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DESIGN OF MANUFACTURING OF *WELDING NECK* TYPE RINGS

1. INTRODUCTION

Design of the efficient technology for a new ring or a new material usually requires a number of the experimental trials in the industrial conditions, what involves substantial costs. Essential decrease of the number of the industrial experiments can be obtained by application of numerical simulations, which allow evaluation of the metal flow, heat transfer and strain distribution for various technological variants. Thus, analysis of processes of preform shaping and ring rolling on the Thyssen-Wagner RAW 125-100 mill [1] was the main objective of this project. Rolling of shaped rings in the radial-axial mill creates additional difficulties, which are not observed during rolling of rectangular rings. Rolling of *welding neck* (according to DIN 2632-2635) type rings (Fig. 1) is a particularly difficult process. Obtaining of required shape and dimensions of final product, which satisfy the technological demands regarding further grinding operations, is the main criterion for the ring rolling process. Shape of the preform, shape of the

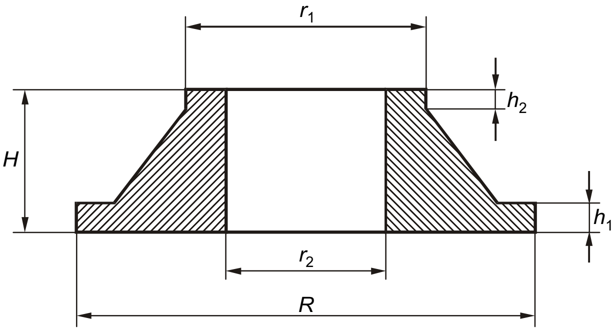

Fig. 1. *Shape and dimensions of Welding Neck type ring*

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*** M.Sc., Ing.; Bankowa Steelworks, Dąbrowa Górnicza, Poland ring, steel chemical composition, rolling velocity, reductions in the vertical and conical rolls and friction conditions are the main parameters, which influence the process of ring manufacturing.

Analysis of correlation between the mentioned above independent process parameters and properties of the final product has to be based on the numerical simulations of the process. There are finite element models of the ring rolling process available, see for example [2, 3]. The complex numerical model developed by the authors covers all operations involved in the ring manufacturing process, namely, upsetting, piercing and rolling. This model is described in detail in [4–8]. Results of simulations of rolling of the *welding neck* 20″ and 24″ rings are presented in this paper and they allow evaluation of relation between the independent process parameters and the final product shape and properties. Validation of the model was performed by comparison of the results with the experimental data acquired during industrial runs. Software ***RRCharge*** [4] was used for preliminary analysis of the shape of preforms. Simulations of processes of upsetting, piercing and rolling were performed using ***RingRoll*** [5–8] software.

2. TECHNOLOGICAL PROCESS OF *WELDING NECK* RING ROLLING

Figure 2 shows schematically the process of ring manufacturing. Technological process of manufacturing of *welding neck* rings is composed of selection of the billet, heating of the billet, manufacturing of the preform by upsetting of the billet, piercing and shaping of the final ring by rolling in the radial-axial mill. In the process of radial-axial rolling material is deformed in the two pairs of rolls. The first pair is composed of the non-driven mandrel and driven main roll, both of them are vertical. The second pair is composed of the two, individually driven conical rolls, which reduce the height of the ring.

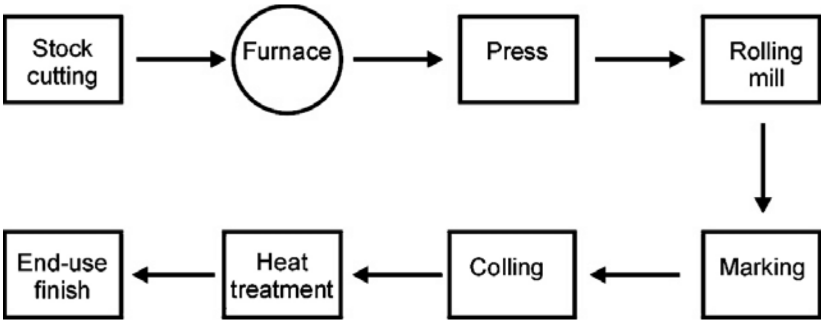

Fig. 2. *Scheme of the ring manufacturing line*

Schematic illustration of the ring rolling process is presented in Figure 3. In both passes, axial and radial, the cross section area is decreased and, in consequence, the diameter of the ring is increased, with the mass maintained constant. Reduction of the wall thickness and height of the ring, magnitude of feeds, increase of the ring diameter and time of rolling are mutually dependent parameters of the process [9].

