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RESEARCH ARTICLE

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Study the influence of the pre-finish gauges form on the effectiveness of the grooves filling in the finishing pass of reinforcing steel rolling

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ABSTRACT

During reinforcing steel rolling such geometric defect as the absence of longitudinal or transverse ribs is spread. For a detailed study of the process of reinforcement profile rolling and its further optimization, computer simulation in the software complex DEFORM-3D was carried out. In the previous works the most rational, from the authors' point of view, forms of pre - finishing gauges for rolling of reinforcing steel are proposed - a one-radius oval and a flat oval with double concavity. Also, a new calibration for rolling of round and reinforcing steel was proposed, the main feature of which is the pre-finishing caliber, made in the form of a smooth barrel. To assess the impact of the pre-form gauge on the strain state, a single simulation was conducted, i.e. modeling only the pre-finishing caliber, after which the calculation of the finishing pass was conducted.

From considered calibers, the most uniform distribution of deformation provides a flat oval with double concavity, where the distribution in the vertical and horizontal directions is approximately the same. In other two calibers, the spread difference is quite different. After rolling in the finishing pass, the metal completely filled the contour of the caliber, as well as the screw incisions of the transverse ribs. The longitudinal ribs are also fully formed. All geometric parameters with tolerances fully comply with the requirements of GOST 10884-94.

