OPTIMISATION OF COLD ROLLING MILLS*

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Abstract

All metals producers are on an unending search for a competitive advantage. They need to produce in the most cost effective way. Sometimes a new mill might be considered but in this paper we present examples of how this might not always be necessary. A detailed investigation by an equipment vendor who can consider the mill and or plant as a complete entity: mechanics, automation and process control can often find solutions that are both lower cost and can be implemented in shorter time frames.

Keywords: Through process know-how; Integrated solution; Optimisation.

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1 INTRODUCTION

Modern economic life is increasingly challenging. Globalisation has enabled new producers to enter world markets in a disruptive and significant way.
Everyone is looking for ways to improve. These improvements generally fall under three broad headings: new products in response to end user requirements, productivity and quality.
Metals producers therefore are looking to their equipment vendors to help improve their operations, this might be at a machine or a plant wide level.
Whatever the scale of the optimisation project, producers are looking for fully integrated solutions.
In this paper we consider this from a rolling perspective.

2 OBJECTIVES OF OPTIMISATION

The first step in this process is to agree a clear set of targets for the optimisation exercise.
Then we need the current and future product mix, from which the rolling schedules can be produced and the required production capacity established.
From the shortfall between the current and desired capacity we can start to identify ways of closing the gap. This might be a speed increase, larger coils or other improvements to speed up operation. If the future product mix differs materially from the current, it may be necessary to model the process (see next section).

3 NEW PRODUCTS

A range of new high-strength alloys are starting to emerge. These often require more load, power and torque to roll and thus the physical limits of the mill may become something that has to be considered in detail and solutions found.
Alternatively, the new products might involve an EDT step (very light reductions with textured work rolls) and this leads to low loads and all the challenges that presents.
At a minimum this requires what Primetals term “Through Process Know-How”, see Samanta [1] and Harvey [2] for examples.
Assessing these new products may also require process modelling, in order to predict what processing parameters will be needed to generate the required microstructure, Hirsch [3].

4 SCHEDULE OPTIMISATION

This process underpins the whole exercise. The first step is to identify the key products that make up the majority of the production – many plants produce a wide range of finished products but production is often dominated by a small number of products – the eighty/twenty rule generally applies.
Pass schedule optimisation involves looking at the reduction pattern and rolling speeds, making larger reductions and thereby removing passes – or adjusting the reduction pattern, and increasing rolling speeds.

5 MILL OBSERVATIONS AND REVIEW

A period of general observation is required to assess the performance in operational and quality terms.

1. General observation to identify areas for improvement.
2. Performance assessment – quality and productivity.
3. Specific equipment tests – roll load cylinder response for example.
4. Coil handling times.
5. Scrap levels.

During the investigation phase extensive use is made of the exisiting datalogging. As a consequence required improvements to the logging and monitoring might be identified. This is discussed in Section 11.

6 DISCRETE EVENT SIMULATION

If the optimisation is considering the plant as a whole, discrete event simulation tools can be used to study the overall flow of slabs/coils in the factory. An example of one of the input screens for this software tool is shown below in Figure 1.

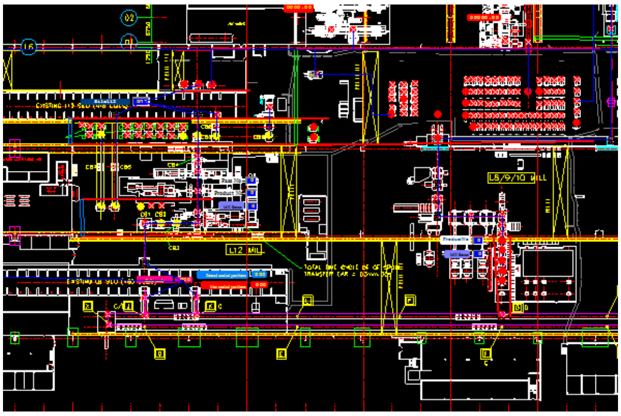

Figure 1 Discrete Event Simulation

We can identify bottlenecks such as cranage and annealing capacity. Inputs include coil rolling and handling times at each rolling stage, coil transport times (crane speeds, coil car speeds etc. and annealing cycle times) - to list but a few. Consideration has to be given to the fact that while slabs or coils are processed individually in the rolling mill, other process units such as annealing furnaces and coil transport vehicles might take several coils at a time. For example, the first coil to arrive an annealing furnace has to wait until other coils have arrived to make up a full load. Similarly for shipping. Is it a lorry load, a train load or a ship load that has to be dispatched, must a whole order of different items for the same customer be shipped together? This all impacts on coil storage requirements.

