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Modelling of the Rolling Process of Titanium Alloy Tube Billets in Laboratory Conditions on a RSP 14-40 Rolling Mill

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Abstract The development of screw rolling technology for the production of hot-deformed tubes over Ø250 mm on a SVP-500 rolling mill faces a number of challenges that influence the quality of tubes, such as: the screw trace formed on the external surface of tubes and bending of tubes that makes impossible subsequent manufacturing operations. The following experimental and laboratory research was performed to solve these problems: a number of experimental tube billets with and without mandrels were rolled to various strains on a RSP 14-40 laboratory rolling mill to obtain the best ratio of wall thickness to the external diameter. The temperature field distribution and the strain intensity in the deformation area of tube billets rolling were analyzed. A quality assessment of the influence of the section of the calibrating rolls used in industrial technology on the external surface of hot-deformed tubes was also carried out at the modeling stage. The angle changing options of the calibrating rollers section of the screw rolling mill were analyzed for the subsequent tool improvement.

1 Introduction
According to the technology existing at Chepetsky Mechanical Plant (SC ChMP), tubes are manufactured using hot extrusion [1, 2], however this technology imposes constraints on the diameter and length of tubes. One of the possible approaches to obtain proper tubes might be hot rolling on a SVP-500 screw rolling mill enabling to increase the diameter and the length of tubes. However, trial rolling has shown the formation of a "screw" surface, the removal of which produces a large amount of scrap. In addition, rolling on SVP-500 resulted in bending of the tube billet on a mandrel due to which the removal of the tube from the mandrel becomes almost impossible.

2 Materials and methods
An alpha titanium alloy PT-7M (the nominal composition in wt.%: Ti - (1.8-2.5)Al - (2.0-3.0)Zr) was used as the program material. The alloy was supplied by SC ChMP in the form of forged tube billets 39 mm in diameter with drilled internal holes of various diameters (Figure 1). The billets had a uniform

microstructure with a grain size of 3-5 μm in both (longitudinal and transversal) directions (Figure 2). A series of experimental rolling was carried out using a RSP 14-40 laboratory rolling mill.

The program of experimental rolling consisted of a series of trial rolling of the billets to various total strain of 31%, 39%, 45%, 46% and 78%. The first rolling was performed on a mandrel, while the remained rollings were done without the mandrel until the final size was obtained. The optimal ratio of wall thickness to diameter did not require additional fixtures in the actual rolling process.

Conditions of experimental rolling:

The heating temperature of the billets was 920 °C;

The angles between the rolls on RSP 14-40 was 16 – 20°;

The rolls rotation speed was 30 – 50 rpm.

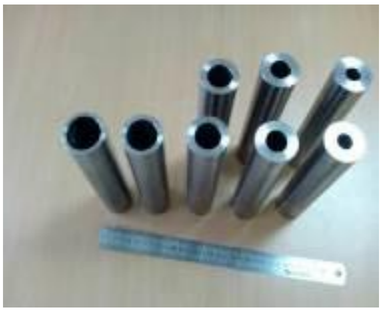


Figure 1. Tube billets for screw rolling.

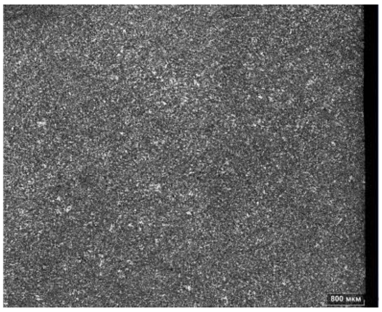


Figure 2. The initial structure of the tube billet; transversal direction.

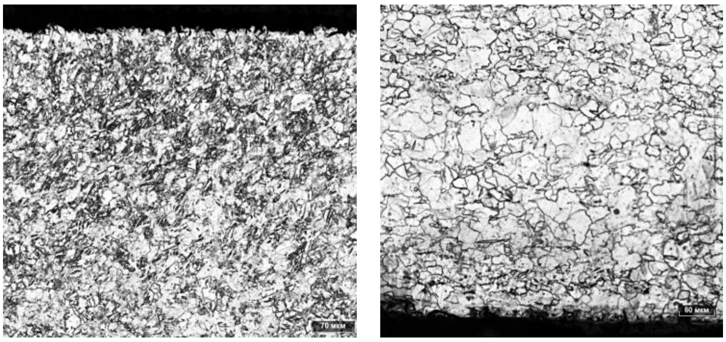
Mathematical modeling of the tube billet rolling was performed by the finite element method (FEM) using a QForm VX 8.2.4 software.

3 Results and discussion

3.1 The Evaluation of the Strain Degree Influence on the Structure of Tube Billets made of PT-7M Titanium Alloy

Since the high temperature of strain completely relieves the internal stresses, the rolling temperature of 920 °C can be considered suitable for use in the technological process.