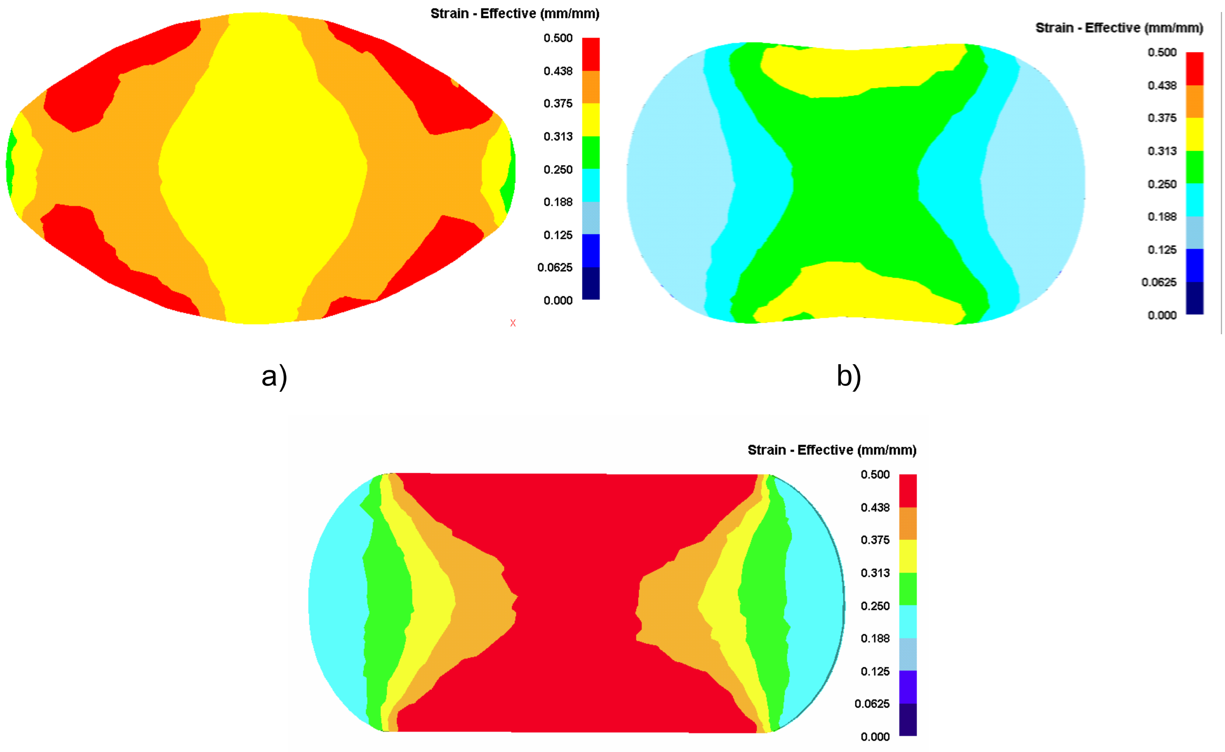
1. INTRODUCTION

Reinforcing steel is used for the manufacture of reinforcement of concrete structures. Reinforcing steel in concrete structures is installed mainly for the perception of tensile forces and strengthening of concrete compressed zones of structures. The strength characteristics of the reinforcing steel depend on the chemical composition of the steel (carbon content, alloying additives) and the nature of its processing (cold hardening of steel by drawing, drawing, flattening, heat treatment, etc.). Despite the constant improvement of the rolling technology in the production of rolled steel products is still a high proportion of the yield of metal in marriage. In particular, during reinforcing steel rolling, such a geometric defect as the absence of longitudinal or transverse ribs is common. It is known [1, 2] that for the best filling of finishing gauges of any shape it is necessary not only to ensure its exact execution of geometric dimensions, but also, if possible, to minimize the anisotropy of mechanical properties throughout the cross section of the deformable metal. If in the first case it is necessary only to comply with the requirements of GOST on the geometric dimensions of the caliber, taking into account the temperature expansion of the metal, then the second task has some difficulties, since it is quite difficult to predict the distribution of the accumulated deformation for all passes as a whole, and for individual calibers. In particular, of great interest is the shape and size of the finishing gauge, after which the roll falls into the finishing gauge, where the final profile is formed. In this work the simulation results of rolling in pre-finish gauges of various form and distribution of strain and rolling forces are presented.

2. PREPARATION OF MODEL

For a detailed study of the process of rolling the reinforcement profile, it was decided to conduct computer simulation in the software complex "Deform-3d". The paper proposes the most rational, from the point of view of the authors, forms of finishing gauges for rolling reinforcing steel. However, there is a controversial question about the so-called "transition" profiles, which some authors refer to small profiles, and others – to large; in particular, profile number 20. For this profile, both an one-radius oval and a flat oval with double concavity are offered as a finishing gauge [3]. Also, in the works [4-5] a new calibration for rolling round and reinforcing steel was proposed, the main feature of which is the pre-finishing caliber, made in the form of a smooth barrel. Therefore, to determine the most rational form of the pre-finishing caliber, it was decided to simulate rolling in all three calibers in order to identify the most uniform distribution of the accumulated deformation across the cross section of the workpiece.

Since deformation is a cumulative parameter, it is very difficult to track its change at any particular stage in the analysis of the entire technological process. Therefore, in order to assess the effect of the shape of the pre-finishing caliber on the deformed state, a single simulation was carried out, i.e. the model included only the pre-finishing



c)

Figure 1. Distribution of equivalent strain. a) one-radius oval; b) flat oval with double concavity; c) smooth barrel.

caliber. In all 3 cases the workpiece was elastic-plastic type. The steel AISI 1035 was chosen as material. The initial workpiece temperature was 900 °C. The friction coefficient on the contact of workpiece and rolls was 0.3. The angular velocity of rolls was 90 rpm, radius of rolls was 320 mm. The initial billet had round cross-section with a diameter 25 mm and length 200 mm.

As a result of modeling the following distribution patterns of equivalent strain were obtained (Figure 1).

For a detailed study of the distribution of equivalent strain on the cross section, two directions were considered: vertical and horizontal, since before entering the final gauge, the workpiece in all three cases is subjected to a 90 degree turning. The rolling force generated by the deformation in these gauges was also considered in order to estimate how much the force value
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changes compared to the reference value. For the reference force value was adopted value received in one-radius oval, as the caliber is most common for section mills, rolled reinforcing profiles.

3. RESULTS AND DISCUSSION

3.1. One-radius oval

When rolling in a caliber in the form of a one-radius oval, the distribution of deformation is extremely uneven. With a fairly uniform distribution in the axial zone (Figure 2), when moving to the walls of the caliber, the deformation values increase sharply, especially on inclined sections of the roll. At the same time, on the side ends, on which the formation of transverse ribs occurs after the edging, there is a significant decrease in the deformation value (Figure 3).

