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The effect of roll strip feeding angle on stress distribution during strip rolling on the break-down stand of a double-stand plate rolling mill

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A theoretical analysis of concast slab rolling on the break-down stand of a double-stand plate rolling mill has been carried out in the study. The theoretical analysis has made it possible to determine the effect of the angle of strip feeding to the rolls on the distribution of stresses within the roll gap during strip rolling.

The theoretical analysis of the rolling process was performed by using the commercial software package FORGE2 developed at Ecole des Mines in Paris. This package operates based on FEM and uses a flat, rigid-plastic model of the deformed medium.

1. INTRODUCTION

The symmetrical model of plate rolling, assumed when developing technologies and designing equipment by taking rough simplifications, leads to serious difficulties during real rolling at the rolling mill department. On the break-down stand of a double-stand plate rolling mill, the strip is fed to the rolls at a certain angle resulting from the difference in the setting of the level of working roller-table rollers in relation to the neutral rolling gap. The adoption of the symmetrical rolling model results in the occurrence of an uncontrollable phenomenon of strip bending on exit from the deformation region, which makes the failure-free running of the technological process difficult. The bending of the strip downwards causes damage to the roller-table rollers, whereas the excessive bending of the strip upwards causes difficulties in feeding the strip to the next pass.

An analysis of concast slab rolling on the break-down stand of a plate rolling mill has been carried out within this study. The theoretical analysis has made it possible to determine the effect of the angle of strip feeding to the rolls, θ, on the values of stresses. The theoretical analysis was performed by using the commercial software package FORGE2 developed at Ecole des Mines in Paris. This package operates based on FEM and uses a flat, rigid-plastic model of the deformed medium. The behaviour of the deformed material is described by the Norton-Hoff law which, in a tensor form, can be written as follows:

$$\mathbf{s} = \frac{2 \cdot K(T,\varepsilon)}{\left(\sqrt{3} \cdot \dot{\varepsilon}_i\right)^{1-m}} \cdot \boldsymbol{\varepsilon}$$

The function describing the plastic resistance of the material depending on strain and temperature is represented by the relationship below:

$$K(T,\bar{\varepsilon}) = K_0 \cdot \left(\bar{\varepsilon} + \varepsilon_0\right)^n \cdot e^{-\beta T}$$

In order to model the mechanical properties of steel 22G2A, the following coefficient values were applied: m=0.02522, K_0=240.28MPa, ε_0=0.001, β=3.23 10^{-3} and n=0.10. The strip temperature was assumed to be constant within the whole volume and equal to 1134°C for the strip of a thickness of h_0=76.68mm ;1152°C for the strip of a thickness of h_0=105.76mm; and 1160°C for the strip of a thickness of h_0=120.90mm. To describe the friction occurring at the contact of the material with the metal, the coulombic model of friction was employed. The friction coefficient value of μ=0.33 was taken for calculations.

2. RESULTS OF THEORETICAL EXAMINATIONS

The theoretical analysis of was conducted based on the conditions of plate rolling on roughing mill 3600 of the double-stand plate rolling mill at the Częstochowa Steelworks. A constant value of working roll diameters equal to 1080mm and a working roll rotational speed equal to 60 rpm in a steady process were taken for simulation, which corresponds to the real rolling conditions. The results of theoretical examination, presented below, apply only to the strip with an initial thickness of h_0=105.7mm.

2.1. The effect of the strip feeding angle □ and the relative strain □ on stress distribution in the deformation region

As a result of the performed computer simulation of the rolling process under conditions as described earlier, the following distributions of stresses occurring during strip rolling have been obtained. Figures 1÷6 illustrate distributions of normal stresses, σ_y, and distributions of mean stresses, σ_m, within the roll gap during the rolling of strip of a thickness of h_0=105.7mm with a rolling reduction of ε=10%, with the strip being fed to the rolls at angles of θ=0°, θ=2°and θ=4°, respectively.

Fig.1. Distribution of stresses σ_y within the roll gap, with h_0=105.76 mm, ε=10%, θ=0°

Fig.2. Distribution of stresses σ_m within the roll gap, with h_0=105.76 mm, ε=10%, θ=0°, positive values means compression

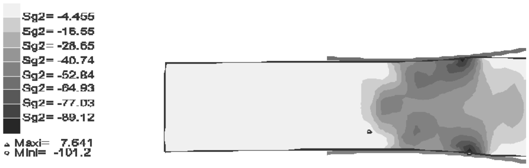


Fig.3. Distribution of stresses σ_y within the roll gap, with h_0=105.76 mm, ε=10%, θ=2°

Fig.4. Distribution of stresses σ_m within the roll gap, with h_0=105.76 mm, ε=10%, θ=2°, positive values means compression

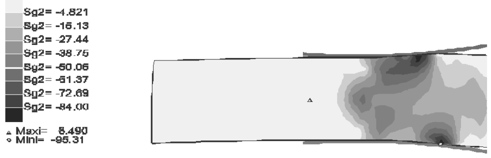


Fig.5. Distribution of stresses σ_y within the roll gap, with h_0=105.76 mm, ε=10%, θ=4°

Fig.6. Distribution of stresses σ_m within the roll gap, with h_0=105.76 mm, ε=10%, θ=4°, positive values means compression