During rolling, the deformed material rotates on the table of the mill with the angular velocity, which depends on the reductions imposed by the vertical and horizontal rolls. In consequence, elongation of the material leads to motion of the position of the roll gap outwards the centre of the ring, which is also the centre of rotations. In the finite element software ***RingRoll*** the two roll gaps are modeled in the domains, which are constrained by the entry and exit planes.

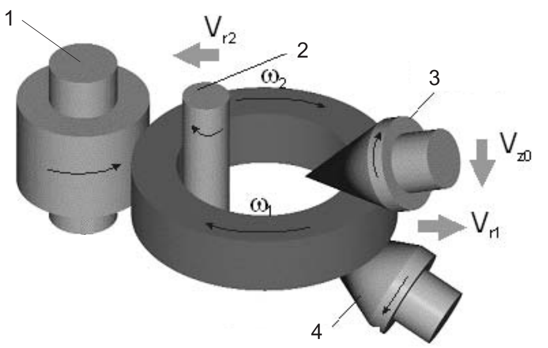

Fig. 3. *Scheme of the ring rolling process: 1 – power roll, 2 – becking bar, 3 – upper roll, 4 – bottom roll*

The complex character of the deformation and the complex shape of the ring cross section require solution of the non-stationary problem of plastic flow. Theoretical basis of this solution is described in [6, 7]. The problem is strongly non-linear and the boundary conditions are changing with time. Thus, the problem is difficult to solve and iterative, incremental procedures have to be applied. In this approach the correction of the boundary conditions is made after each increment of time.

3. 20″ AND 24″ *WELDING NECK* RING

Shape and dimensions of 20″ i 24″ 150 lb/sq.in. *welding neck* XS rings after rolling are presented in Figure 4. The preforms designed for these rolling processes are shown in Figure 5. The results of simulations of the rolling process are presented in Figure 6. Analysis of shape of the cross section of the 20″ *welding neck* ring after the seventh rotation (Fig. 6a) and after rolling (Fig. 6b) leads to a conclusion that reductions assumed in calculations gave correct shape of the ring after 14 rotations. This correct shape of the 24″ *welding neck* ring was obtained after 20 rotations, what is well seen in Figure 7. Shape and dimensions of vertical rolls (main roll and mandrel) for the 20″ and 24″ rings are shown in Figure 8. The overfill of the groove in its bottom part is small and negligible from the technological point of view. In both analysed cases, simulation and industrial rolling were performed according to the rolling curves presented in Figure 9. The rolling curve is employed to control the rolling mill. It presents the gap change of the horizontal rolls versus the gap of the vertical rolls. The rolling curve and the rolling force applied to the rolls define the reduction of the ring during the rolling process.

Temperature field at the cross section of the ring is an important parameter of the process (Fig. 10). At the final stage of rolling, the temperature at the surface of the ring is within the range 900–1050°C, while in the centre of the ring it is about 1130°C. Possibility of prediction of these temperatures is important not only for proper determination of the rheological parameters of deformed material (flow stress), but it also plays crucial role in further simulations of controlled cooling of rings, as well as modeling of phase transformations and properties of products, as it is show in [10].

