Optimal Width Reductions in Hot-strip Mills

By Jan-Olov PERÄ,** Risto PIETOLA*** and Urban SJÖGRENN****

Synopsis

Investigations have been carried out to optimize the pass-schedules of the rougher in hot-strip mills. The aim was to increase the yield and reduce the number of necessary slab widths. In this paper results from industrial trials using varying edging schedules are presented. The working range for early as well as late edging is discussed. Pilot plant trials on hot steel at MEFOS show that by varying the roll gap during rolling, a strip with uniform width and small crop losses can be produced.

I. Introduction

The yield in hot-strip rolling depends to a great extent on the geometry of the edges and the form of head and tail ends. In some cases, large parts of the hot-rolled material have to be cut off in order to get a good product. Especially when rolling high-alloy steels, this results in financial losses.

A great deal of the shape errors are created during reversing rolling in the roughing stand, where slabs are rolled to transfer-bars before the final rolling in the continuous mill. The rougher consists of either an universal mill or separate vertical and horizontal stands. Figure 1 shows the lay-out of the hot-strip mills in Raahé (Rautaruukki Oy) and Borlänge (Svenskt Stål AB (SSAB)).

The aim of this project was to investigate the influence of the pass schedule on the form of the transfer-bars. In this way an optimization of the edging can be achieved, resulting in increased yield and a reduction in the number of slab-widths.

The flat pass-schedule used in all the industrial trials presented in the following chapters is according to normal practice, as shown in Table 1.

II. Preliminary Trials

The practical trials started with investigations of the geometry of the slab during edge rolling. At SSAB, two slabs with a cross-section of 1555×222 mm, were rolled in different ways. The first one was edged to 1470 mm with only one edging-pass, while the other was edged the same amount with two passes. The shape errors at the slab-ends were obvious and fish-tail was considerable, especially in the tail end. In the cross-section of the slab the dog-bone profile could be seen. The height of the dog-bone is smaller in the head and tail ends.

The conclusions from these two trials are, that when edging in one pass you get a higher degree of deformation of the slab, i.e., the deformation zone reaches longer towards the center of the slab, resulting in a reduced height of the dog-bone. When the width reduction is done in two passes, the fish-tail tends to be more acutely angled, while at the same time the end zones, where the dog-bone height decreases, tend to be shorter.

Preliminary trials were also done at Rautaruukki. Two slabs, 1290×210 mm, were rolled: the first one with three edging passes and the other one with three edging passes followed by a flat pass. Afterwards the width was carefully measured along the length of the slab. The heavy drafts in the edging passes result in a strong dog-bone. The end zones, where the height of the dog-bone decreases, are long. In the following flat pass the spread is increased, the higher the dog-bone the greater the increase. This results in sub-widths in the head and tail ends. The above course of events is illustrated in Fig. 2.

III. Industrial Trials in Which Normal Edging Has Been Studied

Industrial trials investigating normal width reductions have been performed both at (SSAB) and at Rautaruukki. At SSAB 1290 mm wide slabs were rolled using three different width reductions: 30, 40 and 45 mm. At Rautaruukki 1490 and 1030 mm wide slabs were rolled to 1450 and 1000 mm, respectively.

During the trials, the edging schedule was varied (i.e., the pass-schedule at the vertical stand).

<p>| Table 1. Pass schedule and rougher data (SSAB). |</p>
<table>
<thead>
<tr>
<th>Pass no.</th>
<th>Height</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat pass-schedule</td>
<td>1</td>
<td>189.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>155.9</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>123.1</td>
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<td></td>
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<td>90.2</td>
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<td></td>
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<td>60.4</td>
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<td></td>
<td>6</td>
<td>39.7</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>26.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Roll diameters</th>
<th>ø815 mm—Horizontal stand</th>
<th>ø960 mm—Vertical stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab dimensions</td>
<td>220×1305×3500 mm</td>
<td></td>
</tr>
<tr>
<td>Furnace temperature</td>
<td>1250°C</td>
<td></td>
</tr>
</tbody>
</table>

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mally the gap of the vertical stand is, in principle, set to the desired final width from the first pass. The result is that the main part of the edging work is done in the first passes. During the trials the roll-gap was varied pass by pass. The edging work was thereby displaced to the latter part of the pass-schedule. The construction of the pass-schedule was done with the aid of a model by Okado et al. and a computer program previously developed for parameter analysis in hot rolling.

The difference between the new and old schedules is illustrated in Fig. 3, where the calculated width
For narrow bands no improvement in yield is achieved. Nevertheless, when rolling according to the new schedule, the slabs did not climb up the vertical rolls. This is otherwise a common problem when the width reductions are greater than 30 mm.

