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Numerical Modelling of the Forging Process of Bars with Circular Section from Scrapped Rails Heads

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KEY WORDS

Elongating forging process, rail, finite element method, rolling in impressions

ABSTRACT

This paper presents the results of research works concerning processing of scrapped rails heads into bars with circular sections in the elongating forging processes. The formed semi-finished products will be used as billet in the cross-wedge rolling and skew rolling processes of balls applied in ball mills. Numerical analysis were made with the application of finite element method (FEM) in the conditions of three - dimensional state of strain, using the commercial software DEFORM 3D. The shape of rolled semi-finished products was analyzed in calculations, temperatures distributions and the process force parameters were determined. The possibility of using forging techniques for the processing of worn out rails was also confirmed. The results of numerical simulations were verified in industrial conditions.

1. Introduction

Large competition that can be observed in worldwide industry imposes searching for manufacturing methods which will allow for reduction of production costs and which will lower the price of finished products at the same time. Because of this tendency, metal forming processes meet with a large interest as they are characterized by large material, energy and labour savings in comparison with other manufacturing methods.

Considerable savings in costs of manufacturing should be searched for also in using relatively cheap billet materials in the form of various functional scrap, which, in many cases after the initial processing, can be applied as billet of full value. A large group of such materials constitutes exploited rails, which in a traditional processing were used by steel plants and remelted. A more profitable solution is partial or even total usage of this raw material. Such an utilization process of worn out rails is cheaper than the traditional one. It also allows to reduce energy and material consumption, and in that way it protects the natural environment. Steel used for rails production of R200 type is characterized by relatively high resistance properties. Therefore, it is fully justified to make use of it for various types of design elements.

At the Department of Metal Forming and Computer Modelling at Lublin University of Technology, the way of forming of scrapped rails with marking S60 into various balls used in ball mills for size reduction of aggregate was worked out. The proposed technology is mainly based on combination of different rolling processes, which, in comparison with other forming methods, are characterized by a number of technical and economical advantages [1-5]. Only the head, which is cut from the rest of the rail,

is used in this worked out technology. It is, however, possible to use the rest of the rail fragments as semi-finished products for the further processing. In order to make the process of balls forming possible, the cut head undergoes the process of elongated rolling into round bars with required diameter dependent on the manufactured balls size. To confirm rightness of the worked out technology, numerical simulations of the scrapped rails S60 heads rolling process in the rolling mill were made, and later the process was realized in industrial conditions.

This paper discusses the results of numerical analysis on the basis of finite element method (FEM) of the elongated forging process of scrapped rails heads into bars with circular sections. The process was realized in four roll passes, applying the impressions: oval-circle-oval-circle. Such a schema of rolling allowed for obtaining round bars of two diameters ϕ_{50} and ϕ_{42} .

2. Geometrical model of scrapped rails heads forging

Numerical simulations of the elongated forging of bars with round sections from scrapped rails heads in four impressions were made by means of finite element method (FEM) in the conditions of three-dimensional state of strain, using the commercial software DEFORM 3D in version 10.0. The shape and dimensions of bars rolled from scrapped rails heads are given in Figure 1.

For the analysis needs, four geometrical models of rolling for each of the roll passes were built. For the process of rolling in the first impression-oval, the model shown in Fig. 2 was used. This model consists of two equal segments-1 and the billet - 2. On the segments circumference oval impressions were made. The billet for the first roll pass was the rail S60 head of the length $L = 250$ mm, cut at the height 50 mm. Segments rotated in the opposite directions with the constant velocity $n = 65$ rot/min. The billet was modeled by means of four – nodes tetragonal elements. The billet material model-steel R200, from which rails are made, was determined in plastometric research works [6]. It was assumed in simulations that the billet was heated to the temperature 1150°C , yet, the tools temperature during the process was constant and equal 200°C . Other parameters considered in calculations included: friction factor on the metal-tool surface of contact

$m = 1$, heat exchange coefficient between material and tool - $10 \text{ kW/m}^2\text{K}$ and between material and the environment - $0.2 \text{ kW/m}^2\text{K}$.

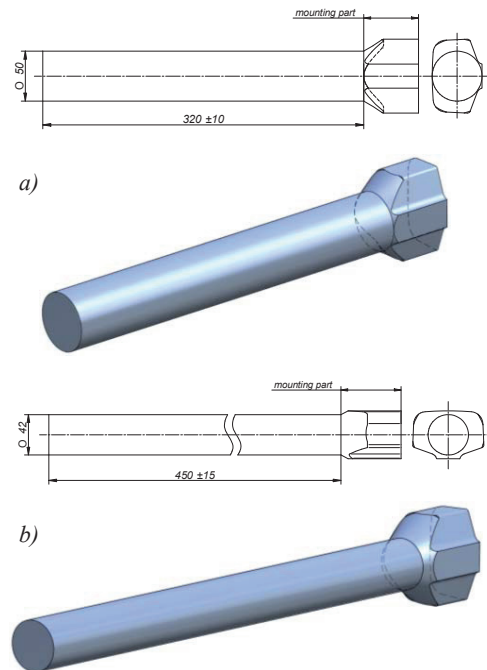


Fig. 1: Shape and dimensions of bars rolled from scrapped rails heads :a) in the second roll pass, b) in the fourth roll pass

