, E. Tomaset, SN. Welsh, C. Yank and others [12-16].

The theoretical study of rotational drawing is aggravated by the presence of local deformation and the large character of the stress-strain state of the metal in the plastic zone. The possibilities of theoretical study of rotational drawing are mostly determined by the level of its schematization. The study of the process of rotational drawing cannot be carried out without making a certain number of assumptions.

In theoretical studies, as a rule, the tool is usually assumed to be perfectly rigid. The metal to be machined is assumed to be homogeneous, isotropic, fitting the model of either a rigid-plastic or elastic-plastic body. Free mass and other mass forces are not taken into account. Volumetric deformation is replaced by plane deformation, the validity of the choice of which is confirmed by experimental research works.

The assumption of plane deformation, usually perceived in the longitudinal section. This assumption, originating from the results of E. Thomsen's research work, makes it possible to compare the similarity between the processes of rotary drawing and drawing or pressing of tubes with thin walls. This type of metal working process was further developed in the works of V.F. Barkoy, L.G. Yudin, A.I. Walder and others.

At the same time, a large number of authors refer to the preferential transverse movement of the tool. The deformation in this case takes place by rolling rather than by drawing. This method is most realized in models that take their basis from the analysis of the transverse rolling process, the basis of which is the model of pressing a flat die into a solid half-plane.

In contrast to the previous model, the analysis is carried out in the cross-section of the part with the assumption of plane deformation. On the basis of the above models, the problems of analyzing the stressed and deformed state and determining the energy-force characteristics of the process are solved.

In this work, a method that takes into account the volumetric nature of metal flow was chosen. The theoretical study of the process of rotary drawing with wall thinning in this case is realized by the method of “upper” estimates. The relations for the volumetric flow of material in the deformation zone are also obtained during the work.

An attempt to demonstrate the complicated character of volumetric flow during rotary drawing with wall thinning was made by the Soviet scientist A.A. Kiryakov. The forming process is described as a step-by-step process of deformation of ring elements.

Localization of the deformation zone leads to the formation of elastically deformed foci around the plastic deformation zone, which significantly affect the character of metal deformation. This was first proved by E.A. Popov. Taking into account the influence of elastically deformed centers of the part on the character of forming was considered in a number of works.

In the works of foreign scientists, the energy method is mainly used to determine the energy-force characteristics of the process. At the same time, the deformation state under the pressing element is assumed to be flat, and simple shear of the material is taken as the main one. The energy of forming a unit volume is taken as a function of stress intensity and contact overload along the entire deformation zone.

Along with the energy method, the method of thin sections and the method of slip lines have been used by scientists to establish force characteristics in many cases. In the course of research work, dependencies between the constituent elements of the resultant force in rotary drawing have been found, based on a comparison with drawing treatment on a flat material press. E. Thomasett evaluates the process of rotary drawing as precipitation. The formulas for finding the constitutive forces in this case are half empirical.

The study of the dependencies described by different scientists to find the forces of rotary drawing shows that in addition to the dimensional parameters of the tool, mechanical characteristics of the metal, the formulas also contain different coefficients (coefficient of efficiency of the process; coefficients that take into account the method of rotary drawing; roughness of deformation; compaction, etc.), which vary depending on a variety of process parameters.

Establishing the above-mentioned coefficients for specific rotational drawing process conditions is problematic in many cases. Incorrect assessment of the impact of individual causes, or lack of consideration of those or other factors in the considered dependencies, leads to significant errors in the calculation of forces, in consequence of which their difference with experimental data is 1.5-2 times.

One of the factors of significant discrepancy between calculated and experimental values of forces of the rotary drawing process by the direct method is considered to be the failure to take into account the change in the actual feed of material into the deformation zone, which significantly affects the size of the contact area of rollers with the metal of the workpiece, consequently, and on the volume of forces generated during the rotary drawing process. Therefore, with the change of the actual material feed into the deformation zone during the rotary drawing process by the direct method, the character of the forces appearing during metalworking has its own features.

Research results

During the study of the rotary drawing process, one of the key issues is the study of the possibilities of forming without fracture and the determination of critical degrees of deformation. However, due to the difficulty in describing the local character of deformation and the significant impact of out-of-contact deformation on the metal flow, the limit degrees of deformation in rotary drawing processes have been investigated, in many cases, experimentally.