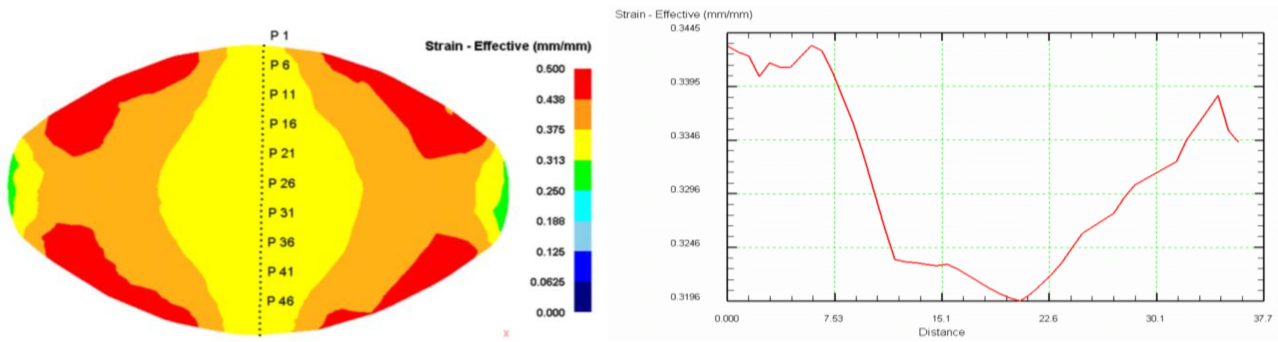

Figure 2. Distribution of deformation during rolling in a one-radius oval in the vertical direction.

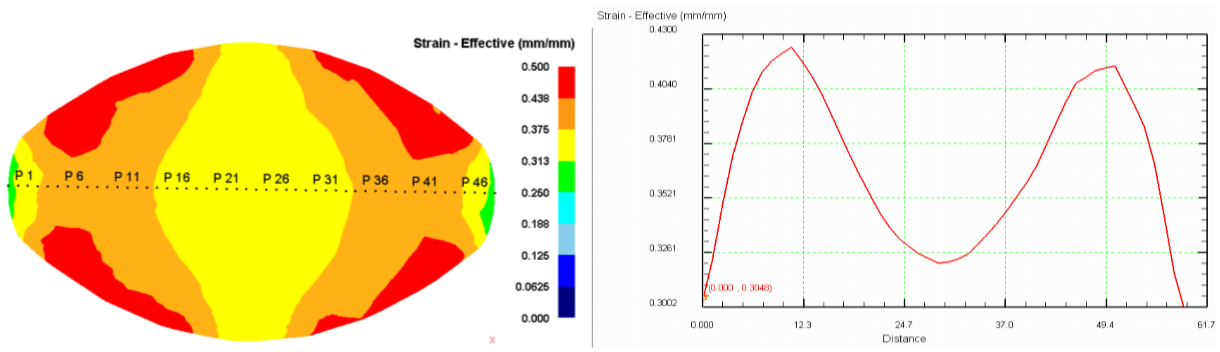

Figure 3. Distribution of deformation during rolling in a one-radius oval in the horizontal direction.

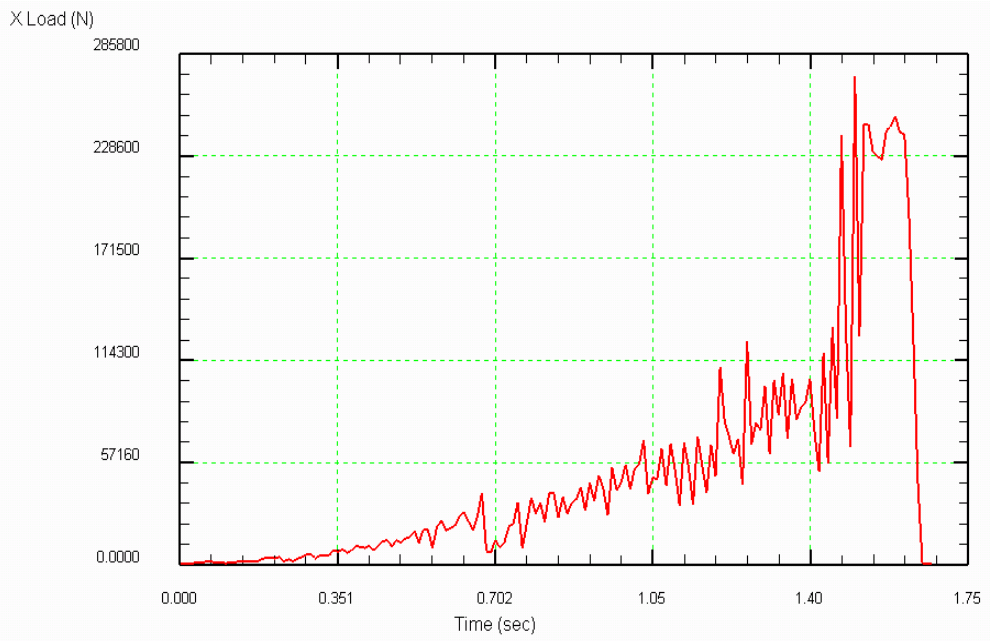

Figure 4. Rolling force in an one-radius oval.

