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Slitting criterion for various rolling speeds in MSR rolling process

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ABSTRACT

Purpose: The main idea of MSR technology is the capability of producing two, three, four and even five rods simultaneously from a single strip in a hot rolling process. Correctly separation of the joined strips is the one of the mainly problem in MSR process. Changing the rolling speed may causes easier of the strand division. In this paper results of the computer simulation of the double slitting rolling process were presented.

Design/methodology/approach: For numerical modelling of the multi rolling process a computer program Forge 2005, based by the finished element method was used. As a slitting criterion normalised Cockroft – Latham criterion was used.

Findings: For the analysis performed in this study, it was found that increasing of the rolling speed causes of increasing the normalized Cockroft – Latham criterion. For the small values of rolling velocity the strip separation was easier.

Research limitations/implications: Multi Slit Rolling process is applied in ribbed rods rolling. Adjusting of the rolling speed in multi slit rolling process could improve of the slitting band to the separated strips.

Originality/value: Incorrect construction or bad gap matching could cause lack of separation propelled slitting rolls. The separation of the band is effected by means of separating rollers, which shape must be properly designed to suit to the slitting pass. Changing of the rolling speed could improve of the separation to the single strips.

Keywords: Plastic forming, Engineering design, Slitting passes, Strip slitting, FEM

1. Introduction

The Multi Slit Rolling technology is generally employed during ribbed wired rods rolling process [1,2,3]. This technology enabled of the making two, three, four rods simultaneously from a single strip (a continuous casting or billet) during hot rolling process. . Rolling in multi-strand passes can be conducted on the existing rolling mills without having to incur any considerable investment outlays or install any special equipment. It allows a considerable increase in the production capacity of a rolling mill. The processes of rolling in multi-strand passes are characterized by a spatial state of strain and are difficult to be accurately described by mathematical models. Particularly difficult to define is the pattern of metal flow in the slitting pass and the strip slitting process itself [4]. In MSR technology special shape of the roll pass is the finishing rolls group - pre-slitting pass and slitting pass - is used. In pre – slitting pass the preliminary division of the material is made. In the slitting pass billet is formed to the single strips joined only by the thin bridges. Final division to the separated strips is made in the special guide box by the not propelled slitting rolls. Moving band impact against the separating rollers, setting the rollers in rotation. During moving of the band by the slitting rolls in the joining bridge are arise high tensile stress (square to the rolling direction). To the analysis of the slitting process the normalized Cockroft – Latham criterion is used [5]. To critical value of the slitting criterion mainly affect: geometry of the slitting rolls, temperature of the band and rolling speed. The rolling of rods with slitting of the strip calls for the use of special mathematical models that would allow for the tearing of metal. For the numerical modeling of double rolling computer program Forge 2005 was applied [6]. Application of this software shows god comparison of the theoretical and industrial data [7,8].

2. Numerical modelling of the double slit rolling process

For the examination of influence of the rolling speed to the criterion of separation of strands during rolling with longitudinal band splitting, a two-strand roll pass design, as used in one of the Polish steelworks for the rolling of Ø 16 mm ribbed rods, was utilized. Figure 1 shows the shape of slitting pass used in this work.

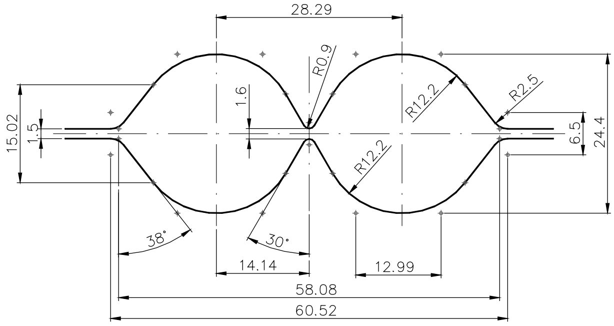

Fig. 1. Shape and dimension of the slitting shape (Ø 16 mm round ribbed rods rolling)

Table 1.
Chemical composition of the BSt500S steel

C	Mn	V	Si	Cr	Ni	S	P	Cu
0.2	1.4	0.1-0.15	0.4-0.5	0.04	0.25	0.04	0.04	0.25

Table 2.
Parameters of function (1) for the BSt500S

A_0	m_1	m_2	m_3	m_4
16086.83	0.00387	0.434633	0.060926	0.99398

2.1. Material

The accuracy of numerical modeling highly dependent on the accurate determination of the properties of materials used for tests [9,10]. Undertaken experimental studies aimed at the determination of the effect of strain parameters on the magnitude of yield stress for steel BSt500S (according to the Polish standard). Chemical composition of materials used for tests is given in Table 1.