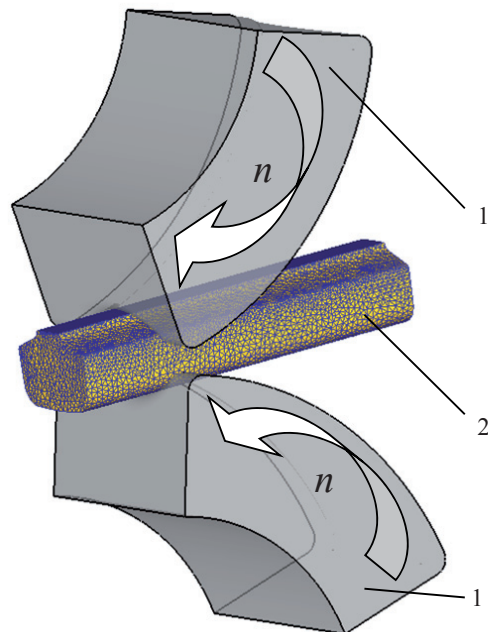


Fig. 2: Geometrical model of scrapped rail S60 head forging process in the first roll pass in oval impression, (description in the paper)

In other roll passes the applied geometrical models differed from the first one in terms of impressions shape on segments, segments length and type of the used billet, which was the semi-finished product rolled in the former impression and imported with the whole temperature history. This allowed for analyzing of shape and temperature changes during the whole rolling process of scrapped rail head into bars with circular sections. The determined nu-

merically shape of semi-finished products obtained in simulations of forging process in all four impressions respectively is given in Figure 3. After forming of semi-finished product in the first roll pass, it was transmitted into the next roll pass with the rotation 90°. In this way, the complete cycle of the rolling process of bars in elongated rolling mill was simulated.

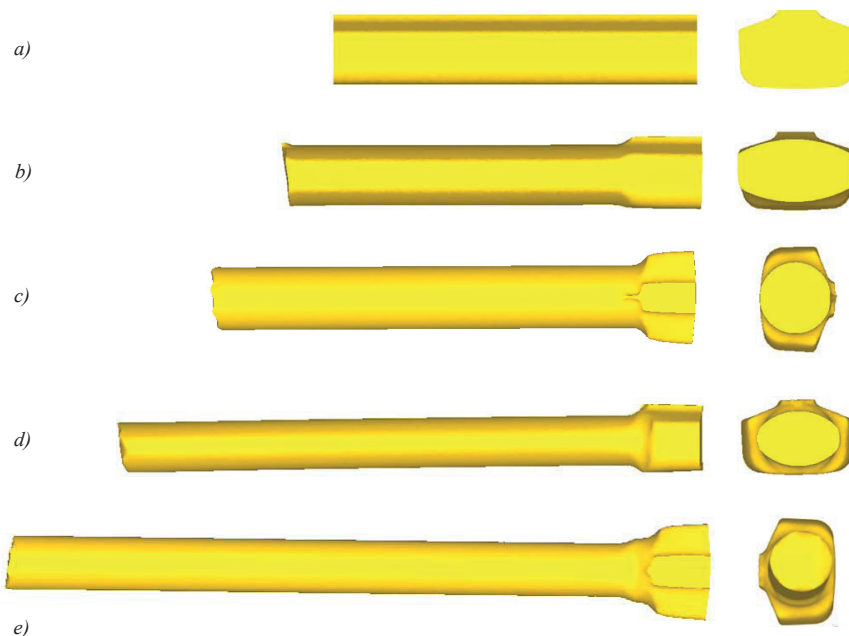


Fig. 3: Shapes of bars rolled in the rolling mill in four impressions determined in FEM simulations: a) billet, b) semi-finished product rolled in the first impression (oval), c) semi-finished product rolled in the second impression (circular $\phi 50$), d) semi-finished product after the third roll pass (rolled in the oval impression), e) semi-finished product rolled in the fourth roll pass (circular impression $\phi 42$)

Due to the fact that research works were conducted in forging conditions, in which the billet is provided into the workspace by means of forge overlaps and held in them through the whole process, unrolled part of the rail head was left at the beginning of the formed bar, allowing for gripping-so called "mounting part". It constitutes technological allowance, which is cut after the rolling process. Determined numerically semi-finished products (Fig. 3) are characterized by large shape convergence in relation to tools assumed at the designing stage. The rightness of solutions considered in numerical simulations was confirmed during industrial tests of rolling of bars from scrapped rails heads. Semi-finished products shapes rolled at four roll passes in the rolling mill are presented in Fig. 4.