In the vertical direction, the strain distribution is from 0.3195 to 0.3435 (value spread = 7.5 %). In the horizontal direction, the strain distribution is from 0.3008 to 0.4248 (value spread = 41.2 %). When taking into account the inclined zones, where the deformation value reaches a value of 0.5, the spread is 66.2 %.

Two zones are clearly visible on the force graph: in the first zone, characterizing the capture of the workpiece, the force increases smoothly as the deformation center is filled. With the steady-state rolling process, the force value remains at the same level and is approximately 251.5 kN (Figure 4).

During rolling in a caliber in the form of a flat oval with double concavity, the distribution of deformation in the vertical and horizontal directions proceeds more evenly compared to a one-radius oval. In the axial zone, there is some increase in deformation due to concavities (Figure 5). At the lateral ends, the distribution of the deformation value is more uniform than in a one-radius oval (Figure 6). This is confirmed by the strain distribution graphs – in the first case, the peaks characterizing the sharp increase are clearly visible, then the decrease and then the increase in the strain value. In the second case, the graph is more monotonous.

3.2. Flat oval with double concavity

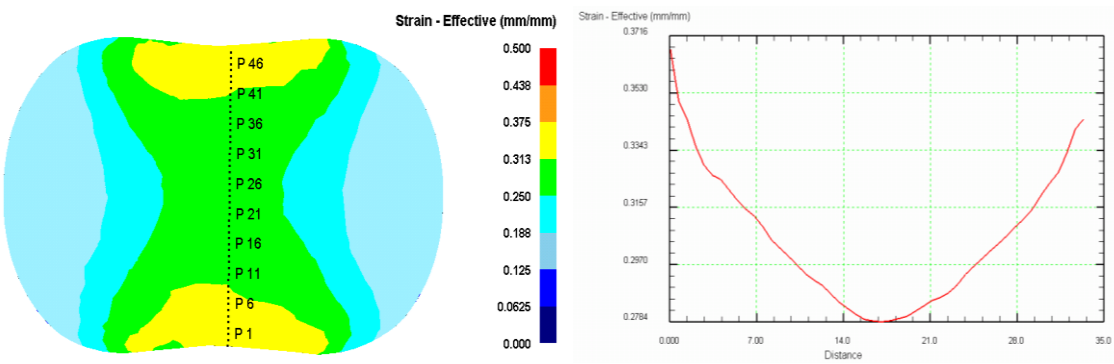

Figure 5. Distribution of deformation during rolling in a flat oval in the vertical direction.

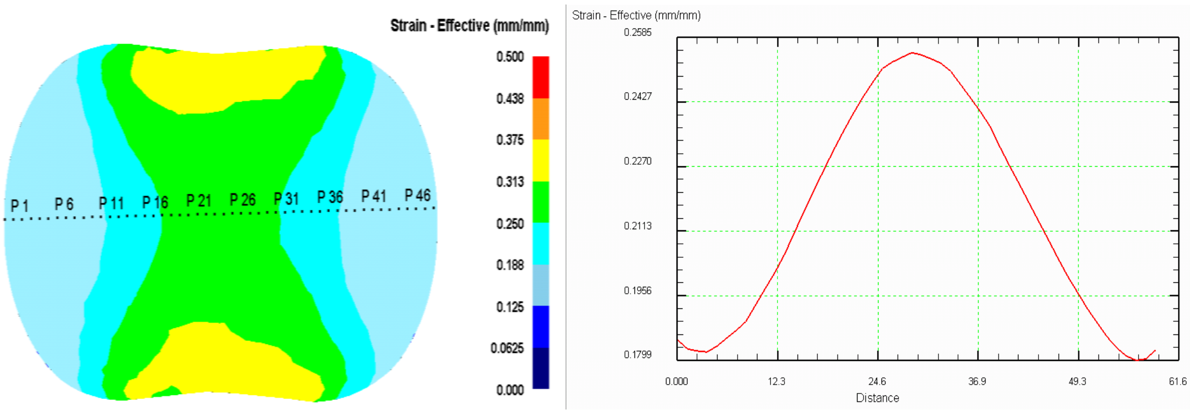

Figure 6. Distribution of deformation during rolling in a flat oval in a horizontal direction.

