3-D FEM SIMULATION OF THE ROUND BARS ROLLING PROCESS

Sebastian Mróz, Henryk Dyja
(*Częstochowa University of Technology, Częstochowa, Poland*)

The paper presents the results of numerical studies on the effect of the round bar roll pass design on reduce the chance of rolled in defects. For tests, the Forge2007® computer program was used, which uses the FEM for solving the problems of the theory of plasticity in the design of the grooved rolling process technology. The tests were performed for 70 mm-diameter round rolled bars of constructional steel S355J2NbTi (according to the Polish standard).

The defects of shape mill products may involve an incorrect shape, inaccurate bar dimensions, external and internal disturbances of metal integrity and surface damage. They can appear in the rolling process itself, but may also be "transferred" from the previous stages of manufacturing, e.g. from the steelmaking process of continuous steel casting [1].

The application of numerical modelling in the sphere of investigation of process technologies enables the development and verification of existing rolling technologies [2-4]. The computer program Forge2007® [5] was used in the present study for the analysis of the process of rolling 70 mm-diameter round bars of steel S355J2NbTi, manufactured in a continuous bar rolling mill.

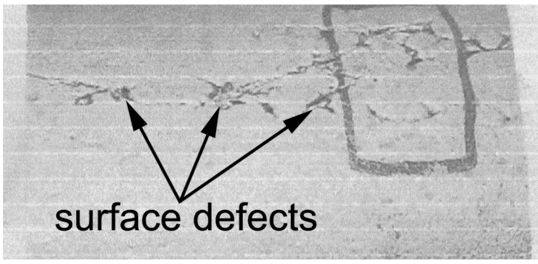

Figure 1 – Surface defects in 70 mm round bars

Figure 1 shows a template taken from a 70 mm-diameter round bar with a visible defect appearing irregularly on the surface. The defects happen sporadically on round bars and it can extend for several meters.
At present, the process of rolling 70 mm-diameter round bars of steel S355J2NbTi is carried out in 8 roll passes in the following arrangement of passes: box-square box-oval-circle (Fig. 2). The mill feedstock is a continuous casting of a size of 160x160 mm.

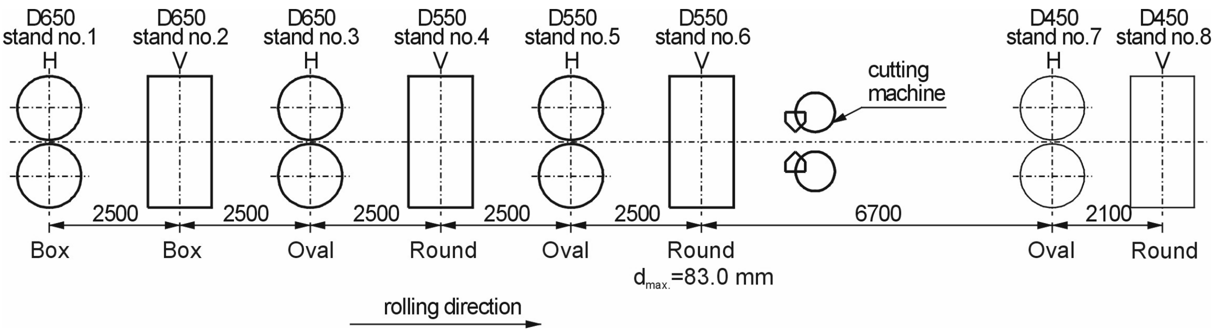

Figure 2 – The scheme of 70 mm-diameter round bars rolling process

On the basis of the performed analysis of the rolling scheme it has been found that the cross-section losses applied in the first two roll passes are too large and cause surface defects of metallurgical origin to appear on the surface of the strip being rolled.

The effect of the roll pass design scheme on the improvement of quality and the elimination of the potential for the formation of surface defects in 70 mm-diameter round bars has been determined in this work. The thermo-mechanical simulation of the groove-rolling process was carried out with the use of a visco-plastic model in the triaxial state of strain by using the Forge2007® [5] program, whereas the properties of the deformed material were described according to the Norton–Hoff [5] conservation law.

