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Development of Energy-saving Technological Process of Shafts Forging Weighing More Than 100 Tons without Ingot Upsetting

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The technological scheme for forging of heavy ingots by means of special figured block head is represented in the article. Its influence during the ingot drawing is described. Appliance of specialized tools and cooling-down provided receipt of metal required characteristics and positive results in ultrasonic testing. Combined technological solution gives the opportunity to extend the critical forgings assortment.

Keywords: FORGING, SHAFT, FORGED PIECE, TECHNOLOGY, PROPERTIES

Introduction

An increase in the capacity of metallurgical and mining industries in Ukraine and in the world requires the development and use of new energy-saving processes of fabrication of forging workpieces for the parts of responsible destination, the weight of which exceeds 100 tons. Such forgings are unique, they meet high requirements in quality of products according to ultrasonic testing (UST) and homogeneity of mechanical properties throughout the volume of parts. Under current conditions prevailing in Ukraine and in the world it is required to develop new energy-saving processes of forging of large ingots for improving castings quality and reducing the cost of forging.

The necessity of the development of new forging technological processes is caused by the following factors as the rise of the output of forgings and their competitiveness. New, more complex orders require special investigations for the development of rational technological processes to obtain forgings of high quality without purchasing new forging equipment. One of the problems concerning forging of large ingots is impossibility of realization of power-intensive operation of forging upsetting. The classical technological process of shafts forging from ingots without the use of upsetting operation does not provide the recommended metal deformation which is a mean-integral factor of forging quality. Therefore the technological processes of forging of large ingots of important destination without upsetting operation have not been executed at "Novokramatorsky mashinostroitelny zavod" (NKMZ). The working of cast structure without forging upsetting is possible by using either shortened ingots with ratio H/D=0,8…1,2 [1] or special tool with convex working surface [2, 3] and certain thermomechanical drawing modes of forging workpieces of classical configuration. The shortened ingots make it possible to obtain the desired dimensions of forgings and the prescribed degree of deformation and the special tool and modes of forging – a scheme change of the stress-strain state for working of ingot cast structure, elimination of its defects and improvement of mechanical properties uniformity in the forging volume.

An alternative for the exception of upsetting operations is forging by convex dies [4, 5]. A flat plate [3] or similar convex die are used as a lower tool. Forging of an ingot is accomplished on four sides with cooling of the worpiece surface during the forging process, with a consequent effects on the rigidity scheme of the stress state in the axial defective area of the ingot and this will contribute to elimination of axial defects. Forging by a convex die will allow to reduce the zones of difficult deformation which occur while forging by flat dies through the square, resulting in improvement of strain distribution in the workpiece body and the finishing forging of a workpiece with cavities on the side surface by cut-out dies will assist in the emergence of macroshear strains [6] improving the working of ingot cast structure.

The purpose of the work is investigations of the effect of convex dies and special modes of forging on working of metal structure without the use of upsetting operation. As a result of the research it is necessary to determine the possibility of implementation of the new forging process without upsetting in terms of metal structure working. The research was carried out by applying of commercial finite-element program DEFORM 3D (temporary license for Forging Department of Donbas State Engineering Academy) which, with a high degree of reliability, allows to simulate forging processes [7], with a consequent exclusion of experimental investigations for searching optimum condition of producing forgings of responsible destination. The program enables to take into account the non-uniform temperature field during the forging process that is an essential condition for improving the scheme rigidity of the stress-strain state.

Method of research: temperature range of forging simulation 1200-850◦C; material-steel 38CrNi3MoV, ingot weight – 170 tons. The distribution of logarithmic strain intensity is shown in **Figure 1**.