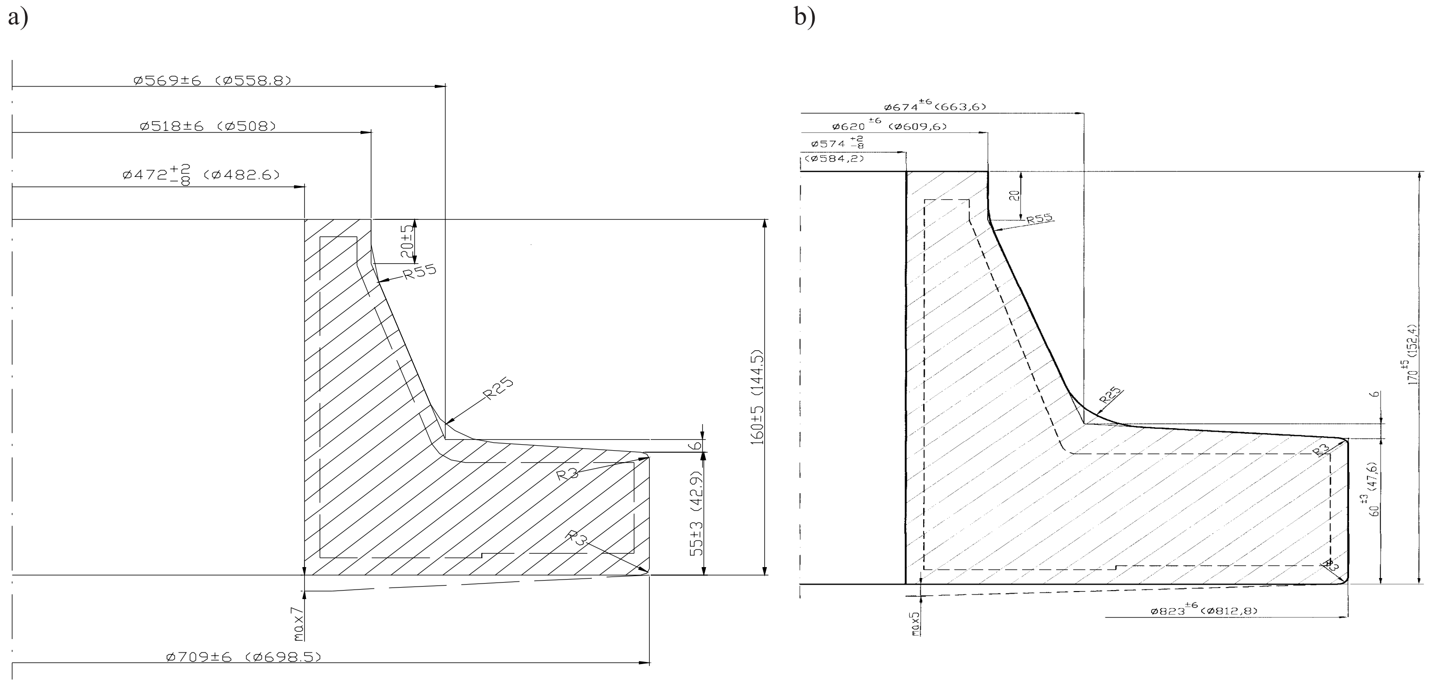

Fig. 4. *Shape and dimensions of welding neck type ring: a) welding neck 20"; b) welding neck 24"*

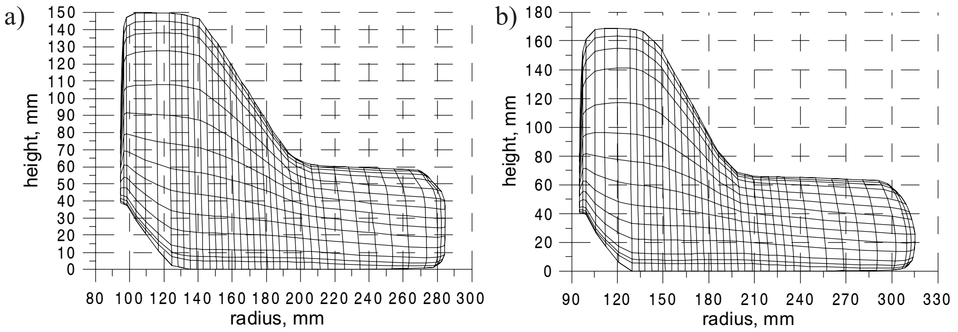

Fig. 5. *Preform designed for rolling of welding neck ring: a) welding neck 20"; b) welding neck 24"*