The ability to shape in the process of rotary drawing is usually defined by the degree of deformation ε, which should not exceed the maximum possible value ε_{pr} for a given metal or metalworking conditions.

M.A. Gredetor as a criterion of plasticity takes the conditional compression of the neck of the workpiece during tensile testing ψ and gives the following approximate formula:

$$\varepsilon_{pr} = \psi/(0{,}17 + \frac{\psi}{100}) \quad (1)$$

Using the above formula ψ, it is possible to calculate the ability of the metal to the rotary drawing process in the cold state by value. It has been experimentally established that relative elongation cannot be used as a deformation criterion for rotary drawing because it varies with the size of the workpieces.

It is indicated that the values do not differ dramatically when deforming after several operations ε_{pr}. As a consequence, during the rotary drawing process, the ultimate degree of deformation ε_{pr} can be found from the cross-sectional contraction in tensile testing of the samples taken in longitudinal direction from the original workpiece.

In the works by V.I. Zheltkov and A.I. Walder, an attempt was made to investigate at the theoretical level the nature of the change in the degree of application of the plasticity resource of the deformed metal according to the method of V.L. Kolmogarov, as well as to estimate the maximum degree of thinning on the basis of the strength condition of the wall of the deformed part of the workpiece depending on the shape of the tool, the value of the working feed and the number of passes in the process of rotary drawing with thinning [19].

A large number of works were devoted to the visual study of force and deformation characteristics, obtaining geometric quality parameters of thin-walled cylindrical parts (Figure 1), produced by rotary drawing process on special equipment with rollers (direct and reverse methods) and ball rolling heads.

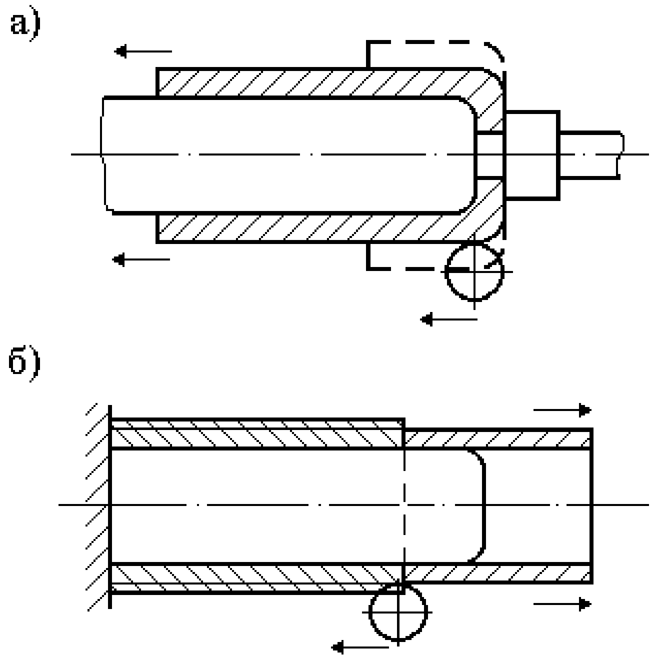

Figure 1 - Rotary drawing of a cylindrical thin-walled part by direct (a) and reverse (b) methods

The information obtained by empirical and theoretical studies on the process of rotary drawing of cylindrical thin-walled parts and shells has established that the course of plastic deformation is influenced by mechanical features of metal (hardness, conditional elongation, strength); degree of deformation; configuration, dimensions and geometry of press rollers; number of mandrel revolutions; longitudinal feed of the device; method of the process of rotary drawing (direct or reverse); gap between the mandrel and the workpiece; and the distance between the mandrel and the workpiece.

Experimentally it was found that at the degree of deformation $\varepsilon = 40 - 85\%$, the hardness of the surface after deformation changes in a small amount, and the ability to form is only dependent on the rigidity, vibration resistance of machines and tools.

Discussion

The rotary drawing process of tube billets is an important technology widely used to obtain high quality products with required mechanical and geometrical characteristics. Theoretical analysis methods, such as analytical approaches and numerical simulations, provide a deeper understanding of material deformation patterns and predict the outcome of drawing processes. Analytical methods provide simple solutions for basic calculations, while numerical methods, including the finite element method, provide more accurate results, especially when complex shapes and material properties are taken into account.

