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Wedge - rolls rolling of hollowed parts

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ABSTRACT

Purpose: Presentation of the possibilities of application of a new manufacturing method, called wedge rolls rolling (WRR) in forming of axi – symmetrical hollowed parts.
Design/methodology/approach: The research work was done in a specially designed laboratory rolling mill LUW-2. During the research, hollowed parts from steel were rolled in hot forming conditions. Basic kinematical and force parameters of the process were noticed during rolling.
Findings: On the basis of the conducted research it was stated that the WRR method could be used for forming of hollowed parts with the precision compared with the precision obtained in the typical cross wedge rolling processes (CWR). At the same time, it was proved that this method could be used for rolling from billets with the wall thinner than the wall given in the CWR.
Research limitations/implications: The research were limited to the wedges with spreading angles within range of $\beta = (5° \div 9°)$, with the constant values of forming angle $\alpha = 30°$ and relative reduction ratio $\delta = 1.45$. In the future, it is planned to analyse the influence of changes of angle α and relative reduction ratio δ on the WRR process.
Practical implications: The conducted research can be used for designing of a new industrial method of metal forming of hollowed parts.
Originality/value: The innovation of this solution is based on the application of only one wedge for forming. Because of that, the WRR method is cheaper for implementation than used so far CWR processes. This method can be applied mainly in automotive and aviation industries.
Keywords: Plastic Forming; Wedge rolls – rolling; Hollowed parts; Experiment

1. Introduction

Hollowed products are more and more widely applied in the modern constructions. These hollowed parts, at the required by constructors stiffness and resistance, allow for the reduction of weight of up to 30% in comparison with the full parts. This leads to considerable material savings, and in the case of vehicles (cars, building machines, agriculture machines etc.) it results in limiting the fuel consumption and pollution and in lowering the operating costs. The main buyers of this type of parts are automotive, aircraft and engineering industries. The formed hollowed parts, including stepped shafts, can be made in many different ways. Among present manufacturing technologies of hollowed parts, there should be mentioned: traditional forging and punching, rotary forging, swaging, internal forming at high pressure, cold drawing, cold drawing with deep drilling. A new method of hollowed parts manufacturing has recently gained popularity. This method is called cross-wedge rolling (CWR) [1].

The most widely applied in industry is the cross rolling method with flat tools put vertically or horizontally [2]. One of the advantages of this method is lower (than in the case of two wedges method- which is also very popular) cost of tools manufacturing. The CWR process requires precise technology designing (the choice of tools shape) in relation to the assumed scope of manufacturing. The final, each time designed tools shape is usually preceded by numerical analyses, which results are considered during designing process. This results in relatively high costs and time consumption of the assumed implementation. Such a precise choice of tools shape leads, however, to lower assortment flexibility and makes this method appropriate in

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the case of mass or large-lot production applied e.g. in automotive industry. The CWR technology used for forming of hollowed shafts provides large limitations within the range of inequality in distributions of products walls thickness and ovalization of shafts cross sections. Among the dangerous phenomena are: the risk of slipping or internal deformities and the necking of the formed part. All these phenomena considerably reduce the range of useful tools geometrical parameters and the applied in the process reduction ratio degrees [2, 3]. The presence of instability of the CWR process is usually accompanied by variations of force parameters. Hence, after detailed analysis of this technology, it is justified to make further research on cross rolling processes of hollowed parts in order to increase the process stability and lower the implementation costs in industrial conditions. It seems that a new method of wedge-rolls rolling confirms these assumptions.