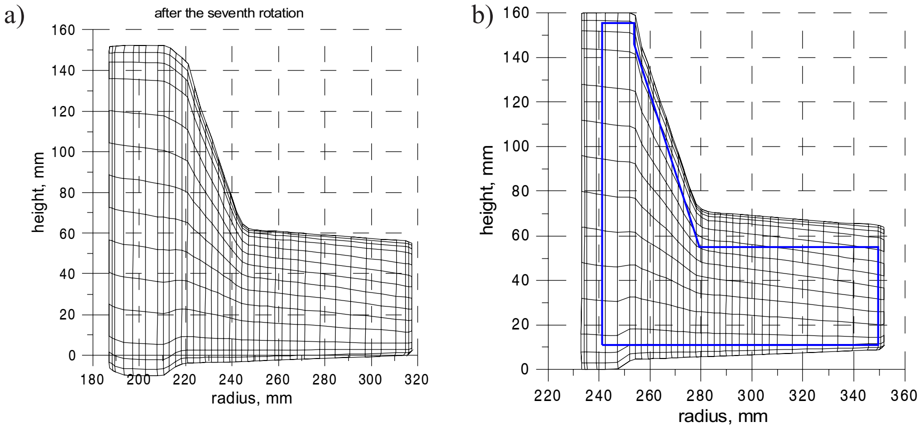

Fig. 6. *Finite element mesh in the cross section of the welding neck 20" ring: a) after 7 turns of the ring; b) after rolling*

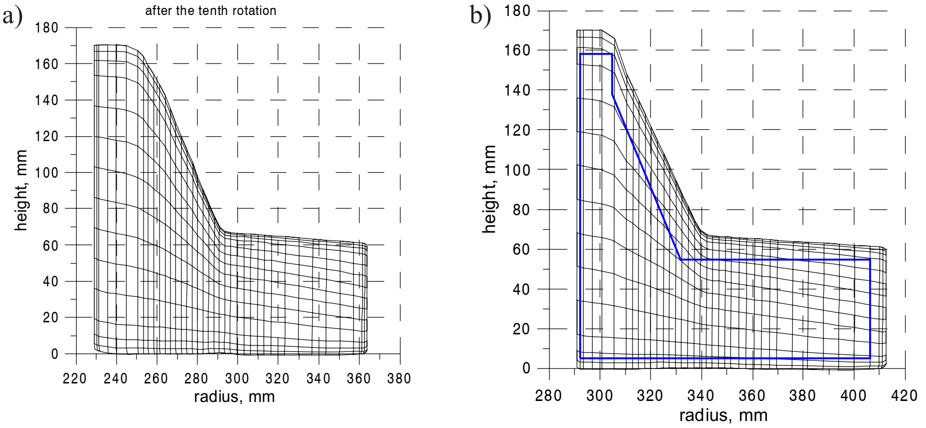

Fig. 7. *Finite element mesh in the cross section of the welding neck 24" ring: a) after 10 turns of the ring; b) after rolling*

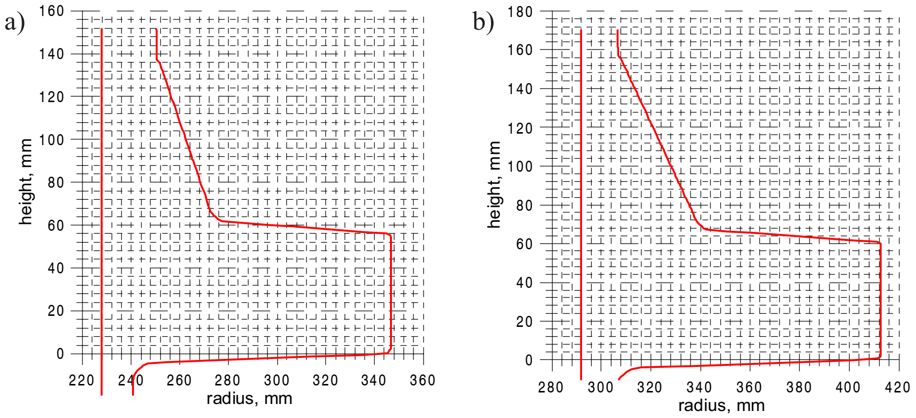

Fig. 8. *Profile and dimensions of the vertical rolls for rolling of: a) welding neck 20" ring; b) welding neck 24" ring*