Plastometric tests were performed on a DIL 805 A/D dilatometer-plastometer possessed by the Institute of Modelling and Automation of Plastic Working Processes, using strain velocities of $0.1s^{-1}$, $1.0s^{-1}$, and $10s^{-1}$. In order to obtain a mathematical relationship making the value of yield stress, σ_p, dependent on deformation parameters, (ε, $\dot{\varepsilon}$, T), the results of the performed tests were approximated with a functional relationship described with Equation (1). The yield stress σ_p dependence of strain intensity ε, strain rate $\dot{\varepsilon}$ and temperature T is approximated by Henzel-Spittel formula expressed as:

$$\sigma_p = A_0 e^{m_1 T} \varepsilon^{m_2} \dot{\varepsilon}^{m_3} e^{m_4 \varepsilon} \quad (1)$$

Estimated coefficients A_0, m_1, m_2, m_3, m_4 of the BSt500S steel are given in Table 2. The mean square for this function was 0.1164.

2.2. Mathematic model of the numerical modeling rolling in slitting shape

The theoretical analysis was performed for the real rolling conditions [11]: the initial strip temperature – 1000°C, the working roll diameter D = 350 mm, the slitting roll diameter d = 164 mm. The distance of the working rolls axis from the slitting rollers axis is 350 mm. The slitting rolls did not have a constant speed and were not propelled. In order to reduce the computation time, a ½ of the band was used. Moreover the following were taken for simulations: tool temperature - 60°C, ambient temperature – 20°C, friction factor – 0,8 [12], coefficient of heat transfer between the material and the tool α – 3000 W/Km^2, coefficient of heat transfer between the material and the air α_{air} – 100 W/Km^2. Also three rolling speed was put into use: case I – 3 m/s, case II – 6 m/s and case III – 9 m/s. To define shape of the band, templates rolled during the preliminary rolling mill setting were used. Figure 2 is shown schematic diagram of the system used in the numerical modelling.

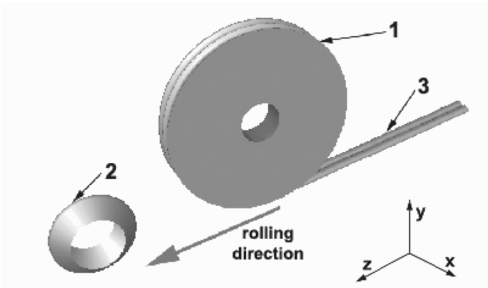

Fig. 2. Schematic diagram of the system used in the numerical modeling of the Ø 16 mm round ribbed rods rolling process: 1 – working roll, 2 – slitting roll, 3 – band

3. Slitting criterion dependence from rolling speed

3.1. Distribution of the normalized Cockroft – Latham criterion

Theoretical investigation of the double rolling ribbed rods rolling was performed without taking slitting to separate strips process. Because the distribution of the normalized Cockroft – Latham criterion is symmetric [13], to the analysis zone of the joining bridge was taken (Fig. 3).

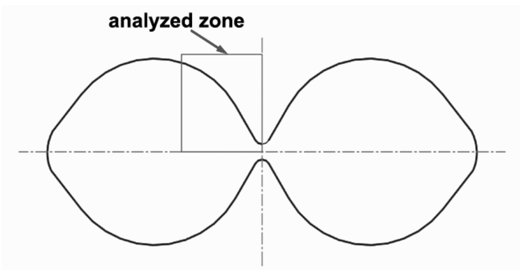

Fig. 3. Location of the analyzed zone (joining bridge)