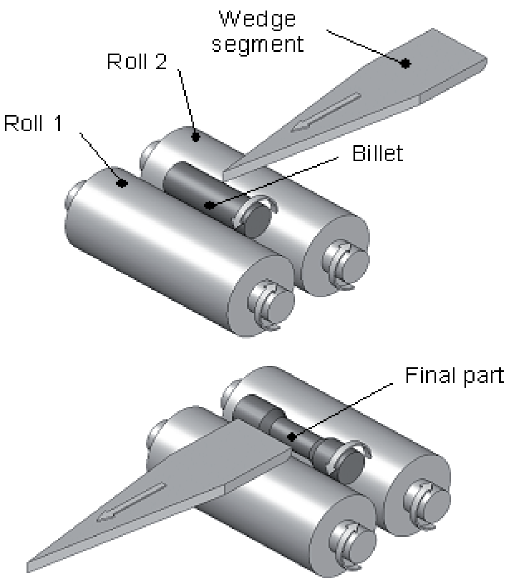

Fig. 1. The schema of wedge rolls rolling (WRR)

2. Characteristic of the wedge-rolls rolling method (WRK)

Forming by means of three working tools in form of rolls with rolled wedges [4, 5] is a CWR method rarely used in industrial conditions. The advantages of this method are elimination of guiding devices keeping the workpiece between rolls during forming and more favorable stress and strain schema in the rolled part. This results in the high precision of the obtained in that way parts within wide range of forming parameters. Hollowed shafts, impossible to form with the use of two tools CWR methods, are formed without difficulties and dimensional tolerances remain within very small limits. However, the large costs of implementation of this technology are connected with protection of the appropriate unit and three wedge rolls manufacturing.

Hence, it is necessary to find alternative solutions for the three wedges method, yet, characterized by similar forming schema.

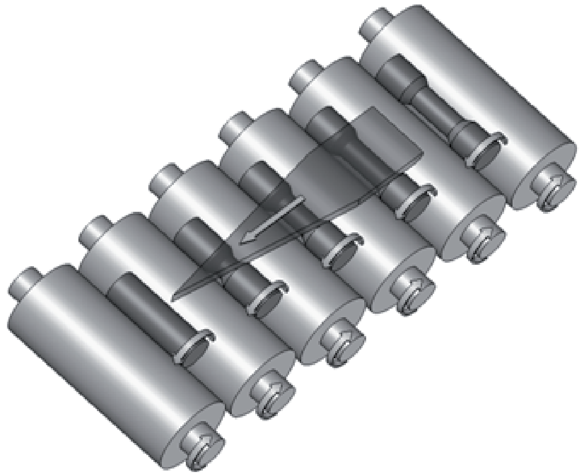

Fig. 2. The schema of wedge rolls rolling of more then one formed part

The method which fulfils these conditions and appears to be a promising technology of hollowed parts forming is the wedge-rolls rolling method (WRR), which was worked out at Computer Modelling and Metal Forming Department of Lublin University of Technology [6]. The WRR method is based on forming of axi-symmetrical products with the use of only one forming wedge and two supporting and driving rolls (Fig. 1). The billet is put on rolls which are driven and move with the same velocity (in the direction opposite to the wedge movement). These rolls cane be made as smooth or profiled rolls. The wedge moving with plane motion cuts into material and forms at its diameter a necking of the assumed dimensions. In comparison with the used up to now methods CWR, the wedge-rolls rolling of hollowed products has many advantages which mainly include:

- lower costs of implementation, resulting from the application of only one flat wedge;
- making easier the removal of scale from the rolling mill working surface;
- the increase of productivity due to the WRR schema implementation (Fig. 2), allowing for forming many products.

The presented above advantages of the WRR method show that this method can be used in factories producing smaller and more flexible manufacturing series than in the case of typical, mass production recipients of CWR in its different variants.

3. WRR test stand

Experimental research were realized in a specially designed and made laboratory rolling mill LUW-2 shown in Fig. 3. This rolling mill consists of a body, upper slide, rolls gear and power transmission system. The upper slide drive is realized by means of hydraulic cylinder, the rolls gear is powered by electric motor by means of chain transmission and worm gear. Step-less regulation of rolls rotary velocity was possible due to the application of inverter. The rolling mill was equipped with a special digital measuring system.