For numerical computation, technological data concerning the rolling of 70 mm-diameter round bars from 160x160 mm continuous castings in the D350 continuous rolling mill were taken. The numerical tests were divided into two stages. In the first stage, numerical modelling of the process of rolling bars according to the presently used technology was performed. The formation of the bar was done in 8 passes. In the second test stage, the roll pass design was changed in the sixth passes. A limitation in changing the roll pass design (Variant 2) was the roll pass in Stand 6 (an 83 mm-diameter round pass). Owing to the fact that there is a shearing machine after Stand 6, intended for end cropping and emergency strip cutting, the maximum cross-section of rolled metal may amount to 83 mm (Fig. 2).

The kinetic parameters and the boundary conditions of the rolling process were entered to simulation designs created in the Forge2007® program. The following input data were taken for the simulation: the tool temperature - 60°C; ambient temperature - 20°C; coefficient of heat exchange between the material and the tool, α - 3000 W/Km^2; coefficient of heat exchange between the material and the air, α_{air} - 100 W/Km^2; coefficient of friction - μ = 0.35, rolling temperature - 1050°C. To shorten the numerical computation time, the ¼ part of the stock and rolls was used.

In order to most accurately reproduce the actual conditions prevailing during rolling, a cooling process was conducted before rolling and after rolling in each stand, according to predefined parameters and cooling time. After each roll pass and cooling, the beginning and the end of the strip was cropped to avoid the inhomogeneity of temperature distribution and to remove “rolling tongues” forming during rolling. So prepared strip was fed to the next roll pass. For the next roll pass, the deformation history was removed because of occurring recrystallization, while the strip temperature distribution was passed on.

The determined value of the area reduction is shown in Figure 3.

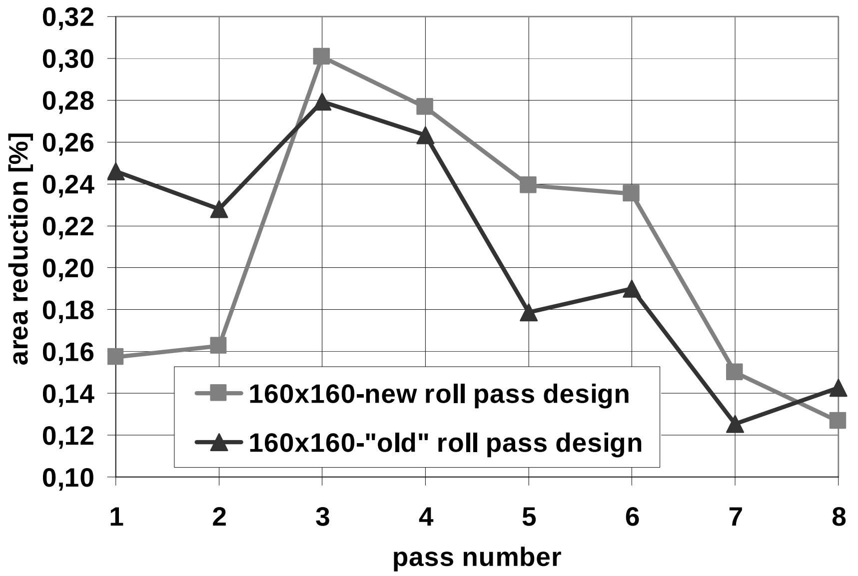

Figure 3 – Relative strip cross-section loss during rolling 70 mm-diameter round bars

On the basis of the analysis of the data in Fig. 3a it was found that the change of the roll pass design had had an effect on the cross-section loss of the strip rolled in individual roll passes. It was found that during rolling 70 mm-diameter round bars, as a result of applying large rolling reductions in box passes (roll passes 1 & 2), surface defects of metallurgical origin emerged after the second roll pass. To close and weld those defects, the rolling reduction value was decreased in the first two roll passes, which resulted in a reduction of strip cross-section loss from approx. 24% to 16%. As a result of decreasing the rolling reduction in the first two roll passes, in order to obtain a strip of a diameter of approx. 83 mm after the 6th roll pass, it was necessary to increase the strip deformation in roll passes 3 to 6. The strip cross-section losses, after using the new roll pass design in roll passes 3 to 6, increased by approx. 7% in roll pass 3, 20-30% in roll passes 4-5 and 15% in roll pass 6. Whereas, the strip cross-section losses in roll passes 7 and 8 remained at the previous level.