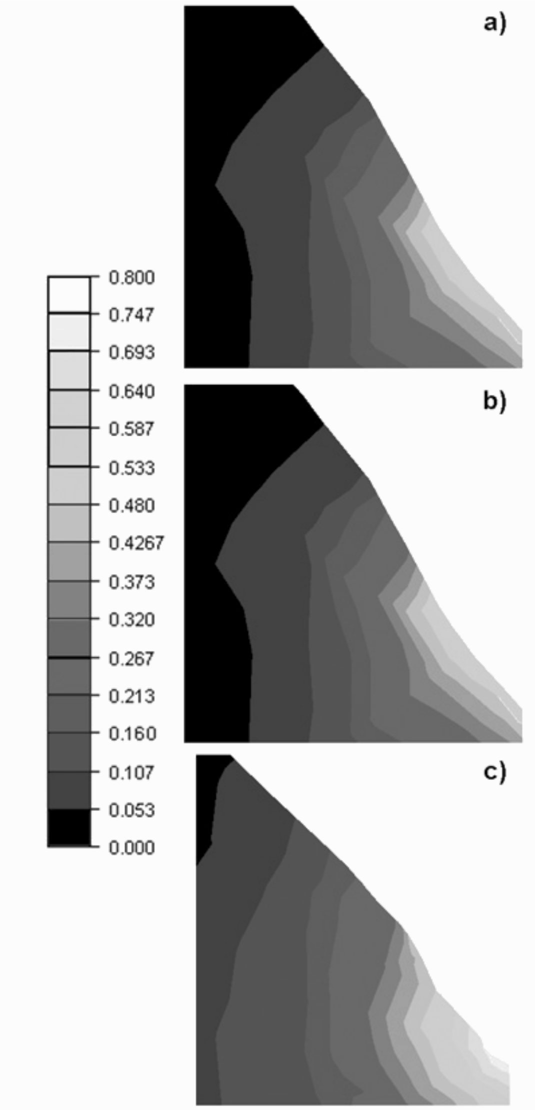

Fig. 4. Distribution of the normalized Cockroft – Latham criterion in the analyzed zone for rolling speed: a) 3 m/s, b) 6 m/s, c) 9 m/s

Analysis was performed in the half in the zone between location of contact of the strands with the separating roller and the separating roll rotation axis.

On the Fig. 4 distribution of the normalized Cockroft – Latham criterion in the analyzed zone is presented. As is shown the maximum values of the normalized Cockroft – Latham criterion are estimated at the bridge surface, in turn minimal values are observed in central zone of the bridge.

For the I case values of the normalized Cockroft – Latham criterion are smallest. Normalized Cockroft – Latham criterion reach the greatest values in the III case. It can be found that increasing of the rolling speed causes increasing of the value normalized Cockroft – Latham criterion in the zone of joining bridge. For greeter rolling speed during the slitting also increase strain velocity in the bridge.

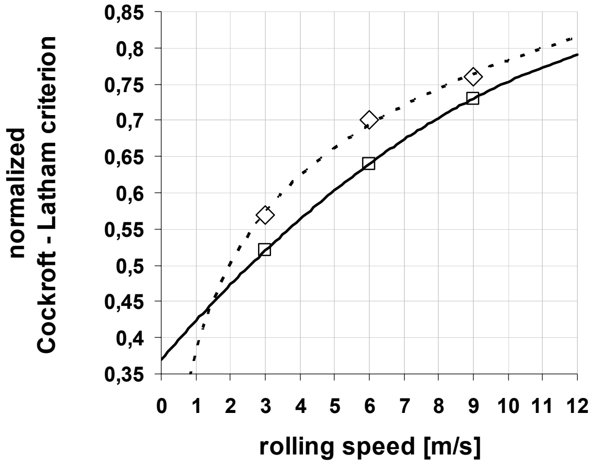

Fig. 5. Relationship of the normalized Cockroft – Latham criterion vs. rolling speed

Changing of the values normalized Cockroft – Latham criterion is engendered by change of the stress condition in the joining bridge. Increasing of the rolling speed causes increase of the strain rate and strain intensity in the joining bridge during strand slitting in the separation rolls. For estimated data median values of the slitting criterion in the vertical axis was calculated. It can be found that medium values of slitting criterion (for the axis of symmetry joining bridge) equal: 0.52 (rolling speed 3 m/s), 0.64 (rolling speed 6 m/s), and 0.73 (rolling speed 9 m/s).

To identification of the influence of the rolling speed to the slitting criterion, estimated in theoretical analysis data were compared with the experimental results of the normalized Cockroft – Latham criterion in tensile test [14,15]. Stress condition during tensile test is similar to the slitting process. To the correct compare compatibility of the temperature and strain rate to both processes must be keep.

On the Fig. 5 relationship of the normalized Cockroft – Latham criterion vs. rolling speed was presented. Solid line represents the values of the slitting criterion estimated from numerical modeling MSR process; in turn dotted line represents critical values of the normalized Cockroft – Latham criterion gained for the tensile test. For both cases data were extrapolated to the speed rolling 0-12 [m/s] range.

As is shown on the Fig.5 values of the normalized Cockroft – Latham criterion estimated from tensile tests are greater (for the same physical conditions) than calculated in numerical modeling of the ribbed rods rolling to rolling speed range 3-9 [m/s].

For speed rolling equal 1.5 [m/s] value of the normalized Cockroft – Latham criterion for tensile test and for MSR rolling process are the same. It means that in this case it is possible slitting rolled band into two separated strands in point located in analyzed point.

4. Conclusions

Changing of the rolling speed during multi slit rolling process may affect to the accurate division rolled band to separated strips. It can be found that increasing of the rolling speed over 9 m/s in the slitting – pass could improve band separation conditions. Also decreasing of the rolling speed less than 3 m/s causes that separation condition during multi slit rolling process are accurate. In industry conditions it isn't probable put into use the smaller rolling speeds, thus is recommended increasing of the rolling speed to ensure advantageous correct band separation.

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