In order to determine the basic parameters and relations during the WRR process of hollowed products, in the research the interchangeable three wedge tools with various spreading angles (β= 5º, 7º, 9º). At the same time the value of wedge side walls inclination angle α=30º was constant all the time. In the research were used billets from steel of C45 type of external diameter d_0= 25mm and of internal diameters *d*=7.5; 10.0; 12.5; 15 mm. These billets, heated to the temperature 1150ºC, underwent rolling in order to reduce the diameter up to d_F=17.2mm.

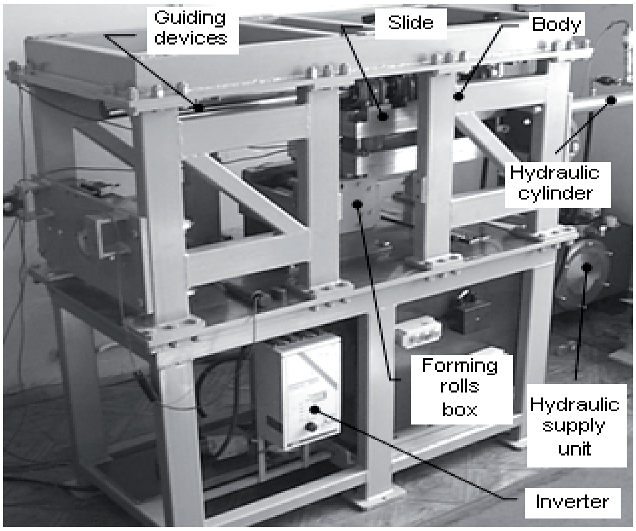

Fig. 3. Laboratory rolling mill LUW-2 equipped with forming rolls box for the WRR process

4. Results & discussion

The research aimed at quality and precision of the formed hollowed parts. Wall thickness distributions and the size of ovalization in the cross sections of hollowed parts were analyzed. During research were also checked the distributions of tangential and radial forces in relation to forces present during the WRR of full parts.

According to Fig. 4, in which are presented determined in experiments wall thickness distributions in parts rolled at different values of wedge angle β and internal holes diameters *d*, it was stated that the shafts wall after forming underwent thickening. Yet, the lower the billet wall thickness was, the bigger the relative thickening was obtained. Moreover, it was noticed that in some places (in the part conical zones) the wall thinning appeared. This effect increased when the wall thickness of billet was enlarged and values of angle β were lowered, leading to the presence100 of undesired necking. For billets with the thickest wall (*d*=7.5 mm and *d*=10.0 mm) relative reduction of wall thickness was in the conical zones as follow: 18% and 16% (for the wedge with angle β= 5º). In both cases, the forming with tool with angle β= 9º proved to be impossible due to the presence of uncontrolled slipping and squeezing of workpiece.

The second phenomenon analyzed in the paper was the cross section ovalization of the rolled step of hollowed part. During forming by means of WRR method workpieces cross sections undergo ovalization. This disadvantage, in the properly designed processes, is eliminated to a certain extent (to the accepted value). Analyzing the changes of this section shape, it is stated that the critical moment of the process (because of the ovalization) is in the transition from the knifing phase to the forming one. At this point exists a probability of the appearance of uncontrolled slipping leading to the squeezing of workpiece (Fig. 5). In this figure are presented ovalization values measured for the analyzed cases of WRR from hollowed billets and for comparison, from full ones.

The analysis of data from this diagram shows that the application of wedges with spreading angles β= 5º and β= 7º leads to the appearance of small ovalization of the cross section of the rolled part. Its value for the tool with angle β= 5º was not larger than 0.4 mm in all analyzed cases. However, the application of tools with angle β= 9º led to the increase of ovalization in all cases or to the presence of uncontrolled slipping and squeezing. It should be also taken onto consideration that the observed ovalization values for parts formed by means of WRR method with wedges with angles β= 5º and β= 7º are within permissible deviations of shape. According to the guidelines of supplier of rolling mills for CWR – the Czech company Šmeral – the permissible tolerances of manufacturing for the analyzed case of this diameter are as follow: $\phi 17.2^{+0.6}_{-0.3}$.