As a result of changing the shape of passes (Stands 1-5) and changing the distribution of rolling reductions in individual roll passes, different distributions of strain intensities and longitudinal stresses (in the rolling direction) were obtained in the strip being rolled. Examples of test results are shown in Figures 4÷7.

The results of calculation of the strain intensity distribution in the plane of metal exit from the deformation region during strip rolling in box passes (roll passes 1 & 2) are shown, respectively, in Figs. 4 and 5.

Comparison of the presented distributions of strain intensities in these passes indicates their higher homogeneity during rolling in the new box passes compared to rolling in the box passes used presently. The obtained strain intensity values are lower by approx. 50% compared to the strain intensity values obtained using the present roll pass design.

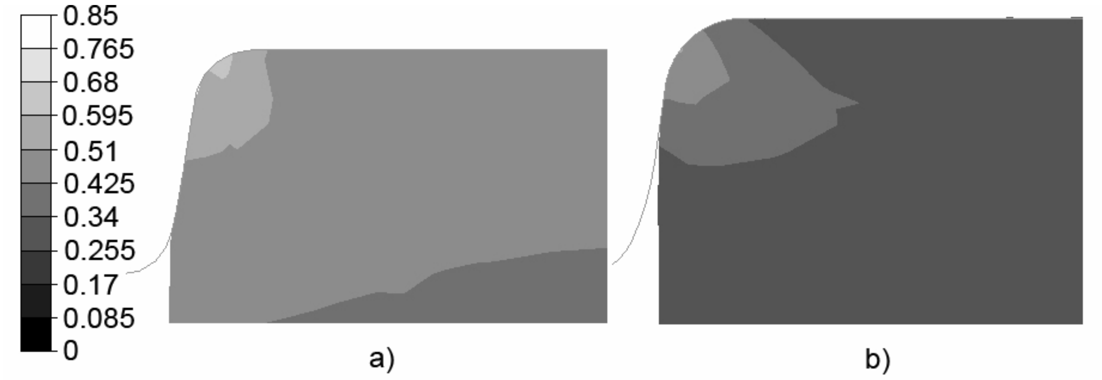

Figure 4 – Distribution of strain intensity (1st pass) on ¼ cross-section of band exit from the roll gap: a) roll pass design used at the present, b) new roll pass design

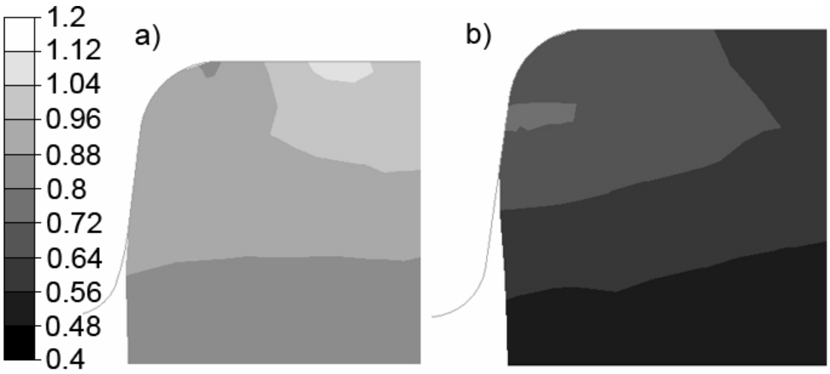

Figure 5 – Distribution of strain intensity (2nd pass) on ¼ cross-section of band exit from the roll gap: a) roll pass design used at the present, b) new roll pass design

An important factor that characterizes the potential for occurring cracks in the strip being rolled are longitudinal stresses (in the rolling direction). The fields of distribution of these stresses in the rolling direction on the rolled strip cross-section and in the plane of exist from the deformation region during rolling in box passes (roll passes 1 & 2) are shown in Figs. 6 and 7.