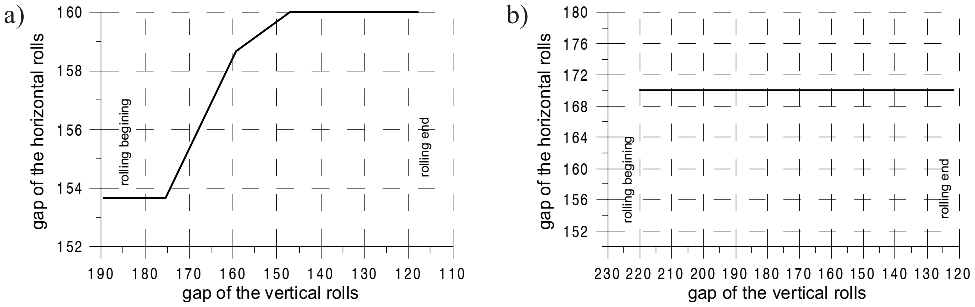

Fig. 9. *Rolling curve designed for rolling welding neck type ring: a) welding neck 20"; b) welding neck 24"*

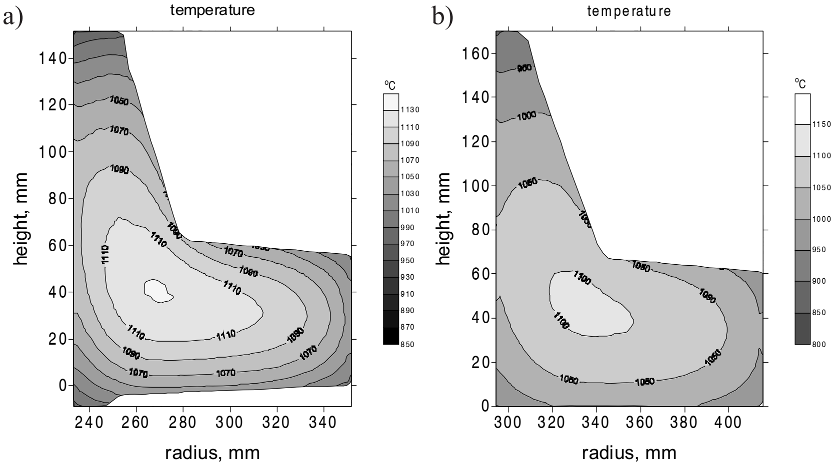

Fig. 10. *Temperature field in the cross section welding neck type ring after rolling: a) welding neck 20"; b) welding neck 24"*

Calculated effective strain and flow stress after rolling are presented in Figures 11 and 12. The largest strains and stresses occur close to the contact with the upper roll, in particular in the corners of the ring. The maximum values of the effective strain exceed 6, while in the centre of the ring they are close to 1.5. The effective strain in the contact zone with the conical rolls is about 2.5. These numbers represent deformation of the material and they control the final structure, but due to recrystallization the strains are decreased in the flow stress function. Superposition of the influence of the temperature field and the strain field results in the largest values of the flow stress in the areas of contact with the rolls.

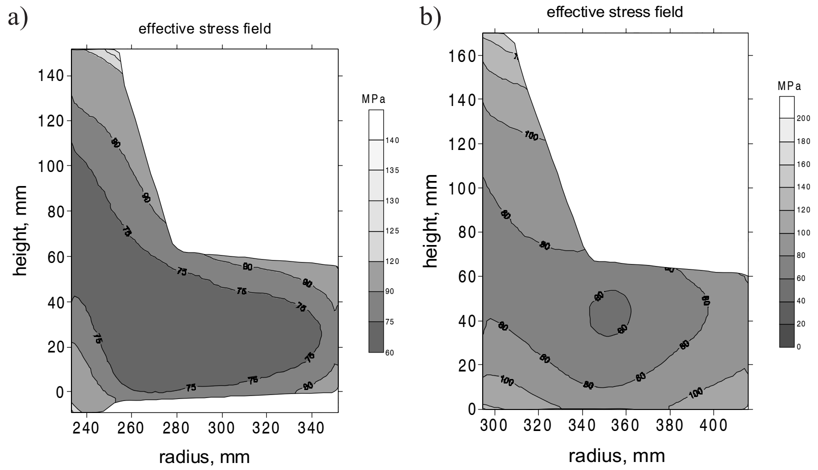

__Fig. 11.__ The effective strain field in the cross section of welding neck type ring after rolling: a) welding neck 20"; b) welding neck 24"

