SIMULATION OF PUSH-BENCH PROCESS IN MANUFACTURING OF SEAMLESS TUBES

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Abstract
Tube rolling by means of the push bench process is the fourth technological operation in ZP rolling mill. The principle is that the mandrel bar with elongated and mounted steel shape is being pushed through retrenching roll calibers on a high speed (up to 7 m/s), causing that the steel shape is being rolled over a mandrel bar. The roll calibers are not driven, they are rolled on material as a result of its rectilinear movement and friction. The aim of this work is to describe thermo-deformational processes and to define the critical phenomena, which appear by the push bench process itself. One of these is the risk of the hollow bottom tear off, where in preference the shear stress applies and we have pointed out, that the tear off may coincide with the bottom thickness as well. Another objectionable phenomenon is the size of “threadbare end” whose length is negatively influencing the weight of technological scrap. We suppose that its size is determined by the input material shape – nibs that occur in previous technological operations – calibration and punch pressing. The article also shows, that the “threadbare end” is also created by the push bench process itself and that its creation is in coincidence with an uneven heat generation by the deformation through retrenching roll calibers and consequential formation of longitudinal strips with uneven temperature fields.

Key words:
push-bench process, numerical simulation, thermo-deformation processes

1. INTRODUCTION
Push bench (Stossbank) represents final forming operation in the production of tube stock (tube semi-product). The hollow bloom is transported from three-roll elongator to push bench and further elongated using a mandrel bar as an internal tool. The push force is applied to the mandrel bar by rack-and-pinion arrangement, reaching operating speeds up to 6 m/s. In ZP push bench, 16 roll stands are arranged in push bench bed. All roll stands comprise three non-driven, circumferentially distributed grooved rollers. The gradually decreasing cross sections of the roller passes cause the hollow bloom to be rolled on the mandrel bar. Because the rollers are non-driven, they rotate due to friction force, acting between rollers and linearly moving tube stock. In ZP push bench, tube stock with wall thickness of 3.0 ± 12.5 mm can be produced. The calculation of particular calibration series considers mandrel bar diameter, 2 x wall thickness and required tolerance, respectively. For every calibration series, both fixed and adjustable calibers are usually considered. According to the last fixed caliber used, adjustable calibers are determined in order to match actual and required final tube dimensions [1].

2. SIMULATION PRELIMINARIES
Parameters of simulation were as follows:
Numerical model of a push bench was created with nine fixed and two adjustable roll stands. Due to symmetrical arrangement of modeled process, ½ model was chosen to speed up computation time (¼ model is also possible). Initial conditions of the model were set up, using basic data from previous operations. Input characteristics of ZP Tube Rolling Mill At were provided, ensuring tube stock with 141 mm diameter and 5.5 mm wall thickness as the simulation result.
Input data:
- Material: grade 11 steel with carbon content of 0.1 %
- length of hollow bloom : 1590 mm
- inner diameter: 222 mm [2]
- bottom thickness: 30 mm
- temperature of hollow bloom : 1200 °C

The rollers are non-driven. The rotation of rolls was modeled by means of rotation function in DEFORM 3D software where user can enter a small torque and thus simulate rotation of rollers by means of friction forces.

Fig. 1 Work pass of a push-bench roller (up), estimated length of elongated tube stock

3. SIMULATION RESULTS

3.1 Rolled shape analysis
Gradual reduction of wall thickness of a tube stock passing through selected roll stands can be seen in Fig. 2. Reduction of a particular caliber can be seen in Fig. 1. The shape of the tube stock cross-section as it passes through each roll stand takes the shape of a cylinder caliber. It can be seen that the smallest wall thickness of the tube stock coincides with axes of mirror symmetry of rolls whereas the biggest wall thickness can be observed between each of the neighboring rolls. Nevertheless, unevenness of the wall thickness is gradually reduced as the tube passes through the last two adjustable roll stands.
3.2 Stress distribution analysis

Mechanical stresses induced in material as it passes through each roll stand are caused by oval-shaped rollers. Calculated effective stress reached minimum of approx. 70 MPa and the maximum of approx. 170 MPa (Fig. 3).

Stresses during the rolling process didn’t change significantly. Maximum value of effective stress obtained after 7th roll stand was approx. 170 MPa.

3.3 Temperature field analysis

The temperature of a rolled material during elongation gradually increases from the initial temperature of 1200 °C to approx. 1300 °C (Fig. 4). This is mainly due to the heat generated at high strain and, especially, at high strain rate when passing through each roll stand. Heat transfer into the rollers and to the surroundings is not significant given the short duration of the process (approx. 3.5 s). Heat transfer into the mandrel bar is also reduced due to the 550 °C mandrel bar preheating.
In Fig. 4 we can clearly see that the surface temperature at the same distance of the material is not the same. This is mainly due to the heat generated during oval rollers passes, as mentioned above. The largest amount of heat is generated right in the middle of each roller (smallest caliber). For this reason, we can observe longitudinal strips of different temperatures (Fig. 5). These temperature strips occur during elongation in real push-bench production process as well.
3.4 Uneven deformation of tube end

Fig. 6 End of elongated material, exhibiting uneven deformation

In presented numerical model, uneven deformation of tube end occurs and is clearly visible in Fig. 6. Such uneven deformation is common in real production process, exhibiting even longer "protrusions". In our case, the simulation confirms formation of these protrusions even if the input model did not include data with the uneven deformation that naturally occurs during technological processes of calibration and piercing. For this reason, we can conclude that the resulting protrusions would be even more pronounced.

As this uneven deformation of tube end occurs even without considering the previous technological operations, we can conclude that its occurrence is caused by high strain-rate heat generation and subsequent formation of longitudinal strips of different temperatures.

4. CONCLUSIONS AND RECOMMENDATIONS

Simulation fourth technology step on the push bench process in the production tubes in ŽP a.s. is important to the knowledge of all the thermo-deformation processes that govern the process of rolling materials. By the push bench process we meet with some inconvenient events, which is much as possible to eliminate them. One is the danger of secession the bottom of tube stock, which operate at the bottom shear stresses in this case the stress reaching the size of approx. 120 MPa. We think that the cause of secession bottom may have a bearing on the actual thickness of the bottom (in our case 30 mm) is therefore suggested the possibility of numerical simulations of various thicknesses diene and their subsequent comparison.

Another objectionable phenomena is the size of "threadbare end". This tube end is of course cropped of by hot saw. But its length is negatively influencing the weight of technological scrap. As described in section 3.5 we assume that its size determined by the uneven deformation end from the calibration and punching but also pointed out that ends generated by push bench process.

We assume that their generation is caused by the already mentioned generation of heat on longitudinal strips of different temperatures.

REFERENCES