Yield improvement strategy and thickness control at 2-stand cold reversing mill – the Marcegaglia case

The usual way to operate a cold reversing mill for threading and tail-out is to open the roll gap to minimise the risk of strip pinching and the consequent loss of time for work roll changing. The disadvantage of this is reduced material yield due to the length of material not rolled to the correct thickness. Danieli has developed a way to increase the mill yield by operating the head threading and tail-out phases while keeping the roll gap closed.

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Danieli Wean United and Danieli Automation

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Danieli Wean United and Danieli Automation have developed a way to increase the mill yield by operating the head threading and tail-out phases while keeping the gap closed.

This innovative way to operate the mill is based on the following points:

- A free entry bridle to keep a constant specific tension in front of the stand during tail-out at the end of the first pass
- Optimised head threading sequence and set up
- Optimised tail-out set up
- Reduction control
- Enhanced bending and tilting adjustment control
- Advanced thickness tracking
- Fully automatic sequences

The advantages of the new mode of operating the mill are up to 60% scrap weight reduction and higher

**Fig 1** 2-stand cold reversing mill at Marcegaglia
productivity. The new procedure for head threading foresees the gap closing for each stand when one meter of strip is out of the stand, when the head reaches the exit tension reel, the stand set up changes from the threading set-up to mill rolling low speed set-up.

This new operating strategy has been applied for the first time to operate the 2-stand cold reversing mill supplied by Danieli for the Cold Complex of Marcegaglia at Ravenna (see Figure 1).

**MILL OUT OF TOLERANCE LENGTH**

In a 2-stand cold reversing mill, the out-of-tolerance length is determined by the mill layout, considering that the distances of the tension reel axes with respect to the stand axes cannot be changed, and these distances define the length of non-rolled or partially rolled length (see Figure 2).

The out-of-tolerance length is defined by:

\[ L_1 + L_2 + L_3 + 1.5 \text{ wraps on entry tension reel (TR)} + 1.5 \text{ wraps on exit tension reel} + \text{length rolled with automatic gauge control (AGC) not in operation}. \]

The value of the out-of-tolerance length for a 2-stand reversing mill is approximately 25m as calculated in Table 1.

The scrap weight is affected by the thickness wrapped on the entry and exit tension reel during the head threading and tail-out sequences before the start of rolling.

The following phases in mill processing are now described.

**BEGINNING OF FIRST PASS**

At the beginning of the first pass there can be two different conditions:

- **Open stand threading...the old method**
- **Closed stand threading...the new method**

See Figure 3 for a 2-stand reversing mill.

The scrap weight in the case of open stand threading is defined by following formula:

\[ \text{Scrap weight OS1} = (A + B + C) \times h_{in} \times W \times \gamma \]  \hspace{1cm} (1)

Where

- \( A \), \( B \) and \( C \) are linear lengths
- \( h_{in} \) is the nominal thickness of the entry coil
- \( W \) is the strip width
- \( \gamma \) is the steel density

The scrap weight in the case of closed gap threading is defined by formula 2 (see Figure 4).

\[ \text{Scrap weight CS1} = B^* \times h_{in} \times W \times \gamma + A \times h_{in} \times (1 - \text{red std1}) \times W \times \gamma \]  \hspace{1cm} (2)
FINISHING PROCESSES

**Where**

A, B^ are linear lengths
h_in is the nominal thickness of the entry coil
W is the strip width
red std1 is the reduction factor of entry stand in threading mode (ie, 0.3 means 30% reduction)
\( \gamma \) is the steel density

The effect of this new mode of operating can be seen in Figure 5.

**END OF FIRST PASS**

See Figure 6 for a 2-stand cold reversing mill.

Scrap weight of the tail at the end of first pass is defined by the following formula:

\[
\text{Scrap weight TAIL} = (G+H) \times h_{in} \times W \times \gamma \quad (3)
\]

Where

G and H are linear lengths
h_in is the nominal thickness of the entry coil
W is the strip width
\( \gamma \) is the steel density

**BEGINNING OF SECOND PASS**

At the beginning of the second pass we can have two different operating modes:
- Open stand threading
- Closed stand threading

Scrap weight at beginning of second pass with open stand threading is defined by formula (4)

\[
\text{Scrap weight OS2} = D \times h_{in} \times W \times \gamma + E \times h_{in} \times (1-\text{red std1}) \times W \times \gamma + F \times h_{in} \times (1-\text{red std1}) \times (1-\text{red std2}) \times W \times \gamma \quad (4)
\]

Where

D, E and F are linear lengths
h_in is the nominal thickness of the entry coil
W is the strip width
red std1 is the reduction factor of entry stand in threading mode (ie, 0.3 means 30% reduction)
red std2 is the reduction factor of exit stand in threading mode (ie, 0.2 means 20% reduction)
\( \gamma \) is the steel density