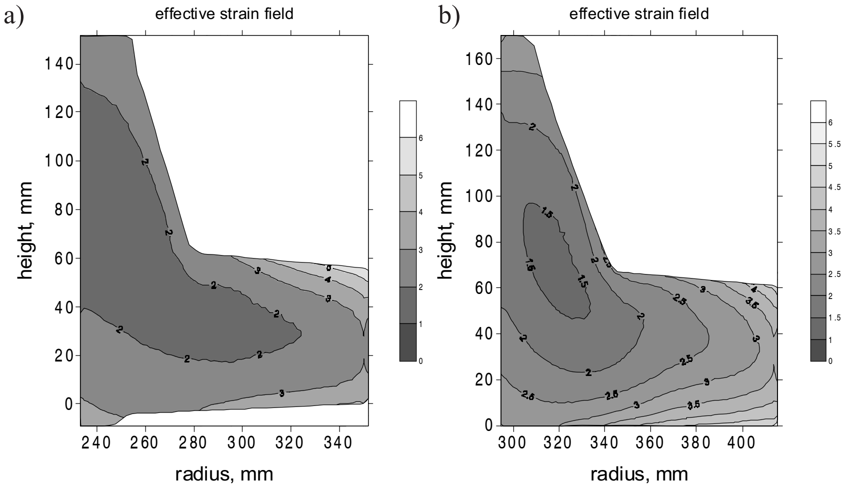

__Fig. 12.__ The effective stress field in the cross section of welding neck type ring after rolling: a) welding neck 20"; b) welding neck 24"

4. INDUSTRIAL TRIALS

Twenty four samples were selected for the industrial experiments for the *welding neck* 20″ and 24″ rings, 12 samples were selected for each ring diameter. Rolling experiments were performed in two series. Nine *welding neck* rings were rolled for each type of the rings (Fig. 13). One sample in each series was selected for validation of dimensions and shape of the preform after forming, these samples were not rolled. There were no problems or difficulties observed during rolling of all rings. Ten *welding neck* 20″ rings were rolled according to the rolling curve presented in Figure 9a. However two rings were rolled according to the standard rolling curve. The height of the preform was slightly increased (153 mm) comparing to the conventional one (150) mm. In consequence, better filling of the neck of the ring and proper profile of the ring were obtained. Rings *welding neck* 24″ were rolled according to the rolling curve presented in Figure 9b. Similarly to the previously discussed *welding neck* 20″ rings, proper filling of the neck of the ring and required profile of the ring were obtained.

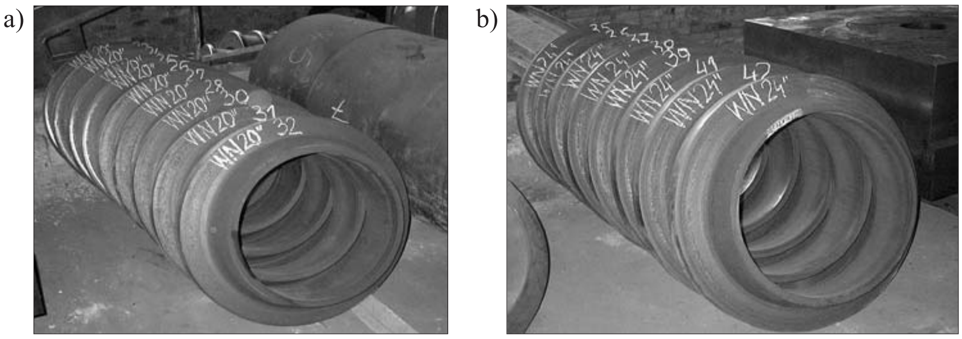

Fig. 13. *Welding neck rings obtained in the industrial tests: a) 20" rings; b) 24" rings*