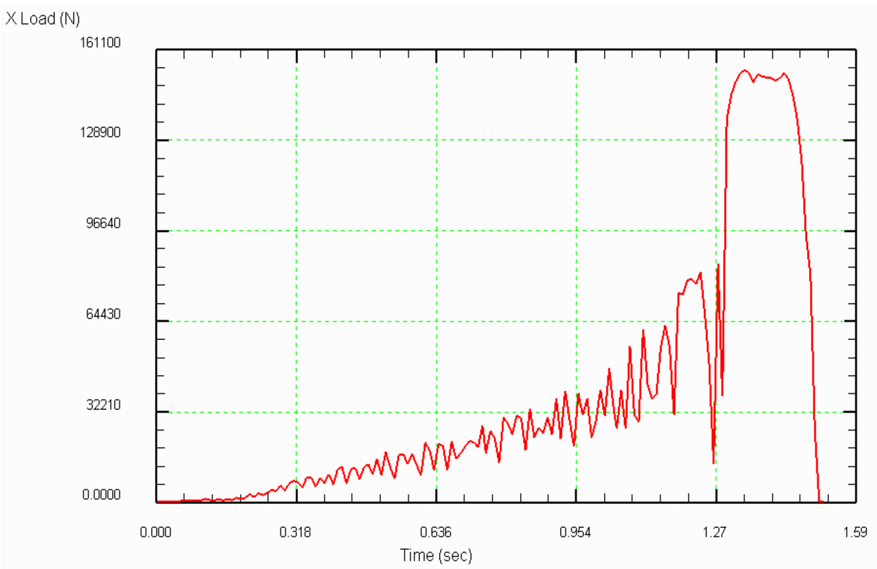

Figure 7. Rolling force in a flat oval with double concavity.

In the vertical direction, the strain distribution is from 0.2784 to 0.3678 (value spread = 32.2 %). In the horizontal direction, the strain distribution is 0.1799 to 0.2512 (value spread = 39.6 %).

The force graph, as in the first case, clearly shows two zones: the capture zone of the workpiece and the zone of the steady-state rolling process, where the force value remains at the same level and is approximately 154.6 kN (Figure 7).

3.3. Smooth barrel

When rolling on a smooth barrel, the distribution of deformation in the vertical and horizontal directions is very uneven. With a fairly uniform distribution in the axial zone (Figure 8), when moving to the side ends, where the metal contact with the rolls is absent, there is a significant decrease in the deformation value (Figure 9).

In the vertical direction, the strain distribution is from 0.4463 to 0.4705 (value spread = 5.4 %). In the horizontal direction, the strain distribution is from 0.2249 to 0.4517 (value spread = 100.8 %).

On the graph of effort, as in the above calibers, two zones are visible. In the area of the steady-state rolling process, the force value is approximately 184.3 kN (Figure 10).

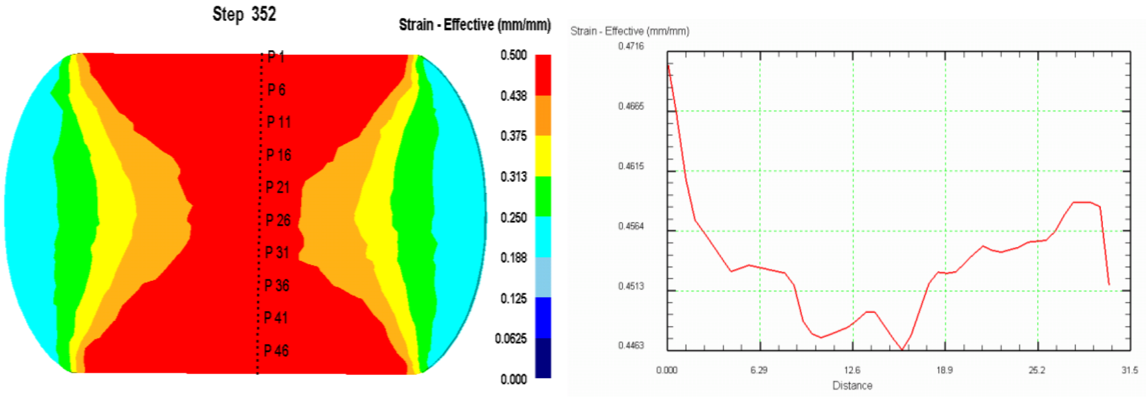

Figure 8. Distribution of deformation during rolling on a smooth barrel in the vertical direction.

