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VOLUME STAMPING UNDER ISOTHERMAL CONDITIONS

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Annotation: This article discusses the technological and structural advantages of isothermal stamping compared to conventional stamping methods. The study highlights the reduction in specific deformation force and the uniform distribution of heat in the workpiece under isothermal conditions, which contribute to improved workpiece quality and mechanical properties. Special attention is given to the influence of strain rate, temperature, and lubrication methods—particularly the use of glass coatings—on the forming of titanium and hard-to-deform alloys. The application of isothermal forming techniques in the production of complex-shaped parts, especially from low-plasticity and heat-resistant materials, is also addressed.

Keywords: Isothermal stamping, deformation, titanium alloys, forming force, glass lubrication, strain rate, heat-resistant materials, plasticity, press forging, metal forming.

In conventional bulk stamping using equipment heated to high temperatures, the ability to maintain an optimal thermal deformation regime is limited due to the inevitable cooling of the heated billet during its transfer from the heating unit to the deforming equipment, its placement in the die, and the subsequent deformation process.

The cooling of the workpiece increases the material's resistance to deformation, as well as the required deformation force and work. As a result, a non-uniform temperature field and heterogeneous strength properties arise within the volume of the deformable body, leading to uneven flow and reduced plasticity of the stamped material.

The greater the ratio of the surface area to the volume of the workpiece, the more intense its cooling becomes. Significant challenges arise during the stamping of complex parts with wide, thin sheets and small-height ribs.

Preventing or minimizing the cooling of the heated workpiece requires deformation to be carried out at high speeds. However, increasing the deformation rate leads to higher resistance to deformation, which is attributed to the reduced time available for strength reduction processes. High-speed deformation also intensifies the thermal effects of plastic deformation and increases contact friction.

The thermal effect of plastic deformation accumulates in the zones of maximum deformation within the workpiece, which intensifies the inhomogeneous flow of the metal and may lead to undesirable structural changes. The heat generated at the contact interface between the metal and the equipment increases the surface temperature of the metal and reduces the durability of the tooling.

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To compensate for the cooling of the workpiece, it is often necessary to heat it to a temperature higher than that required for deformation. However, this increases the intensity of interaction between the metal and the surrounding environment, leading to scale formation, the bonding of surface layers with alloying elements, and contamination with harmful impurities.

A simpler and more effective method for reducing heat loss from the heated workpiece is the heating of the tooling. When the temperature of the dies is increased, the deformation force decreases, deformation becomes more uniform, and the flow of metal into hard-to-fill die cavities is improved. Die heating is especially essential when deforming metals that have a narrow processing temperature range.

Heating the tooling reduces the temperature gradient between the surface of the metal and the core of the tool, which in turn decreases the resulting stresses and the thermal fatigue of the die material. In conventional hot stamping, the die heating temperature typically ranges from 250–350 °C, depending on the stamped material and the heating method. When using high-alloy die steels, the heating temperature may reach 350–480 °C.

Further increasing the heating temperature of the tooling is limited by the risk of detrimental softening and reduced strength of the die steel, as well as the challenges associated with heating the dies to high temperatures. Therefore, conducting bulk stamping processes using highly heated tooling requires the development of heat-resistant die materials, as well as special coatings and techniques to enable heating and maintain high temperatures during the deformation process [47].

Isothermal deformation processes differ from conventional hot bulk stamping methods in that the shaping of the heated workpiece is carried out using tooling that has also been heated to the deformation temperature.

Thus, the term “isothermal deformation,” commonly used both in our country and abroad, refers not to the temperature of the stamped metal itself, but to the conditions of the stamping process, where the temperature may increase as a result of thermal effects during deformation [48].

Isothermal conditions are created using special stamping blocks that allow the tooling to be heated to the deformation temperature with relatively low energy consumption.

Low-temperature isothermal stamping is used for producing workpieces from aluminum and magnesium alloys, with the maximum heating temperature of the tooling—made from conventional die steels—reaching up to 500 °C.

High-temperature isothermal stamping is used for producing workpieces from steels, titanium, nickel, and other alloy-based materials. Cast tooling made from heat-resistant alloys is heated to temperatures ranging from 700 to 1000 °C. In high-temperature isothermal stamping, lubricating materials such as glass, enamel, and powdered substances are used [25].