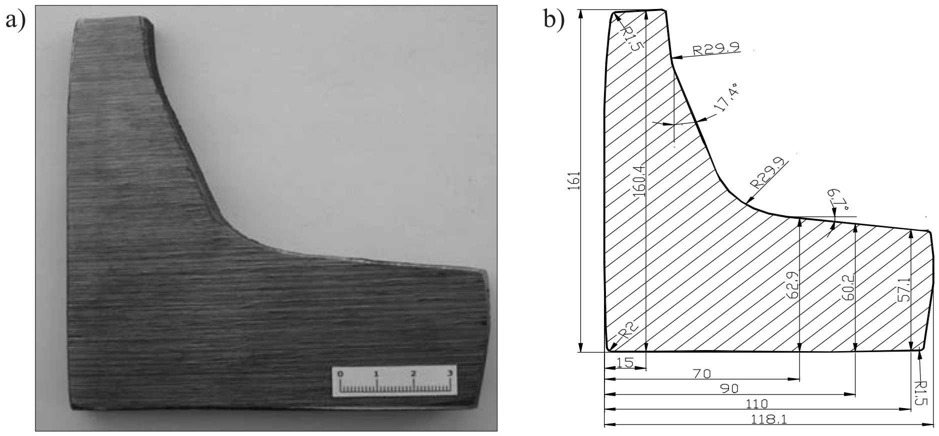

Fig. 14. *Sample of the cross section of the 20" welding neck ring: a) sample of the cross section; b) scheme of the cross section*

Figures 14 and 15 show shape and dimensions of the *welding neck* 20″ and 24″ rings after rolling. Comparison of dimensions of experimental and theoretical preforms shows a slightly different shape in the lower part of the sample due to technological forging operation.

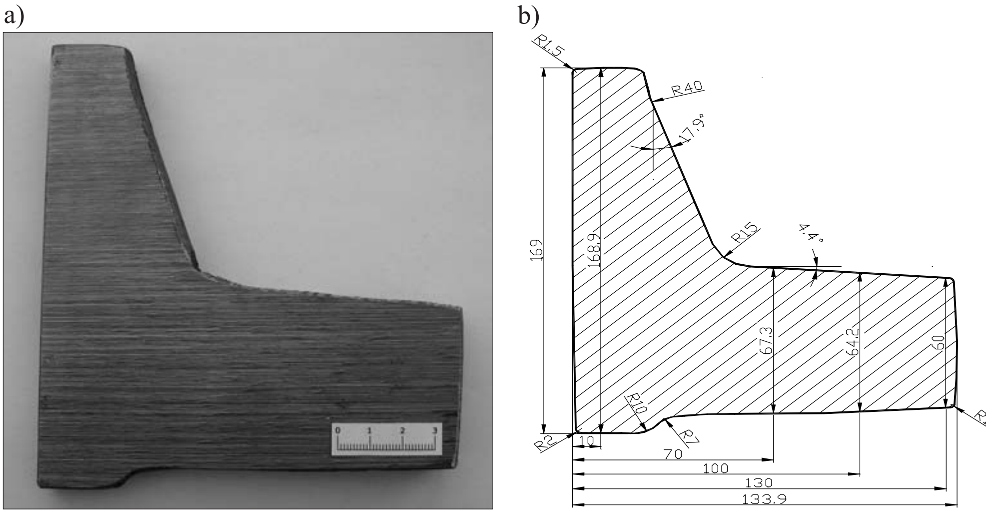

Fig. 15. *Sample of the cross section of 24" welding neck type ring: a) sample of the cross section; b) scheme of the cross section*

5. DISCUSSION

Results of simulations, computer aided technology design and industrial trials for rolling of *welding neck* 20″ and 24″ rings are presented in the paper. Analysis of results of simulations and industrial experiments allows to draw the following conclusions:

- Finite element mesh allows to follow changes of the shape of the ring during rolling and enables to introduce corrections of the rolling curve and testing various shapes of preforms.
- Shape of the preform is the dominating factor influencing metal flow in the deformation zone and filling the roll grooves.
- Application of preforms forged in the shaped dies (lower plate) improved distribution of stains in roll gaps. Better filling of grooves and correct shape of the ring after rolling were obtained.
- Temperature of the ring during rolling decreases slightly, to about 950–1050°C in the area of contact with the rolls. Temperature in the centre of the ring cross section maintains at the level of about 1130°C.
- To obtain proper shape of the 20″ and 24″ *welding neck* rings, the height of the preforms should be maintained close to the height of the final ring. Too low preform causes elongation of the outer maximal ring diameter and too late launching of rolling of

the side of the ring. Thus, the material cannot be efficiently moved to the neck of the ring and the required final height of the neck is not obtained.

– Proper conditions of rolling are reached when the maximum temperature of the preform at the beginning of rolling is about 1150°C.

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