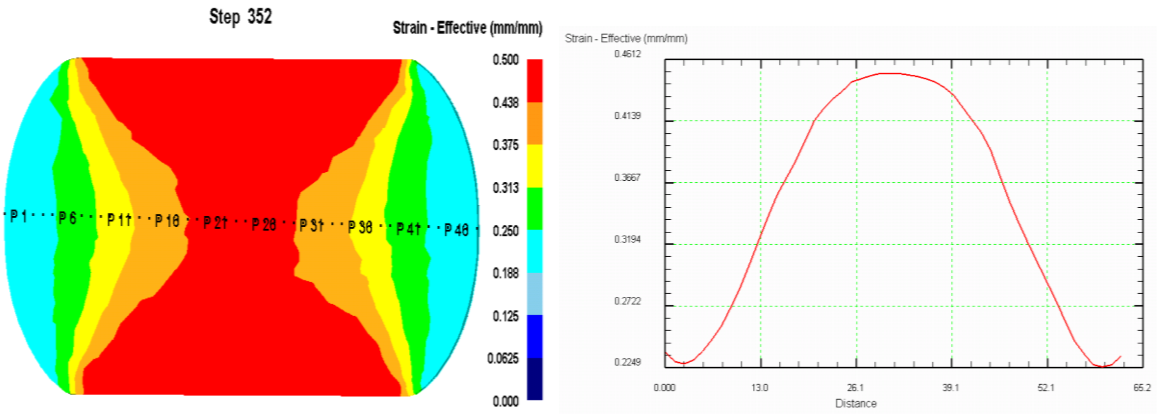

Figure 9. Distribution of deformation during rolling on a smooth barrel in the horizontal direction.

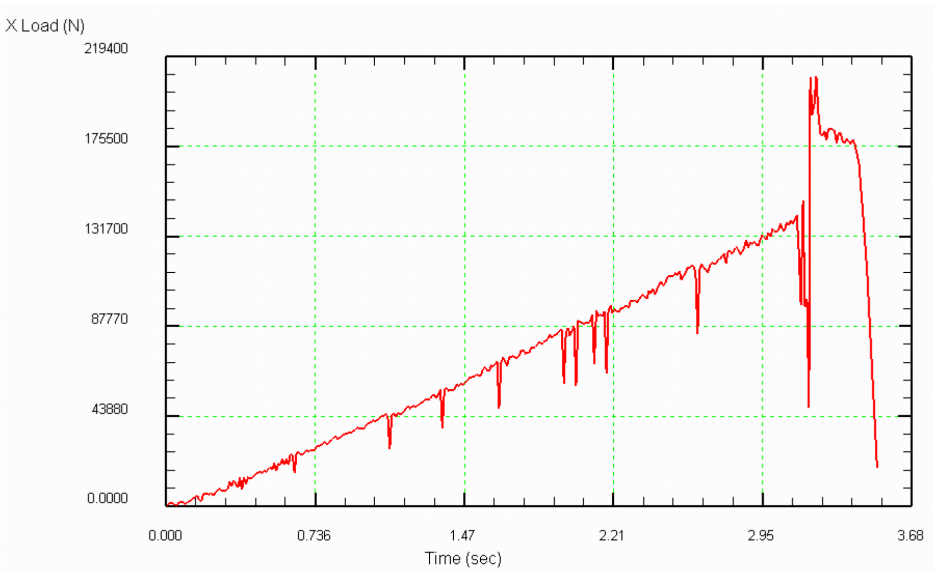

Figure 10. Rolling force on a smooth barrel.

When rolling in all three versions of the gauges, the distribution of deformation is uneven in the vertical and horizontal directions. Analysis of the force graphs showed that when rolling in a flat oval and on a smooth barrel, the force values do not exceed the value for a single-radius oval, which indicates the possibility of using these gauges on existing equipment without its modernization. From all considered calibers, the most uniform distribution of deformation provides a flat oval with double concavity, in which the spread in the vertical and horizontal directions is approximately the same; in the other two calibers, the difference in the dispersion is quite significant. As a result of the calculation of the model of the final caliber after rolling in a flat oval with double concavity, the following results were obtained (Figures 11-12).