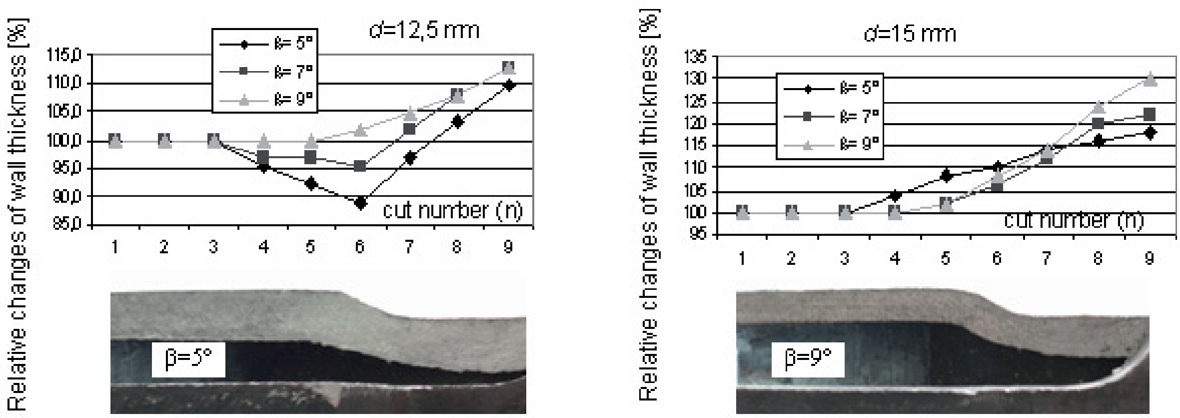

Fig. 4. Relative changes of wall thickness in cross cuts of wedge rolls rolled hollowed parts

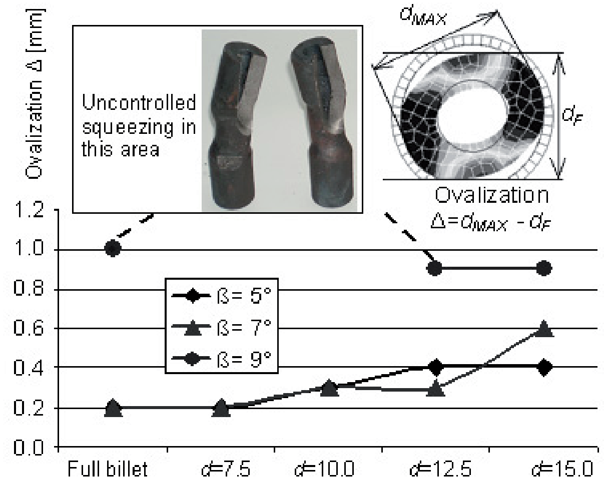

Fig. 5. The obtained values of cross cut ovalization of rolled parts

In the Fig. 6 are presented distributions of forces in the WRR processes in which hollowed billets and wedge segments with angle β= 5º were used. In this case, the enlarging of billet wall thickness led to the increase of radial force, which reached maximal values for the full billet. The enlargement of spreading angle β changes the situation. During forming with wedge with angle β= 7º, large forces than in the case of rolling from full billet were measured while rolling from hollowed billets with internal diameters d=7,5 mm and d=10,0 mm. This happens because of faster and larger deformation of tube cross section than it is in the case of forming from full billet. The present deformity increases resistance of workpiece rotary movement, which in consequences, leads to the increase of radial and tangential forces. It provokes decrease of the precision of parts forming. Hence in the WRR cases of hollowed parts, relatively lover values of spreading angles β should be assumed than those recommended during forming of full parts.