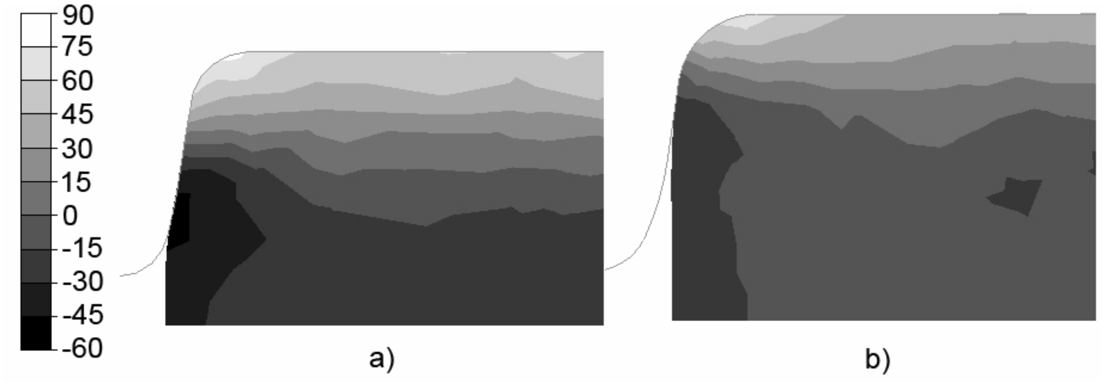

Figure 6 – Distribution of longitudinal stress (in the rolling direction), (1st pass) on ¼ cross-section of band exit from the roll gap: a) roll pass design used at the present, b) new roll pass design

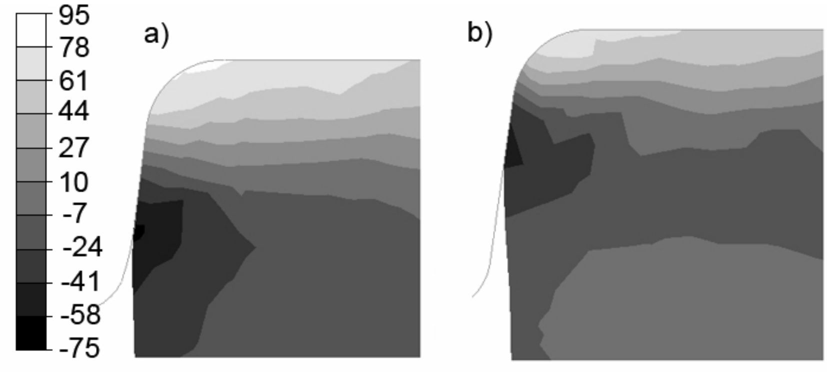

Figure 7– Distribution of longitudinal stress (in the rolling direction), (2nd pass) on ¼ cross-section of band exit from the roll gap: a) roll pass design used at the present, b) new roll pass design

From the obtained distributions one can observe a clear decrease in the magnitudes of tensile stresses in the strip regions being under a direct effect of the pass groove, when using the new roll pass design, compared to the presently used roll pass design. Moreover, the change of the roll pass design has resulted in a decrease in the values of stresses in the strip regions adjacent to the pass corners (the transition from the flat part of the pass bottom to its side part).

Conclusions

The Niobium and Titanium addition influence steel properties but they also influence the surface defects during the continuous casting and rolling processes.

Roll pass design which is used at the present during the rolling process of round bars from the S355J2NbTi casting billet of 160 x 160 mm can lead to defects.

Using of the new roll pass design influences on the value of strains and stresses which can lead to get final products with surface defects at the present technology.

Literature

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