Research on the Effect of Reduction Distribution in Universal Stands on the Process of Metal Transition from Sides to the Center Line of Transfer Bar

A V Polyakov and I P Mazur

1 Lipetsk State Technical University, 30 Moskovskaya Street, Lipetsk, 398043, Russia

E-mail: pool_akov@mail.ru

Abstract. The edge defects formed on the continuously cast slab before entering the hot rolling mill in the roughing group of the broadband mill are moved from the side faces and edges of the slab to the upper and lower surface of the slab. This process is facilitated by alternating compression in vertical and horizontal rolls. This article describes the transition of a metal from the edges and side faces of the slab at the top and bottom surfaces of the slab sheet during rolling in universal stands of the roughing stands of the hot rolling mill. The amount of movement of the defects on the surface of the slab directly affects the amount of lateral trim is necessary for assured removal of marginal defects in subsequent processing. The presented mathematical model based on the finite element method includes compression of continuously cast slab in three separate stands consisting of vertical and horizontal rolls. The influence of a number of technological parameters and modes of adjustment of the vertical rolls on the value of the metal displacement to the center line of the transfer bar is studied.

1. Introduction

In the production of steel strip, a significant number of jams, during both cold and hot rolling, happens due to the presence of defects of the strip, such as sliver, rolled crack, etc. Jam in the rolling mill due to strip breakage results not only in rejects, but also in mill downtime and roll damage. The most critical from the point of view of jamming defects are located near the edges of the strip.

There are several reasons for the formation of cracks, one of which is steel casting on curvilinear continuous-casting machines [1]. Furthermore, when rolling through the roughing stands of continuous wide-strip hot mill and spreading the strip, metal areas are moving from edges and sides to the horizontal surfaces [2, 3].

The objective is to assess the amount of metal transition from sides to the upper and lower surfaces of the transfer bar when rolling through the roughing stands of a continuous wide-strip hot mill, and also to determine the technological parameters of rolling that have the greatest influence on the metal transition. This problem was solved by conducting experiments with a help of a mathematical model based on the finite element method using the ABAQUS software.

2. Model description

The model includes 3 vertical and 3 horizontal rolls arranged in pairs (Figure 1). In this case, the pair of vertical and horizontal rolls form a continuous group (the transfer bar is simultaneously in the vertical and horizontal rolls), and the pairs are arranged in such a way that the transfer bar goes into the next pair.
only after it leaves the previous one. Thus, we obtain a model of reduction of a slab in three universal roughing stands.

For the following modeling conditions:
1) slab’s steel brand Ст3;
2) slab’s temperature 1200 °C;
3) slab’s dimensions: $H = 250$ mm; $B = 500$ mm; $L = 500$ mm;
4) friction coefficient between slab and rolls is constant and equal to 0.5 [4].

The following assumptions are made [4]:
1) process under review – symmetrical in width and thickness of the slab, isothermal;
2) rolls are non-compressible;
3) deformable medium is viscoplastic;
4) slab’s material – homogeneous, isotropic, resistant to deformation described by the equation in accordance with the work [5]:

$$
\sigma = [b-(b-a)e^{-R\lambda}] [1-A_1(1-e^{-\lambda_1 t})-A_2(1-e^{-\lambda_2 t})-A_3(1-e^{-\lambda_3 t})]
$$

(1)

where $\varepsilon$ and $t$ – deformation degree and time from the start of the process; $a, b, A_1, A_2, A_3, B, \lambda_1, \lambda_2, \lambda_3$ – coefficients depending on steel grade and metal temperature.

The diameters of the rolls are shown in Table 1.

| Type of the roll | Roll diameter, mm | Stand No. 1 | Stand No. 2 | Stand No. 3 |
|-----------------|------------------|-------------|-------------|-------------|
| Vertical        |                  | 1000        | 800         | 800         |
| Horizontal      |                  | 1350        | 1080        | 1080        |

In the research of the transition of metal from the sides to the upper and lower surfaces, 3 points lying...
on the lateral edge of the slab are considered:
1. Point A – 50 mm from the «head» of the slab.
2. Point B – in the middle of slab’s length (250 mm from «head» and «tail» of the slab).
3. Point C – 50 mm from the «tail» of the slab.