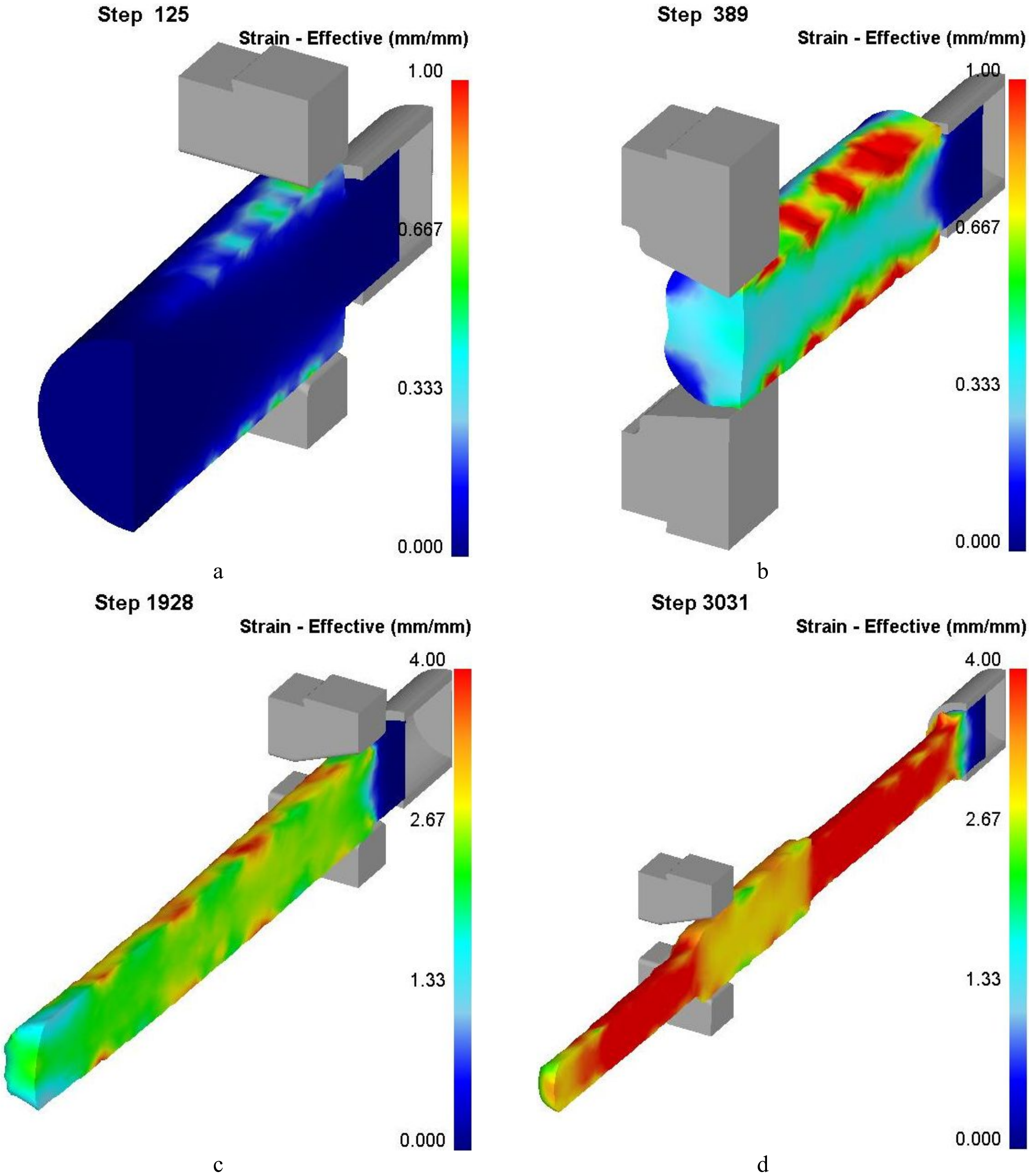

Figure 1. The distribution of logarithmic strain intensity

The forging technological process consists of the the following main operations: forging of an ingot to the diameter 2200 mm with the length of 4200 mm (**Figure 1a**), deformation of a workpiece by complex wedge die to the depth of ≈ 200…300 mm (**Figure 1b**), forging by cut-out dies to the diameter of 1400 mm and length of ≈ 9000 mm (**Figure 1c**), finish forging (**Figure 1d**).