After rolling in the finishing stand, the metal completely filled the contour of the caliber, as well as the screw cuts of the transverse ribs. Longitudinal ribs are also fully formed. The main requirements for geometric dimensions, according to GOST, are the correspondence of vertical and horizontal diameters d_1 and d_2, which characterize the height of the longitudinal and transverse ribs. The ovality of the section (the difference between d_1 and d_2 in one section) should not exceed the sum of the plus and minus limit deviations in size d1. In addition, an important characteristic of the geometry of reinforcing steel is the value t, which determines the distance between two adjacent transverse edges.

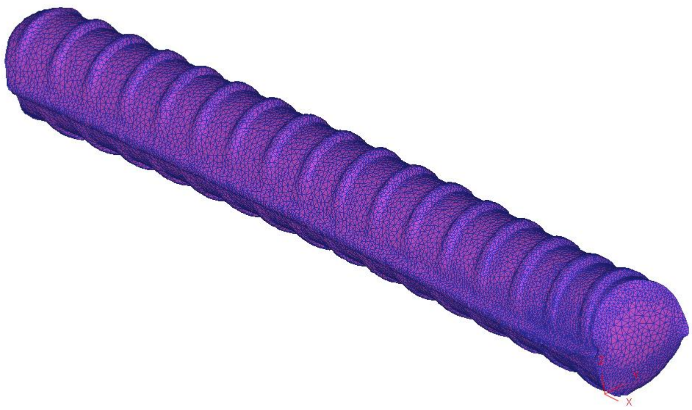

Figure 11. General view of the deformed workpiece.

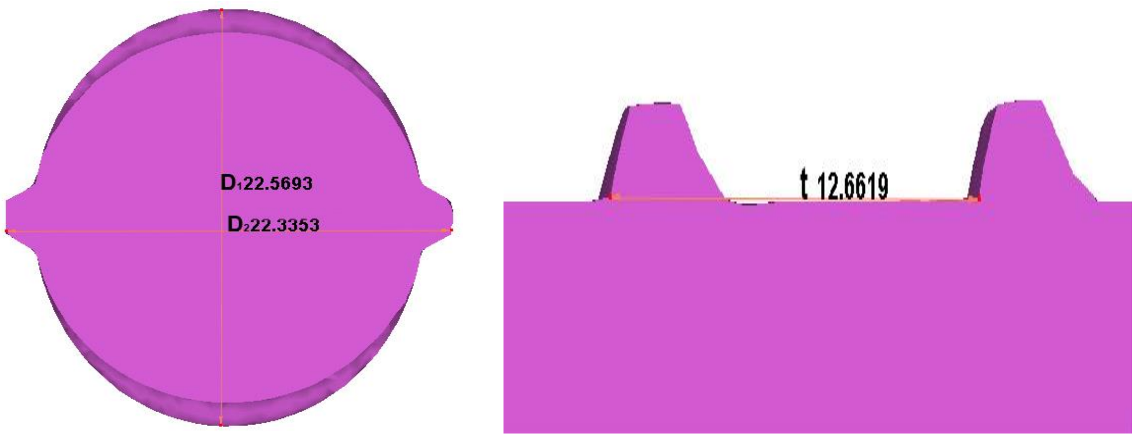

Figure 12. Cross and longitudinal section of the workpiece.

As shown in Figure 12, the value of d_1 in the resulting model is 22.569 mm, the value of d_2 is 22.335 mm. Deviation of d_1 is 0.269 mm, d_2 is 0.035 mm, which fully corresponds to the specified values of the limit deviations. The oval shape of the rod is 0.234 mm, which also meets the requirements of GOST. The value of t is 12.66 mm, which fully corresponds to the table value with a permissible limit deviation of ±15%, (in our case it is 5%).

4. CONCLUSION

1) After rolling in all 3 versions of calibers the strain distribution is uneven in vertical and horizontal directions;

2) The most even distribution of deformation provides flat oval with double concavity in which dispersion of the values in vertical and horizontal directions is approximately the same; in the other two calibers the difference of the dispersions are quite significant;

3) Analysis of the load graphs had showed that values of load at rolling in a flat oval and on the smooth barrel don't exceed a value for one-radius oval that says about the possibility of using these calibers on existing equipment without its modernization.

4) The model of the final caliber (reinforced profile) after rolling in a flat oval with double concavity showed, that obtained billet fully corresponds to the specified values of the limit deviations (two horizontal diameters and distance between two adjacent transverse edges).

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