In this model, the reduction of the slab in three stands is considered, because it is in them that the greatest absolute reduction occurs and, as a result, the greatest spreading of the transfer bar. The inclusion in the framework of the model of the remaining roughing stands (usually there are 5-6 roughing stands) would lead to a significant complication of the model and an increase in the resources used without a drastic change in the results.

3. Modeling results
With the reduction mode No. 1, shown in Table 2, all the points under consideration moved to the upper edge of the transfer bar. The position of these points is shown in Figure 2.

### Table 2. The modes of reduction (as per stand) in the model of rolling a slab in three universal roughing stands.

| Reduction mode | Parameter under consideration | Stand No.1 | Stand No.2 | Stand No.3 |
|----------------|-------------------------------|------------|------------|------------|
| No.1           | Width/thickness after the stand, mm | VV 450 | HV 180 | VV 450 | HV 144 | VV 450 | HV 96 |
|                | Local absolute reduction, mm   | 50        | 70        | 18*       | 36       | 12*       | 48       |
|                | Local percent reduction, %     | -         | 28        | -         | 20       | -         | 33       |
| No.2           | Width/thickness after the stand, mm | VV 460 | HV 180 | VV 470 | HV 144 | VV 470 | HV 96 |
|                | Local absolute reduction, mm   | 40        | 70        | 6*        | 36       | 8*        | 48       |
|                | Local percent reduction, %     | -         | 28        | -         | 20       | -         | 33       |
| No.3           | Width/thickness after the stand, mm | VV 440 | HV 180 | VV 430 | HV 144 | VV 430 | HV 96 |
|                | Local absolute reduction, mm   | 60        | 70        | 30*       | 36       | 16*       | 48       |
|                | Local percent reduction, %     | -         | 28        | -         | 20       | -         | 33       |
| No.4           | Width/thickness after the stand, mm | VV 410 | HV 180 | VV 435 | HV 144 | VV 440 | HV 96 |
|                | Local absolute reduction, mm   | 90        | 70        | 0*        | 36       | 0*        | 48       |
|                | Local percent reduction, %     | -         | 28        | -         | 20       | -         | 33       |
| No.5           | Width/thickness after the stand, mm | VV 474 | HV 180 | VV 454 | HV 144 | VV 440 | HV 96 |
|                | Local absolute reduction, mm   | 26        | 70        | 34*       | 36       | 30*       | 48       |
|                | Local percent reduction, %     | -         | 28        | -         | 20       | -         | 33       |

Note. VV – vertical rolls; HV – horizontal rolls; * – the indicator is given taking into account spreading of the strip after going through the horizontal rolls with an established rolling mode.
As expected, the smallest transition to the center line of the transfer bar turned out to be at a point lying on a section with an established rolling mode (B). After rolling in three stands (total percent reduction in thickness of 62%), point B moved by 12.1 mm (Figure 3). The greatest transition to the center line of the transfer bar was the point lying on the tail of the slab (C). After rolling in three stands, point C moved by 24.5 mm (Figure 3).

3.1. The effect of the edge reduction value
To assess the effect of reduction in vertical rolls, modeling was performed with a smaller (mode No. 2) and a larger (mode No. 3) absolute reduction in three stands relative to mode No.1, considered earlier.

A comparison of the transition value of the points under consideration to the center line of the transfer bar is shown in Figure 3.

All considered points moved mostly to the center line of the transfer bar with a greater width reduction (reduction mode No. 3).

3.2. The effect of reduction distribution (as per stand)
In this series of experiments, an additional limitation is introduced. The final slab width (after Stand No. 3) should be 450 mm.

Modeling was performed with heavy reduction in the vertical rolls of Stand No. 1 and the absence of reduction in the vertical rolls of Stands No. 2 and No.3 (mode No. 4), as well as with uniform reduction in the vertical rolls of stands No. 1 to No. 3 (mode No. 5).

The offset of the points to the center line of the transfer bar at various reduction modes is shown in Figure 4.