The results received show that forging of ingot faces contributes to accumulation of strains of the order of ≈ 0,4…0,5 (**Figure 1a**) allowing to work slightly the ingot surface structure. The working of central layer of the ingot to the deformation value of ≈ 0,4 provides the process of deformation by convex wedge die (**Figure 1b**) on four sides. The workpiece surface accumulates deformation of the order of ≈ 1,0. Forging by cut-out dies with an angle of 1350 (**Figure 1c**) also contributed to the better working of the central layers (deformation value is ≈ 2,2…2,7). forging of part shoulders provides more accumulation of deformation (deformation value is >3,0 **Figure 1d**) with relatively uniform distribution along the length. The barrel of a shaft receives less working in comparison with necks approximately by 20% but the deformation distribution is uniform that is an evidence of sufficient working of metal structure to obtain high quality and eliminate inner defects. So, it has been established that the deformation by a convex wedge die makes it possible to provide the distribution of deformation centre to the defective zone of the ingot with the workpiece diameter more than 2000 mn, which is impossible for forging by combined dies.

By the results of the research in order to guarantee the fabrication of high-quality forgings in accordance with the customer requirements the technological process of forging shafts on the hydraulic press of 100 MN was developed and introduced into production at NKMZ. The upsetting operation was replaced by drawing of a workpiece with cooled surface by convex wedge die with the finishing forging by cut-out dies resulting in an improvement of axial channel working and use of shearing strains for grinding of cast structure.

Comparison of the results of the simulation of ingot forging process with the actual production technology of forging shafts from the ingot of 170 tons has shown their high convergence. Deformation and thermal state of the workpiece during the forging process correspond to the real production data.

The dimensions of the workpiece at each operation coincide with the real data with an accuracy of 3-5%. The temperature of billet after forging was ≈ 850°C, the average temperature by the results of numerical simulations was ≈ 830 °C. According to the proposed technology the shaft forgings of manganese steel from ingots of 170 tons, forging mass of 106 tones, total length of 14700 mm, providing the required level of mechanical properties and the requirements of UST were forged and delivered to the customer. Requirements and the results of ultrasonic testing of billets obtained are shown in **Table 1**.

Table 1. Results of ultrasonic testing

Name	Ingot weight, tons	Number pieces	Ultrasonic testing	Result
Shaft	170,0	7	Ultrasonic testing of EN10228-3 (1,0-0,3)R – class 2 (Ø5 mm); (0,3-0,0)R – class 1 (Ø8 mm)	deviation were not detected
Axis	170,0	4	allowed accumulation of discontinuity to Ø10 mm	deviation were not detected

Conclusions

The stress-strain and thermal state of a workpiece during the forging process was investigated with the application of finite-element program DEFORM 3D. The new energy-saving technological process of forging of large ingots by convex dies without upsetting operation was developed. The results received show the uniform deformation distribution in the forging body with sufficient level of deformation localization in the axial zone of the ingot to eliminate inner defects while forging the workpieces of large diameters by convex dies. The developed technological solution enabled to extend the range of forgings, to increase the competitiveness of an enterprise through the provision of high-quality products.

The unique technology of forging of large worpieces of important destination from very large ingots without upsetting operation with the use of special convex forging dies and thermomechanical conditions of deforming was introduced. As a result, the output of forging of large shafts has increased by 30%, the number of heatings was reduced from 7 to 5. The forgings received meet the requirements of the desired mechanical properties, ultrasonic testing, and part drawing.

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Разработка энергосберегающего технологического процесса ковки валов массой более 100 т без осадки слитка

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В работе представлена технологическая схема ковки крупнотоннажных слитков специальным фигурным бойком. Описано его воздействие при протяжке слитков. Использование специализированного инструмента и подстуживания обеспечило получение требуемых свойств металла и положительные результаты по ультразвуковому контролю. Комбинированное технологическое решение дает возможность расширить номенклатуру поковок ответственного назначения.