Shapes of the formed semi-finished products

are relatively smooth and faultless (no lapping, cracks or deeper indentation were observed). The obtained products are characterized by a relatively large repeatability of shape and dimensions. The bars formed in all four roll passes have deformed head surfaces, which appear in the result of uneven metal plastic flow. Deformed edges of the bars, similarly as in the case of technological allowance in the form of mounting part, will be removed in the further operations and they do not act on the products quality.

During numerical simulations, the temperatures changes of the formed band were analyzed and later presented in Figure 5. The temperature is a crucial parameter of the process. It influences directly the size of deformation resistance, strain intensity and the size of obtained products.



Fig. 4: Shape of semi-finished products formed in four roll passes: a) billet, b) semi-finished product rolled in the first impression (oval) c) semi-finished product rolled in the second impression (circular $\phi 50$), d) semi-finished product after the third roll pass (rolled in the oval impression), e) semi-finished product rolled in the fourth roll pass (circular impression $\phi 42$)

The observed decrease of temperatures is relatively small and has a rather superficial character, which can be explained by contact of the hot billet with cooler tools. However, in central areas of the rolled semi-finished products, the temperature is close to the initial value (1150°C). This is the effect of heat generation in the result of plastic deformation. High value of the temperature of the bar rolled in the last roll pass (above 1000°C) allows for the realization of the next stage of scrapped rails heads processing-rolling of balls in a cross or skew rolling mill, without the necessity of repeated billet heating. Such a process of balls manufacturing allows also for limiting the amount of energy needed and the scale.

During working out of technology, the possibility of proper determining of the process force parameters becomes an important issue. On the basis of these parameters it is possible to choose an appropriate forging aggregate, designing works on

construction of tools and devices necessary for the process realization are also easier.

Distributions of moments determined numerically in simulations of the forging process in four impressions are given in Figure 6. These distributions have similar character. After a rapid increase of the moment at the initial stage, which is connected with the increase of the roll gap surface, stabilization of the moment value takes place - the stage of the defined rolling. Next, at the final stage, moments decrease rapidly, which is the result of reduction of the surface of segments pressure on the formed metal.

The main difference between the presented distributions is connected with maximal values of the rolling moments in particular roll passes.

It can be observed that these moments values depend on the process geometrical parameters. (rolling reduction, elongation, section loss). The largest strain coefficients were assumed during forging in

the second roll pass. Hence, in this roll pass the largest moment was noticed.

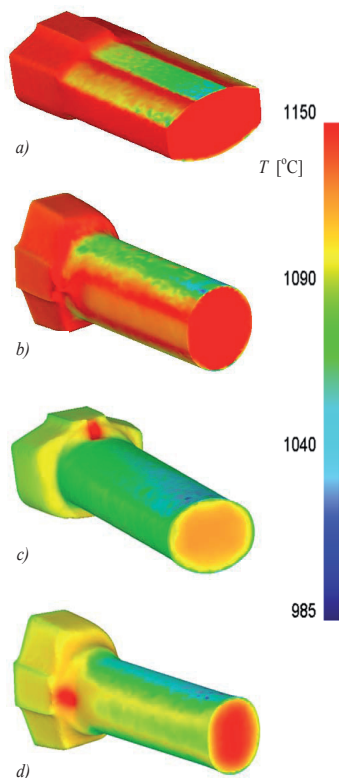


Fig. 5: Temperatures distribution on the surface and cross section of rolled bars determined by means of FEM: a) in the first impression, b) in the second impression, c) in the third impression, d) in the fourth impression.

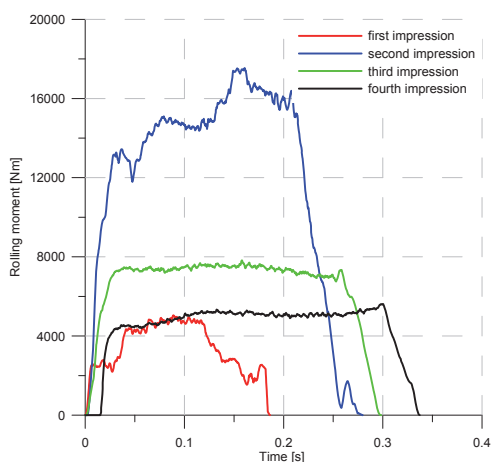


Fig. 6: Distributions of rolling moments of scrapped rails heads in four roll passes, determined by FEM.

3. Summary

The conducted numerical calculations of elongated forging process, later verified in industrial conditions, confirm the possibility and the rightness of processing by means of this technology of exploited rails into semi-finished products used as billet in balls forging processes. The obtained results allow to think that the balls forming process can be realized directly after bars rolling, without the necessity of additional heating. It will make possible reducing energy consumption and shortening time of the final product manufacturing.

Unfortunately, in the forging process a large waste (mounting part) is present, which makes full usage of the material impossible (material yield in this method equals about 80%). Additionally, the time of semi-finished products forming prolongs and the necessity of additional allowance cutting appears. This considerably lowers the process profitability. Therefore, in forming of bars from scrapped rails on industrial scale, the process of metallurgical rolling in shape mills duo should be used. This will guarantee the increase of the process effectiveness and precision of the obtained products at minimal material losses.

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