Figure 3. The offset of the points to the center line of the transfer bar when using reduction modes No. 1, 2 and 3: (a) – the point on the «head» part of slab (A); (b) – the point in the middle of slab’s length (B); (c) – the point on the «tail» part of slab (C).
All metal located on the edge of the slab received the greatest reduction when using mode No. 4, corresponding to excessive width reduction in the vertical rolls of stand No.1 and the formation of the necessary strip width due to broadening during horizontal reduction. In this case, the vertical rolls of stands No. 2 and No. 3 serve as guiding rulers (reduction does not occur).

When assessing the minimum transition to the center line of the transfer bar, point B is taken (the point in the middle of slab’s length). Its transition is minimal under mode No. 5, which corresponds to uniform width reduction in all stands. Points A and C in modes No. 1 and No. 5 have transitioned by a comparable amount.

Thus, the preferred mode of width reduction, from the point of view of minimizing the transition of metal from sides and edges of the slab to the center line of the slab, is a mode in which the absolute width reduction in all stands is distributed uniformly.

### 3.3. The effect of speed ratio of vertical and horizontal rolls
A different ratio of linear speeds of horizontal and vertical rolls forming a pair and its effect on the transition of the points to the center line of the transfer bar are considered. During the experiment, three cases were considered:

- Linear speed of vertical rolls is equal to linear speed of horizontal rolls of the corresponding stand;
- Linear speed of vertical rolls is 30% higher than the linear speed of horizontal rolls of the corresponding stand; thus, the vertical rolls support the horizontal rolls;

![Figure 4](image.png)
Linear speed of vertical rolls is 30% lower than the linear speed of horizontal rolls of the corresponding stand; thus, the tension between vertical and horizontal rolls is created. The modeling results are shown in Figure 5.

When assessing the minimum transition to the center line of the transfer bar, point C is taken (the point on the «tail» part of slab). Its transition is minimal in the mode when the vertical rolls create a support for horizontal rolls. For the remaining points (A and B), an inverse relationship is observed. When tension between vertical and horizontal rolls is created – the smallest transition is observed.

Such a multidirectional effect of the speed mode of vertical rolls is explained by various deformation conditions for the points under consideration. Points A and B were deformed in the horizontal rolls under the following conditions: the transfer bar was simultaneously in the vertical and horizontal rolls, which means tension or support takes place (depending on the mode). Point C was deformed in horizontal rolls under the following conditions: the transfer bar had already left the gap of vertical rolls.

Thus, the preferred mode of width reduction, from the point of view of minimizing the transition of metal from the sides and edges of the slab to the center line of the transfer bar, is a mode in which the absolute width reduction in all stands is uniformly distributed and linear speed of vertical rolls is lower than the linear speed of horizontal rolls.

Figure 5. The offset of the points located on the edge to the center line of the transfer bar at different speeds of vertical rolls: (a) – the point on the «head» part of slab (A); (b) – the point in the middle of slab’s length (B); (c) – the point on the «tail» part of slab (C).
4. Conclusion

Edge defects are the cause of jams, rejects and line downtime. Reducing the transition of the metal, as well as the defects, from the sides of the slab to the upper and lower surfaces of the transfer bar allows removal of the defective areas during subsequent trimming of the side edges. The effect of the distribution of width reduction of the slab and the speed of the vertical rolls on the amount of metal transition from the edges of the slab to the center line of the transfer bar is determined. An optimal mode of adjusting the operation of vertical rolls is proposed in order to reduce the amount of metal transition to the center line of the transfer bar.

References

[1] Ogarkov N N, Platov S I and Urtsev V N 2018 Rolled products 3 15–21
[2] Xianghua L, Hailiang Y and Changsheng L 2006 Proc. 9th Int. Steel Rolling Conf. (France: Paris)
[3] Shabalov I P 2004 Rolled products 9 3–12
[4] Chun M, Kwon H and Park H 2006 Proc. 9th Int. Steel Rolling Conf. (France: Paris)
[5] Konovalov Yu V, Ostapenko A L and Ponomarev V I Calculation of sheet rolling parameters (Moscow: Metallurgy) p 429