It follows from the data shown in Figures 1÷6 that the change in the value of the angle of strip feeding to the rolls does not significantly influence the value of normal stresses and mean stresses occurring in the deformation region during the rolling of strip of a starting thickness of h_0=105.7mm with a rolling reduction of ε=10%. The maximum values of normal stresses and mean stresses (compressive stresses) occurred in the process of rolling at an angle of θ=4°, and were equal to σ_y= –101.2MPa and –76.01MPa, respectively. In the case of the mean stresses, the appearance of tensile stress zones was observed. These zones occur around the points of contact of the strip with the roll, in the planes of entry to, and exit from the deformation region, and in the plane of material entry to the deformation region in the central part of the strip. The strip feeding angle does not change the values of these stresses, which are contained in the range of σ_m=30.95–35.34MPa. The data shown in the figures indicate that the largest values of normal stresses and mean stresses occur around the points of contact of the metal with the roll in the neutral plane, whereas the maximum values of stresses occur in the points of metal and roll contact. It can be noticed that in the points of strip contact with the upper roll these stresses are larger than in the points of strip contact with the lower roll. With increasing roll strip feeding angle, a difference in the lengths of the arcs of metal contact with respective working rolls occurs. The lengths of the arc of strip contact with the lower roll have greater values than the lengths of the arc of arc of strip contact with the upper roll. This causes the neutral zone to displace. When analyzing the data shown in the above figures it can also be noticed that the strip feeding angle has an effect on strip curvature on exit from the deformation region. Increasing roll strip feeding angle from 0° to 4° causes an increase in strip curvature on exit from the roll gap. The strip bends toward the lower roll.

Figures 7÷12 show the distribution of normal stresses, σ_y, and mean stresses, σ_m, within the roll gap during the rolling of h_0=105.76 thick strip with a rolling reduction of ε=27.5%, with the strip being fed to the rolls at angles of $\theta=0^0$, $\theta=2^0$ and $\theta=4^0$, respectively.

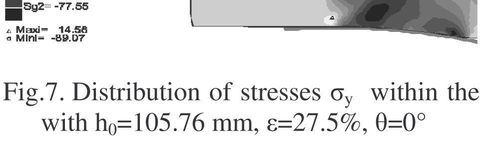


Fig.7. Distribution of stresses σ_y within the roll gap, with h_0=105.76 mm, ε=27.5%, θ=0°

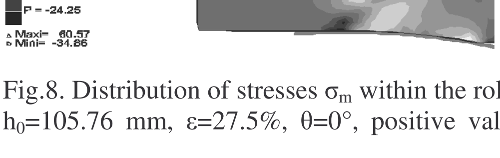


Fig.8. Distribution of stresses σ_m within the roll gap, with h_0=105.76 mm, ε=27.5%, θ=0°, positive values means

compression

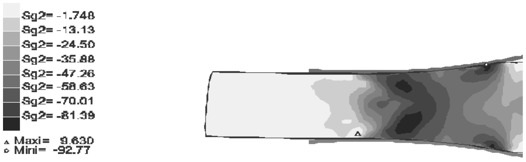
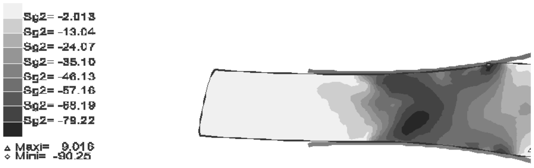


Fig.9. Distribution of stresses σ_y within the roll gap, with h_0=105.76 mm, ε=27.5%, θ=2°

Fig.10. Distribution of stresses σ_m within the roll gap, with h_0=105.76 mm, ε=27.5%, θ=2°, positive values means compression



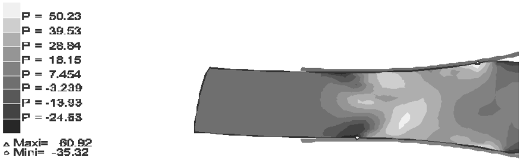


Fig.11. Distribution of stresses σ_y within the roll gap, with h_0=105.76 mm, ε=27.5%, θ=4°

Fig.12. Distribution of stresses σ_m within the roll gap, with h_0=105.76 mm, ε=27.5%, θ=4°, positive values means compression

The data shown in Figures 7 through 12 indicate that change in the value of roll strip feeding angle does not significantly affect the normal stresses and mean stresses that occur in the deformation zone during rolling strip of a starting thickness of h_0=105.76mm using a rolling reduction of ε=27.5%. In the case of normal stresses, σ_y, and mean stresses, σ_m, the maximum value of compressive stresses occurred for a roll strip feeding angle of $\theta=1^0$, amounting to, respectively, $\sigma_y = -94.63$MPa and $\sigma_m = -66.68$MPa. When analyzing the mean stress data shown in the figures, the appearance of tensile stress zones was also noticed. These zones occur around the points of contact of the metal with the roll, in the planes of entry to, and exit from the deformation region, and in the plane of material entry to the deformation region in the central part of the strip. The strip feeding angle does not change the values of tensile stresses, which are contained in the range of σ_m=34.20–35.32MPa. The data presented in Figures 7÷12 show that the maximum values of stresses are distributed in the roll gap on either side of the strip at the points of strip contact with the rolls. At the same time, at the points of strip contact with the upper roll these stresses are greater than for the lower roll. The roll strip feeding angle has the effect of diversifying the lengths of the arcs of metal contact with respective working rolls. The values of these lengths are larger for the lower roll. The strip feeding angle has an effect on strip curvature on exit from the deformation region. Increasing roll strip feeding angle causes the bending of the strip toward the upper roll and increases strip curvature upon exit from the roll gap.

SUMMARY

The article has presented only a small range of parameters influencing the phenomena that occur in the roll gap.

The performed theoretical analysis has demonstrated that the plate rolling process is a process that is influenced by several different factors. This causes a change in one of the parameters to entail a number of changes which, without a detailed analysis, may result in uncontrolled side effects, including even a disruption of the rolling process.