Conclusion.

The study has shown that the quality of finished products is significantly affected by such parameters as tool rotation speed, process temperature, clamping force and properties of the source material. Optimization of these parameters makes it possible to increase manufacturing accuracy, improve mechanical characteristics of products and reduce the probability of defects.

Thus, further development of theoretical analysis methods and their implementation in the practice of computer-aided design will provide an increase in the efficiency and reliability of rotary drawing in the manufacture of tubular products.

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ӘР ТҮРЛІ ӘДІСТЕРДІ ҚОЛДАНА ОТЫРЫП ҚҰБЫР ДАЙЫНДАМАЛАРЫН АЙНАЛМАЛЫ СОРУ ПРОЦЕСТЕРІН ТЕОРИЯЛЫҚ ТАЛДАУ

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Аңдатпа. Мақалада қазіргі заманғы өнеркәсіпте жоғары дәлдікпен және жетілдірілген механикалық қасиеттермен бөлшектер алу үшін кеңінен қолданылатын құбыр дайындамаларынан айналмалы сору процестерін теориялық талдау әдістері қарастырылады. Айналмалы сорғыш-бұл құбыр дайындамалары айналмалы құралдың әсерінен Деформацияланатын процесс, бұл олардың тартылуына және геометрияның өзгеруіне әкеледі.

Бұл процесті зерттеу үшін әртүрлі теориялық талдау әдістері, соның ішінде аналитикалық шешімдер, сандық модельдеу және ақырлы элементтер әдістері қолданылады. Аналитикалық әдістер деформация күштері, дайындамадағы кернеулер мен деформациялардың таралуы сияқты процестің негізгі параметрлерін бағалау үшін жеңілдетілген шешімдер алуға мүмкіндік береді. Сандық әдістер, соның ішінде ақырлы элементтер әдісі, дайындамалардың күрделі формалары мен көп қабатты материалдарды есепке алуға және қалдық кернеулердің таралуын болжауға мүмкіндік беретін егжей-тегжейлі және дәл талдауды қамтамасыз етеді.

Мақалада айналмалы сору процесінің негізгі параметрлерінің әсеріне назар аударылады, мысалы, құралдың айналу жылдамдығы, қысу күші, процестің температурасы және дайындама материалының қасиеттері. Процестің дәлдігі мен тиімділігін арттыру, сондай-ақ дайын өнімнің механикалық өнімділігін жақсарту мүмкіндіктері қарастырылады.

Түйін сөздер: айналмалы сорғыш, құбыр дайындамалары, процесс, деформация, бөлшек, құрал, тиімділік.

ТЕОРЕТИЧЕСКИЙ АНАЛИЗ ПРОЦЕССОВ РОТАЦИОННОЙ ВЫТЯЖКИ ТРУБНЫХ ЗАГОТОВОК С ИСПОЛЬЗОВАНИЕМ РАЗЛИЧНЫХ МЕТОДОВ

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Аннотация. В статье рассматриваются методы теоретического анализа процессов ротационной вытяжки из трубных заготовок, которые широко применяются в современной промышленности для получения деталей с высокой точностью и улучшенными механическими свойствами. Ротационная вытяжка представляет собой процесс, при котором трубные заготовки деформируются под действием вращающегося инструмента, что приводит к их вытягиванию и изменению геометрии.

Для исследования данного процесса используются различные методы теоретического анализа, включая аналитические решения, численное моделирование и методы конечных элементов. Аналитические методы позволяют получить упрощенные

решения для оценки основных параметров процесса, таких как усилия деформации, распределение напряжений и деформаций в заготовке. Численные методы, включая метод конечных элементов, обеспечивают более детализированный и точный анализ, позволяя учитывать сложные формы заготовок и многослойные материалы, а также прогнозировать распределение остаточных напряжений.

Основное внимание в статье уделяется влиянию ключевых параметров процесса ротационной вытяжки, таких как скорость вращения инструмента, усилие прижима, температура процесса и свойства материала заготовки. Рассматриваются возможности повышения точности и эффективности процесса, а также улучшения механических характеристик готовой продукции.

Ключевые слова: ротационная вытяжка, трубные заготовки, процесс, деформация, деталь, инструмент, эффективность.