The microstructure in the central part of the samples after 31% strain was found to be recrystallized without notable metallographic texture. However in areas close to surfaces (both internal and external) an unrecrystallized structure was observed. After 39% strain (Figure 3), the microstructure was almost completely recrystallized; preferential structure orientation was not observed similarly to 31% strain.



a b

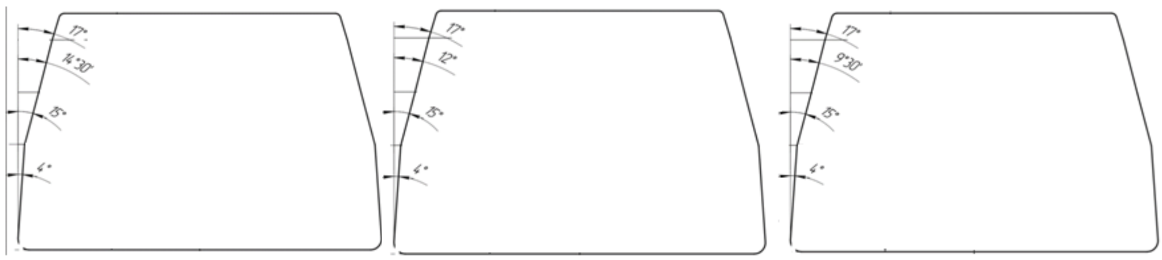
Figure 3 Tube billet structure after 39% deformation (×200); (a) - transversal direction, (b) - longitudinal direction

After 45% - to - 78% strain, traces of plastic deformation in near-surface layers both inside and outside were observed. A noticeable grain orientation in the rolling direction was also detected. Recrystallization in the microstructure of these specimens was not complete again.

The obtained data suggest that the recommended total degree of deformation should be 39%. However the deformed samples were not subjected to recrystallization annealing; static recrystallization most probably could improve the microstructure of the rolled tubes considerably. At the same time work-hardened layer in the near-surface layers can be removed by machining, thereby allowing larger strain to attain required sizes of the tubes.

3.2 Computer mathematical modeling of rolling

Three roll designs were compared using computer simulation in order to study how the geometry of rolls is related to the occurrence of a “screw” mark. Figure 4 shows the considered geometries: industrial version (SVP-500 roll, Figure 4a), with a 2.5° changed angle of the sizing section (Figure 4b) and with a 5° changed angle of the sizing section (Figure 4c).

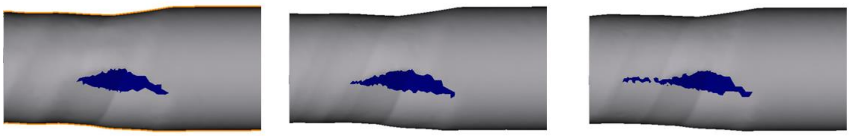


(a) (b) (c)

Figure 4. Roll geometry considered during modeling: (a) industrial version, (b) with a 2.5° changed angle of the sizing section, (c) with a 5° changed angle of the sizing section.

The results of modeling have shown that a change in the SVP-500 roll sizing section results in an increase in the contact mark area on the tube billet. In the industrial version of tool geometry (currently used at SC ChMP), there is no practically reduction in the calibrating section of the roll.

The correction of the computer model with regard to the geometry of the rolls has shown that the metal behaviour during rolling remains unchanged. Figure 5 shows the roll contact point images at the tube billet surface.



(a) (b) (c)

Figure 5. Roll contact point images at the tube billet surface: (a) the sizing section angle is unchanged, (b) the angle change is 2.5° and (c) the angle change is 5°.

It can be seen that for the industrial roll version, no reduction is observed in the sizing section. The 2.5° angle change in the sizing section results in some enlarging the contact point, the reduction occurs on a small area of the sizing section. With increasing the angle change till 5°, a reduction occurs over the entire sizing section range.

The obtained results suggest that the used industrial tool geometry is not perfect and should be significantly improved in order to avoid the appearance of a “screw” mark.

To study the reasons leading to the bending of a tube billet on a mandrel, the processes of heat transfer from the billet to the tool and auxiliary fixtures were investigated using simulation. Figure 6 shows the results of temperature distribution (for better visualization two deforming rolls were hidden).

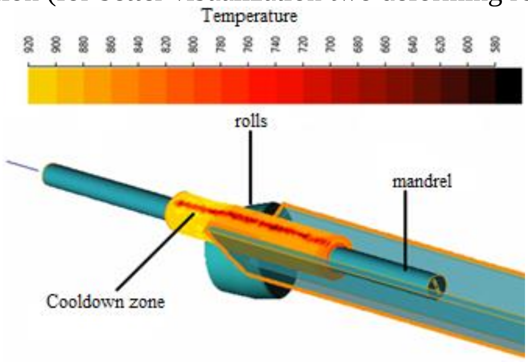


Figure 6. Temperature distribution during screw rolling of tube billets.

It has been found that a prolonged contact of a heated tube billet with cold supply fixtures gives rise to the so-called “cooldown zone” on the tube billet located along its entire length. The minimum temperature in this zone is 750–640°C. The difference in thermal expansion within the bulk of the billet and in the cooldown zone leads to bending of the billet. Deformation-induced heating the stable flow stage of screw rolling has no influence on the cooldown zone and does not lead to heating of the tube billet up to the optimum temperature. The data obtained using computer simulation has shown that reduction of the contact time between the heated tube billet and cold supply fixtures should as much as possible is needed to avoid strong cooldown and the tube billet bennding.

4 Conclusions

Based on the results obtained, the following conclusions were drawn:

i) The total deformation of tube billets to the tube final size on the SVP-500 mill is recommended to be 31 - 39%; the total deformation should be achieved in several passes (3–4 passes).

ii) In order to avoid bending of PT-7M titanium alloy tube billets during screw rolling on the SVP-500 mill, it is required to reduce the time of transferring the tube billet from the furnace to the mill, preventing cooldown.

iii) Before rolling on the SVP-500 mill, the billet should have a well-deformed structure both in the transverse and longitudinal directions.

iv) The temperature of tube billets at the deformation start on the rolls should not be more than 920°C (–20°C).

v) The simulation has shown that the geometry of industrial rolls used in the SVP-500 mill does not allow one to obtain the high-quality outside surface of PT-7M titanium alloy tubes > Ø250 mm. A 5° reduction in the roll sizing section angle is recommended.

References

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