Isothermal bulk stamping is generally carried out on hydraulic presses, although other types of equipment may also be used. When no cooling of the workpiece occurs during the deformation process, the deformation rate can, in principle, be arbitrary; the lower limit of the speed is determined solely by the productivity requirements of the process. This enables stamping to be performed with significantly lower resistance compared to conventional deformation conditions [49].

Figure 3.7 presents the comparative variation of specific forming force for titanium samples under conventional conditions on a crank press and under isothermal conditions on a hydraulic press. The

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workpieces, made from VTZ-1 alloy with a diameter of 15 mm and a height of 20 mm, were deformed at 900 °C without lubrication. The die heating temperature in the crank press was 250 °C. When the deformation was less than 60%, the cooling of the workpieces had little effect on the deformation force. However, as the thickness of the workpiece decreased and the contact surface area increased, the influence of cooling became more significant.

In stamping processes carried out on a crank press and under isothermal conditions, the ratio of specific forces is equal to 2, with the main difference between the conditions being attributed to the deformation rate. At 80% deformation, the ratio of specific forces increases to 2.8.

uring isothermal stamping of thin and wide sheet blanks made from VTZ-1 and VT8 alloys, the average specific deformation force ranges from 250 to 300 MPa when the ratio of sheet width to thickness is equal to 25.

When stamping similar parts on a crank press, the deformation force reaches 800–1000 MPa; however, with such force levels, it is not possible to process blanks with a sheet width-to-thickness ratio exceeding 15.

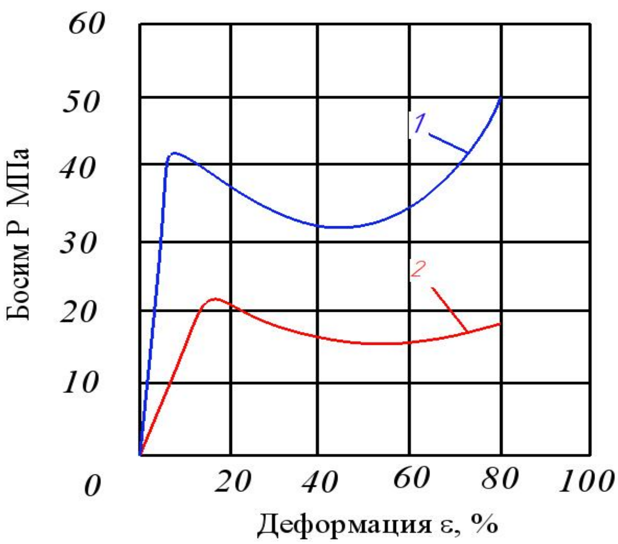

Figure 3.7. Variation of specific force during isothermal upsetting of titanium samples: 1 – on a crank press; 2 – on a hydraulic press

The reduction in stamping force enables the use of lower-power equipment for isothermal stamping, leading to savings in production space and energy consumption. This is especially important when manufacturing large-sized blanks of complex configurations such as beams, brackets, disks, and similar components. Under conventional conditions, stamping such parts becomes unfeasible due to insufficient equipment capacity, necessitating either multiple heating and deformation passes or the use of high-capacity, specialized, and expensive machinery.

As previously noted, glass coatings are used in high-temperature isothermal deformation processes. These coatings are applied to the surface of the blank prior to heating, either by immersion in an aqueous suspension or by spraying. Upon drying and subsequent heating, the glass melts, protecting the metal from oxidation and serving as an effective lubricant during deformation.

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The contact friction coefficient, determined using the cone barrel method and ring specimen upsetting, ranges from 0.04 to 0.06 under isothermal conditions when glass lubrication is applied.

The reduction of contact friction and the uniformity of the temperature field within the blank contribute significantly to minimizing deformation heterogeneity. Differences in deformation behavior are especially pronounced when stamping blanks with a high surface area-to-volume ratio. For example, stamping of VTZ-1 alloy on a crank press using graphite-oil lubrication results in a microstructure that exhibits clearly defined dead zones at the contact regions with the tooling. In this case, the die was heated to 250 °C, while the initial blank temperature was 930 °C. In contrast, stamping on a hydraulic press using glass lubrication and heating both the die and the blank to 930 °C yields a blank with a uniform microstructure across the entire cross-section.