IV. Maximum Edging

The maximum total width reduction is of course obtained when the highest possible edge draft is taken in each pass. Several trials were done in order to find the maximum possible width reduction in existing mills. At Rautaruukki a schedule with three edging passes before the first flat one was tried. With the aid of computer, a schedule with edging-drafts of up to 60 mm was constructed. The resulting total width reduction after completed hot rolling is then around 150 mm. In Fig. 6 the edging schedule is shown for rolling 1 450 mm wide slabs to 1 300 mm. The figure shows the schedule with the spread during the horizontal passes taken into account.

The largest edging drafts caused some problems during rolling. The slab tended to run very slowly through the vertical stand. In the case of SSAB this is especially noticeable when rolling in the reverse direction when, at the end of the pass, the slab is only driven by the vertical stand. In general the total width reduction is maximised to 150 mm for wide slabs and to around 100 mm for slabs narrower than 1 000 mm.

The resulting strip widths from the trials with heavy edging are presented in Fig. 7. The width shortage at the strip ends has a maximum of 55 mm and the longest parts with width shortage are around 20 m long. This would result in end losses of up to 10 %, which of course is unacceptable. This effect has also been reported by Hirano et al.59

Fig. 3. Pass-schedules for the vertical stand when edging early and late in the schedule.

Fig. 4. Length of fish tail for different types of edging schedules.

Fig. 5. Width undersize for different types of edging schedules.
V. Width Enlargement

Rolling with width enlargement means rolling to a transfer-bar wider than the initial slab width. The shape errors created in this way consist of tongue-form and excess width at the strip ends.

At SSAB different types of schedules were investigated in relation to the received width pattern. The conventional type with a fixed setting of the roll gap at the edging stand was compared to a schedule with a small edging draft in each pass. The latter type of rolling puts high demands on the spread calculation model used.

The results from the trials show reduced width deviations with the modified type of rolling. Insufficient knowledge about the actual width at each pass caused difficulties in reaching the nominal strip width. In order to construct an optimal rolling schedule for this type of rolling, width measurements have to be done continuously.

IV. Pilot Plant Trials with Variation of the Roll Gap during the Pass

The industrial trials showed that with heavy edging drafts and when edging late in the pass-schedule problems occur with undersized widths at the strip ends. In order to eliminate these width errors, trials were done by increasing the roll gap in the head and tail end of the pass.

The trials were done in a 1:5 scale on hot steel in the reversible heavy mill at MEFOS. In Table 2 the pass-schedule together with mill data is presented. Edging was simulated by tilting the slab and rolling it in box grooves on each side of the roll. The electro-hydraulic roll gap adjustments were controlled by the roll force signal and photo-sensitive devices on each side of the rolls. The principle of the control system is illustrated in Fig. 8.

During the trials, rolling with varying roll gap was compared to rolling with a fixed gap. Two types of pass-schedules were investigated: edging either early...
or late in the schedule. The rolling trials show that by roll gap regulation an uniform width can be achieved. Figure 9 shows the resulting width when edging late in the schedule and varying the roll gap in the last edging pass.

Width errors in the head end are introduced as soon as edging is done. If the roll gap for the head end of the transfer-bar is increased compared to that of the body, the errors are reduced. The increase in roll gap is preferably done at a distance equal to the slab width. For the tail end it is sufficient with width regulation in the last edging pass.

VII. Discussion

When edging in the roughing stand a dog-bone is created along the sides of the slab. This is because of the inhomogeneous deformation pattern. The height of the dog-bone decreases in the slab ends because of longitudinal material flow. A fish-tail is created while at the same time the width decreases in the end-portions. In the following flat passes the fish-tail elongates. The earlier the fish-tail is created the longer it will be when leaving the rougher. In the flat passes the dog-bone is straightened out and the slab spreads because of the thickness reduction.

Early edging combined with a constant setting of the edging stand in the following passes results in an uniform width profile. Width shortage exists only in short parts of the strip ends.

When edging late in the schedule a larger edging draft is required in the passes available. With big total width reductions, the spread in the following flat passes is insufficient. This results in width shortages in the strip ends.

VIII. Conclusions

In a cooperative research project, yield losses in hot- strip mills have been examined through extensive practical trials. By modifications in the pass-schedule of the reversing roughing stand, the yield losses in hot- strip rolling can be reduced. Width reductions (edgings) in the last passes contribute to a reduced formation of fish-tails at the strip ends. Heavy reductions in the final passes will however result in width shortages in both head and tail ends of the strip.

If the maximum possible reduction is used in each edging-pass, a total reduction of up to 150 mm can be achieved in existing mills. The resulting subwidth will then become extensive.

Pilot plant trials on hot steel at MEFOS show that by varying the roll-gap during rolling, reduced width shortages can be obtained. Edging late in the schedule can be carried out to obtain an uniform width and reduced fish-tail formation. Also, in this way, a
heavier edging can be done while maintaining a high yield.

REFERENCES


