Formation of the Structure and Decarburized Layer During Hot Screw Rolling of Vessels

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Abstract: We studied the influence of temperature and soaking time on rod billets made of steel 50. The development of the decarburized layer after induction heating and soaking in the resistance furnace was taken into account. When analyzing cooled down rod billets subjected to heat treatment, a continuous and stable development of a ferritic layer on the entire surface of rod billets was detected. Rod billets heated in a similar way as those on which the size of the outer decarburized layer had been defined were hot rolled. Experimental rolling was performed in a 3-high stand of the rolling-press line of JSC Scientific Production Association (SPA) “Pribor”. After cooling it was found that the sizes of a ferrite ring on the outer surface of steel vessels had changed. The analysis of the obtained data allowed us to find a relationship between the change in the structure of a ferrite ring formation and a draw ratio \(\lambda\). A regression equation was obtained for determining the influence of drawing during screw rolling on the size of a decarburized layer.

1. Introduction

Recently, in metallurgy and a machine-building industry rolling-press lines (RPL) have been used for producing hollow vessels with a diameter of 30–60 mm using carbon structural steel. These lines allow to produce the items of the required shapes and sizes from round rod billets by consecutive hot screw rolling and stamping [1-3].

The purpose of the vessel production on RPL of JSC SPA “Pribor” is to reduce the expenses by increasing the material utilization rate (MUR) and reducing the machining time. Cut-to-length rod billets made of steel 50 and produced according to GOST 1050-88 with the diameter of 42 mm at small-section mills of Nadezhda Metallurgical Plant are used as a basic material.

In order to increase the ductility of steel 50, rod billets are heated in an induction furnace and soaked in a resistance furnace, which results in the decrease of carbon content and the formation of a decarburized layer on metal surface which remains during further deformation [4].

During hot rolling the rod billets made of steel 50 change their size and shape, at the same time the concentration of ferrite on the external surface of the products changes and a so-called ferrite ring is formed. A decrease in carbon concentration in steel results in the increase of plastic properties and the decrease in strength characteristics [5, 6].
The purpose of the research is to determine the influence of hot deformation of rod billets on the change of a surface decarburized layer during screw rolling and to relate the drawing to the change in size of the ferrite ring.

2. Materials and experiment methods

As a basic material we used hot rolled machined rod billets with the length of 70 mm and the diameter of 42 mm made of steel 50 and produced at Nadezhda Metallurgical Plant (NMP) according to GOST 1050-88, heat No. 7877, batch 061721363 with the specified mechanical properties: tensile strength – 856 MPa; yield strength – 660 MPa; relative narrowing – 43%.

The size of the decarburized layer on the surface of initial rod billets supplied by NMP was studied with CarlZelss optical microscope following the methods of microstructure study GOST 5640-68. Figure 1 shows the microstructure taken from a cylindrical surface of the rod billets made of steel 50 and supplied by NMP at a100x magnification.

Microstructure shown in Figure 1 has a homogeneous distribution of ferrite and perlite in the entire studied field at the ratio of 2:1, the grain size is approximately 7-8 scores. No traces of decarburized layer ferrite were found on the surface of rod billets.

Rod billets made of steel 50 were preheated in the induction furnace to 1160 °C for 12 seconds. The equalizing soaking of rod billets took place in the resistance furnace and continued for 20 minutes at the temperature of 1160 ± 10°C.

The size of the surface decarburized layer was studied following the method of microstructure study GOST 5640-68 for the rod billets made of steel 50 which were subject to heat treatment at 1160 °C with a total time equal to the heating and soaking cycles, while cooling took place in oil.

Figure 2 shows the microstructure taken from the cylindrical surface of rod billets made of steel 50 and subject to heat treatment. The studies were carried out at a 100x magnification.

Figure 1. Microstructure from a cylindrical surface of the rod billets made of steel 50 and supplied by NMP shown at a100x magnification.

Figure 2. Microstructure from the cylindrical surface of rod billets made of steel 50 after a heat treatment shown at a 100x magnification.
As it can be seen in Figure 2, the ferrite layer on the surface of rod billets made of steel 50 is continuous. The deviations of ferrite content on the studied cylindrical surface are within the range from 0.7 to 0.72 mm, which is no more than 3%.