A significant advantage of isothermal deformation is the increased plasticity of the processed metal, which is associated with more complete softening processes and the healing of microcracks at reduced deformation rates. Figure 3.7 shows fractured specimens of VTZ-1 alloy after tensile testing. The test temperature was 850 °C, and the initial strain rates were $14\cdot10^{-4}$, $28\cdot10^{-4}$, and $112\cdot10^{-4}$ s^{-1}. When the strain rate was reduced by a factor of 8, the relative elongation of the specimens increased by 28–30%, while the relative reduction in area approached 100%.

A similar pattern is observed during upsetting. At a temperature of 780 °C and a strain rate of 0.15 s^{-1}, the maximum peripheral strain at which cracks appear on the lateral surface of the deformed sample is approximately 70%. Upsetting was performed on VT8 alloy specimens with a diameter of 15 mm and a height of 20 mm. Reducing the strain rate to 0.005 s^{-1} increases the maximum peripheral strain to 83%. As the temperature increases, the maximum deformation achievable in a single press stroke also increases. At strain rates ranging from 0.002 to 0.1 s^{-1}, the plasticity of VTZ-1 alloy at 800 °C and VT8 alloy at 850 °C remains virtually unrestricted. The samples can be upset up to 95% deformation without failure.

The establishment of isothermal conditions provides significant opportunities for deforming low-plasticity materials. For example, blanks made of Stellite were upset up to 60% deformation in a single press stroke without lubrication at a temperature of 900 °C and a strain rate of 0.005 s^{-1}. Under the same temperature and a strain rate of 0.02 s^{-1}, a gray cast iron specimen—despite the material being considered brittle under dynamic loading—was deformed up to 53%. Crack-free gray cast iron wires were produced using opposing pressure-free pressing. The deformation temperature was 900 °C, the drawing ratio ranged from 2 to 5, and the deformation rate was 0.1–0.2 mm/s. Isothermal deformation should find broad application in the processing of cast and powder-based blanks, as well as composite materials [13, 50].

Under isothermal conditions, the reduction in deformation force and work also leads to a decrease in the amount of heat generated as a result of the thermal effect of deformation. Due to the uniformity of deformation, the heat is evenly distributed throughout the volume of the workpiece, which is especially important when deforming metals whose structure and properties are temperature-dependent. In the absence of hard-to-deform zones and local overheating caused by the thermal effects of deformation, homogeneous deformation of the workpiece typically ensures maximum refinement of the material's structure, improved mechanical properties of the product, and enhanced uniformity of properties throughout the volume of the deformed item.

The absence of cooling of the workpiece and the reduction in specific deformation force under isothermal stamping conditions allow the deformation temperature to be lowered compared to

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conventional processes, enabling processing near the lower boundary of the alloy's workable temperature range. The decrease in deformation temperature, combined with the use of glass coatings, reduces the degree of interaction between the heated metal and the surrounding atmosphere.

The creation of isotheaarmal conditions contributes to an improvement in the dimensional accuracy of stamped workpieces due to the following factors:

a) a reduction in elastic deformation within the press–die system;
b) decreased fluctuations in deformation temperature, resulting in greater dimensional stability of the stamped workpieces;
c) reduction of residual stresses within the volume of the stamped product, leading to decreased distortion during heat treatment and cooling;
d) reduced thickness of the defective surface layer and improved surface quality of the workpiece.

Under isothermal conditions, it becomes possible to stamp workpieces with minimal or no draft angles, sharp section transitions, small radii of curvature, and minimal allowances for subsequent machining. As a result, significant savings in expensive metals can be achieved, along with a reduction in labor intensity associated with cutting and machining operations.

During isothermal deformation at low strain rates, the specific stamping force does not increase significantly with rising complexity of the workpiece geometry. Under certain temperature–strain rate conditions, complex-shaped components—such as a bladed disk—can be formed in a single press stroke. In such cases, metal consumption is reduced by more than a factor of two. Furthermore, the number of intermediate stamping operations is also decreased [51, 52].

An isothermal stamping process has been developed for heat-resistant alloys using specially prepared initial workpieces with a fine-dispersed microstructure.

Isothermal conditions expand the possibilities for selecting the optimal thermomechanical deformation regime. A reduction in deformation temperature or the absence of a sufficiently powerful press can be compensated by lowering the strain rate. Moreover, holding the workpiece under pressure in the die has been successfully applied, enabling the deformation of metals under Superplastic Forming (SPF) conditions.