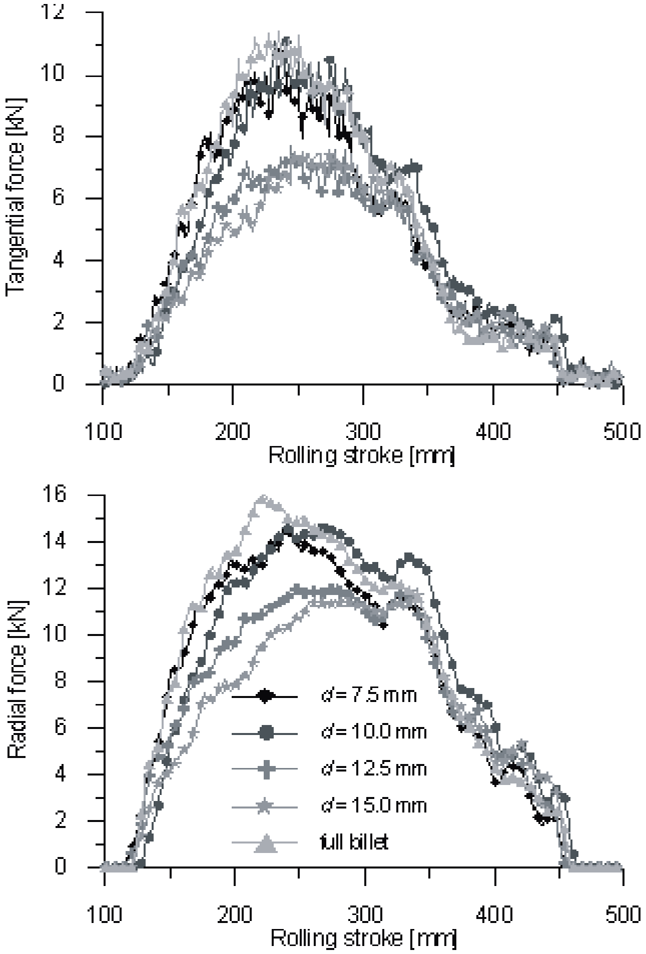

Fig. 6. The distributions of tangential and radial forces during WRR process of hollowed and full parts at β = 5º

5. Summary

In the result of experiments, it was stated that the application of WRR allows for forming of hollowed parts of quality level comparable to quality obtained in traditional CWR processes of full parts. It was also noticed that the WRR method makes possible enlarging the scope of rolling to forming from billets with lower (as in the CWR method) wall thickness. However, it was stated that lowering of wall thickness of hollowed billets led to a larger ovalization of the final part which limited that technology to a certain extent.

Obtaining the lowest ovalization values of the parts cross section is possible when tools with small values of angle β are used. The result of grooving ovalization is enlargement of value of force necessary for putting the workpiece into rotary movement.

The possibility of forming a few parts at the same time leads to the increase of productivity. The lower costs of implementation of this technology are a favorable factor in popularization of this new method of hollowed parts manufacturing.

References

[1] J. Bartnicki, Z. Pater.: The aspects of stability in cross – wedge rolling processes of hollowed shafts, Journal of Material Processing Technology 155-156C, 2004, 1867-1873

[2] Z. Pater: Cross wedge rolling of axi-symmetrical parts, Ed. Lublin University of Technology, Lublin 2001

[3] J. Bartnicki, Z. Pater: The influence of tool geometry on the CWR process of hollowed shafts. STEEL-GRIPS Journal of Steel and Related Materials, Suppl. Metal Forming, 2, 2004, 103-107

[4] A. Danno, T. Tanaka: Hot forming of stepped steel shafts by wedge rolling with three rolls, Journal of Mechanical Working Technology 1984 no. 9, 21-35

[5] J. Bartnicki, Z. Pater: Numerical simulation of three-rolls cross-wedge rolling of hollowed shaft. Journal of Materials Processing Technology 164-165, 2005, 1154-1159

[6] Z.Pater: Comparative analysis of wedge rolls rolling schemata,, Obróbka Plastyczna Metali, nr 5, 2004, 13-24