During the rolling of rod billets made of steel 50 which had been heated and soaked at the temperature of 1160 °C in “30-80” RPL mill of JSC SPA “Pribor” plant the relative deformation and draw ratios λ were checked [7]. After screw rolling the relative deformation of the top part εt and the bottom part εb, as well as the spread of average draw ratios λ were calculated.

The relative deformation of the vessel bottom

\[ \varepsilon_b = \left( \frac{F_0 - F_b}{F_0} \right) \times 100\% \]  

The relative deformation of the vessel top

\[ \varepsilon_t = \left( \frac{F_0 - F_t}{F_0} \right) \times 100\% \]  

where the cross-section area in both cases \( F_0 = \pi/4 \cdot D_0 \).

The draw ratio was defined

\[ \lambda = L_i / L_f. \]  

where \( L_i \) is the initial length of a rod billet and \( L_f \) is the final length of a rod billet after rolling, respectively.

3. Discussion of the research findings

During the processing in a 3-high stand of “30-80” screw rolling mill with a further placement on a rotating mandrel the dimensions changed: outer diameter was 36 ± 0.5 mm, inner diameter was 18 ± 0.5 mm, total length was 120 ± 1 mm and cavity depth was 105 ± 1mm. After rolling with a cavity formation the relative deformation of the steel vessel bottom \( \varepsilon_b \) was about 26% and \( \varepsilon_t \) of the top part was about 45%.

The spread of the drawing values after rolling was \( \lambda = 1.70-1.72 \).

We studied the size of the decarburized layer after rolling in “30-80” line for the vessels made of steel 50 after cooling in oil.

Figure 3 shows the microstructure taken from the cylindrical surface of a vessel made of steel 50 which was subject to hot rolling. The research was done at a 100x magnification.

![Figure 3](image)

**Figure 3.** Microstructure of a vessel made of steel 50 which was subject to hot rolling shown at a 100x magnification.

As it can be seen in Figure 3, ferrite is distributed on the entire cylindrical surface of the vessel made of steel 50 uniformly. No traces of the ferrite ring discontinuity were found. The size of ferrite on the surface decreased as compared to the original rod billets (see Figure 2) and is within the range from 0.4 to 0.42 mm, which is no more than 5% of the limit values. There is a diffusional decay structure underneath the layer of pure ferrite of a decarburized ring resulting from incomplete quenching in oil – sorbitol with the traces of ferrite inclusions at the ratio of 2:1, respectively.
The research findings helped to determine the regularity of the drawing effect after finishing rolling of the vessels made of steel 50 and produced in RPL line of JSC SPA “Pribor”. A consistent relation between the drawing after rolling and the change in ferrite ring sizes for the outer part of a vessel was obtained. Figure 4 shows the influence of drawing during rolling on the thinning of the surface ferrite layer.

![Figure 4. The dependence of the change in the ferrite ring size on the drawing deformation.](image)

The research findings allowed us to derive a regression equation using the methodology from the research [8] that allows to calculate the change in the outer ferrite layer during the elongation of a rough rolled vessel made of steel 50 after screw rolling:

\[ H = 0.7995 - 0.2477 \lambda. \]  

(4)

The obtained equation allows to evaluate the change in the surface decarburized layer of cylindrical billets made of steel 50, as well as during rolling, with a traditional and modern method. The statistical model has a high correlation factor \( R^2 \), more than 0.94, which indicates a high reliability of the established relation.

4. Conclusions

1. The influence of heating temperature and soaking time on the thickness of the decarburized layer of rod billets made of steel 50 is shown. It has been found that a continuous ferrite layer is within the range of 0.70-0.72 mm.
2. Rod billets made of steel 50 were rolled in RPL rolling mill. The deformation of the rolled vessel areas was calculated: in the bottom area \( \varepsilon_b \) is about 26% and in the top area it is about 45%. The spread of drawing values after rolling was determined as \( \lambda = 1.70-1.72 \).
3. It has been found that after screw rolling with the drawing of 1.70-1.72 the structure and the sizes of ferrite near a cylindrical surface of a steel vessel change. The thickness of a decarburized layer ranges from 0.4 to 0.42 mm.
4. The laws of the influence of a deformation degree and drawing on the change in thickness of a surface decarburized layer of vessels made of steel 50 have been established.
5. A regression equation that links the drawing value and the change in size of the decarburized layer on the surface of vessels made of steel 50 during screw rolling was obtained. The obtained equation can be used in the design of rational deformation modes.
References

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