LIST OF REFERENCES

1. А.А.Бочвар, З.А.Свидерская,. Явление сверхпластичности в цинк-алюминиевых сплавах // Изв. АН СССР, ОТН, 1945. - № 9,- С. 821-824.
2. Строганов Г.Б., Кайбышев О.А., Фаткулин О.Х., Мартынов В.Н. Сверхпластичност и износостойкост в машиностроении. «Алтекс». Москва, 2002 г. 320 с.
3. О.А. Кайбышев. Сверхпластичност промышленных сплавов. - М.: Металлургия, 1984. - 362 с.
4. Matmurodov, F. M., Boboyev, X. X., Nugmanov, I. N., & Mamirov, S. S. (2023, September). Analytical dynamic modeling of damping of a multi-hierarchical mechanical system and mobile power engine shaft with the help of multi-mass rheological models. In *Journal of Physics: Conference Series* (Vol. 2573, No. 1, p. 012044). IOP Publishing.
5. AMatmurodov, F. M., Turapov, E. I., Abduvaliyev, U. A., Boboyev, X. X., Abdurakhmanova, M. M., & Bakirov, F. A. (2023, March). Creating an innovative multi-operating wide-covered universal frame with different replacement machine. In *American Institute of Physics Conference Series* (Vol. 2612, No. 1, p. 050040).

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6. УА Абдувалиев, ШШЎ Мамиров, РТЎ Нуруллаев - Universum: технические науки, 2023. https://cyberleninka.ru/article/n/vliyanie-sherohovatosti-poverhnosti-shpindeley-na-zazelenenie-i-stabilnost-raboty-hlopkouborochnogo-apparata
7. U Abduvaliev, A Jumaev, R Nurullaev, A Ashirov… - International Conference on Reliable Systems …, 2024 , https://link.springer.com/chapter/10.1007/978-3-031-70670-7_25
8. U Abduvaliev, A Jumaev, R Nurullaev, S Jakhonov… - E3S Web of Conferences, 2024 . E3S Web of Conferences, https://www.e3s-conferences.org/articles/e3sconf/abs/2024/78/e3sconf_agritech-x_04013/e3sconf_agritech-x_04013.html
9. Р.Т. Нуруллаев. Теоретико-экспериментальные исследовния активности шпинделей. Материалы международной конференции. Наманган 23-24 сентября 2022 г.
10. Абдувалиев У.А., Мамиров Ш.Ш., Нуруллаев Р.Т. ВЛИЯНИЕ ШЕРОХОВАТОСТИ ПОВЕРХНОСТИ ШПИНДЕЛЕЙ НА ЗАЗЕЛЕНЕНИЕ И СТАБИЛЬНОСТЬ РАБОТЫ ХЛОПКОУБОРОЧНОГО АППАРАТА // Universum: технические науки : электрон. научн. журн. 2023. 5(110). с.46-54 URL: https://7universum.com/ru/tech/archive/item/15576
11. Абдувалиев У.А., Нуруллаев Р.Т., Жахонов Ш.А., Влияние Физико-Механических Свойств Хлопчатника И Рельефа Поля На Стабильность Работы Шпинделей Хлопкоуборочной Машины. Vol. 44 (2024): Miasto Przyszłości. https://miastoprzyszlosci.com.pl/index.php/mp/article/view/2391
12. Абдувалиев У.А., Нуруллаев Р.Т., Жахонов Ш.А., ACADEMIC INTERNATIONAL CONFERENCE ON MULTI-DISCIPLINARY STUDIES AND EDUCATION. ВЛИЯНИЕ ШЕРОХОВАТОСТИ ПОВЕРХНОСТИ МЕТАЛЛА НА КОЭФФИЦИЕНТ ТРЕНИЯ ХЛОПКА-СЫРЦА ПРИ РАЗЛИЧНЫХ НОРМАЛЬНЫХ ДАВЛЕНИЯХ φ(N). С.69-73 https://aidlix.com/index.php/us/article/view/40
13. Абдувалиев У.А., Нуруллаев Р.Т., SHPINDEL SIRTIDAGI TISHLARNING JOYLASHISHI ZICHLIGI VA BIR TEKISDALIGINI ANIQLASH. МЕХАНИКА ВА ТЕХНОЛОГИЯ ИЛМИЙ ЖУРНАЛИ, 2023, № 2 (11) С.46-54 https://mextex.uz/file/mex-tex-14.pdf