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### Table 1 Marcegaglia out-of-tolerance length calculation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance between entry TR and stand 1</td>
<td>5,500</td>
<td>mm</td>
</tr>
<tr>
<td>Distance between stand 1 and 2</td>
<td>4,500</td>
<td>mm</td>
</tr>
<tr>
<td>Distance between stand 2 and exit TR</td>
<td>4,500</td>
<td>mm</td>
</tr>
<tr>
<td>Mandrel diameter</td>
<td>610</td>
<td>mm</td>
</tr>
<tr>
<td>1.5 wraps on entry mandrel</td>
<td>2,875</td>
<td>mm</td>
</tr>
<tr>
<td>1.5 wraps on exit mandrel</td>
<td>2,875</td>
<td>mm</td>
</tr>
<tr>
<td>Speed limit to switch on/off AGC</td>
<td>50</td>
<td>mpm</td>
</tr>
<tr>
<td>Acceleration rate</td>
<td>60</td>
<td>mpm/s</td>
</tr>
<tr>
<td>Deceleration rate</td>
<td>90</td>
<td>mpm/s</td>
</tr>
<tr>
<td>L1 = length in acceleration from 0 to the speed limit to switch the AGC on</td>
<td>0.35</td>
<td>m</td>
</tr>
<tr>
<td>L2 = length in deceleration from speed limit to switch the AGC off</td>
<td>0.23</td>
<td>m</td>
</tr>
<tr>
<td><strong>Total out-of-tolerance length</strong></td>
<td>20.83</td>
<td>m</td>
</tr>
</tbody>
</table>

Guaranteed out-of-tolerance:
The theoretical value is multiplied by a compensation factor K that takes into account the possibility that during the plant start up the close gap values are changed by the operator and that for each pass a stopping accuracy of 100mm is achieved.
In Danieli’s experience, K is 1.2.
Guaranteed out-of-tolerance length is 1.2*20.83 = 25.0m

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**Fig 5 Head Thickness with open gap threading (BLUE) and with closed gap threading (YELLOW)**
See Figure 7 for second pass – open stand threading. Scrap weight at the beginning of the second pass with closed stand threading is defined by the formula (5).

\[ \text{Scrap weight CS2} = E^x h_{in} x W x \gamma + F x (h_{in} + h_{in} x (1 - \text{red std1})/2) x W x \gamma \]  

(5)

Where

- \( E^x \) and \( F \) are linear lengths
- \( h_{in} \) is the nominal thickness of the entry coil
- \( \text{Red std} \) is the reduction of the entry stand in threading mode (i.e., 0.3 means 30% reduction).
- \( W \) is the strip width
- \( \gamma \) is the steel density

Working in closed stand mode during head threading and tail-out is possible to reduce the material losses up to 60%.

In this way, after an intensive mill tuning, we have achieved a significant improvement of the material yield as illustrated in Tables 2 and 3.

The values in Table 3 have been confirmed by the results from the two plants where this new procedure has been applied.

**CONCLUSIONS**

Danieli Wean United and Danieli Automation have defined a dedicated mill set-up for head and tail with the target to minimise the deviation from the set value of the thickness after the threading phase at mill start up.

The aim is to achieve a good compromise between threading thickness and shape to minimise the risk of work roll damage.

From an analysis done in one of the Marcegalia mills, defining the tolerance limits as +/-6% of nominal thickness, we achieved the following results:

- Average length OOG (out of gauge) 6% for head = 17.14m
- Average length OOG 6% for tail = 3.24m.

At this value, the length is not sampled by the automation system because it is wrapped without tension and has to be added. It is 6.7m for the head and 7.7m for the tail.

The reduction in material losses produces a significant economic benefit and the operation of the mill in full automatic mode permits higher productivity.

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<table>
<thead>
<tr>
<th>Entry thickness (mm)</th>
<th>Theoretical</th>
<th>Real</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg</td>
<td>material yield</td>
</tr>
<tr>
<td>2</td>
<td>230.39</td>
<td>0.985</td>
</tr>
<tr>
<td>2.5</td>
<td>287.99</td>
<td>0.981</td>
</tr>
<tr>
<td>3</td>
<td>345.59</td>
<td>0.977</td>
</tr>
<tr>
<td>3.5</td>
<td>403.19</td>
<td>0.973</td>
</tr>
<tr>
<td>4</td>
<td>460.79</td>
<td>0.969</td>
</tr>
<tr>
<td>4.5</td>
<td>518.38</td>
<td>0.965</td>
</tr>
</tbody>
</table>

Note: specific coil weight of 15kg/mm, strip width is 1,000mm

**Table 2** Material yield achievable in a 2-stand cold reversing mill working with open gap during mill head threading and tail-out

<table>
<thead>
<tr>
<th>Entry thickness (mm)</th>
<th>Theoretical</th>
<th>Real</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg</td>
<td>material yield</td>
</tr>
<tr>
<td>2</td>
<td>142.47</td>
<td>0.991</td>
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<tr>
<td>2.5</td>
<td>178.09</td>
<td>0.988</td>
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<tr>
<td>3</td>
<td>213.71</td>
<td>0.986</td>
</tr>
<tr>
<td>3.5</td>
<td>249.33</td>
<td>0.983</td>
</tr>
<tr>
<td>4</td>
<td>284.94</td>
<td>0.981</td>
</tr>
<tr>
<td>4.5</td>
<td>320.56</td>
<td>0.979</td>
</tr>
</tbody>
</table>

Note: specific coil weight of 15kg/mm, strip width is 1,000mm

**Table 3** Material yield achievable in a 2-stand cold reversing mill working with closed gap during mill head threading and tail-out