7 CONTROL INVESTIGATION

Early control systems often do not have the full range of features that modern systems do. In the example shown below in Figure 2, the tandem mill was accelerated in a series of steps. The as-found AGC system was not an integrated AGC scheme – there was effectively a system for each stand. The mill therefore had to be accelerated to RUN speed by hand – something that relied heavily on the skill of the operator.

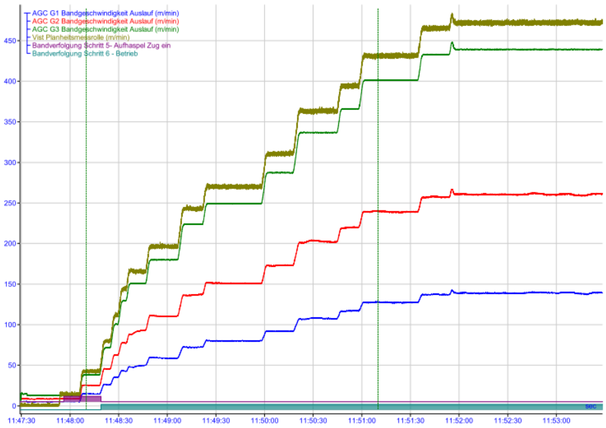

Figure 2 Manual Acceleration

Analysis showed a potential for significant time saving as illustrated below in Figure 3.

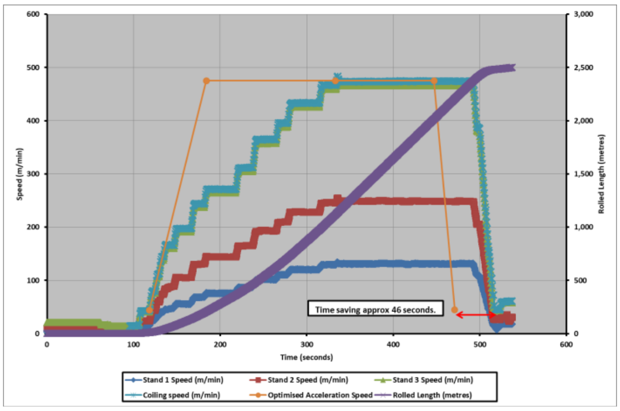

Figure 3 Potential Time Saving

Primetals implemented a modern tandem mill AGC scheme as part of an overall mill modernisation for our client. This allowed a smooth, continuous acceleration to run speed, Figure 4, below.

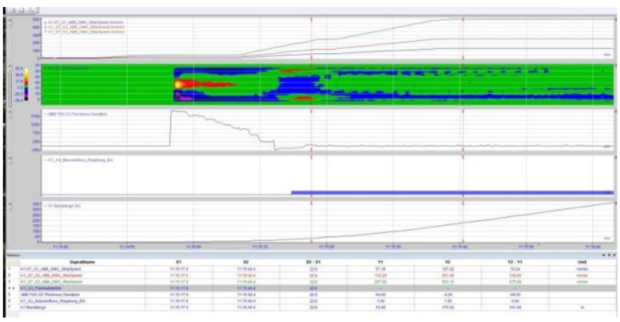

Figure 4 Optimised Performance

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This fully integrated tandem mill AGC scheme resulted in higher average speeds and a reduction in length to reach run speed, and thereby time savings – 46 seconds in the example shown in Figure 3, above. Over the thousands of coils rolled a year this adds up to a significant increase in production. See Meech et al [4] for a discussion of automation issues.

8 EQUIPMENT CHECKS

Revised rolling schedules often result in the mill having to be driven harder with larger reductions or higher speeds, or both. This increases the load on equipment. We may therefore have to look to motor changes or gear ratio changes on the main and reel drive systems.
Component stressing might also have to be looked at, as in the spindle stressing example shown below in Figure 5.

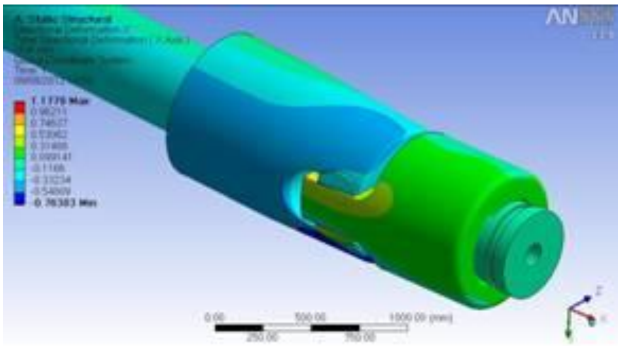

Figure 5 Spindle Stressing

9 EQUIPMENT CHANGES

To obtain the required improvements it may be necessary to fit new equipment: new sprays, new actuators, improved handling and inspection equipment. We will consider this by way of three examples.

9.1 COIL DIAMETER INCREASE

Over the years coil sizes have increased to gain the benefits of higher productivity and higher yield. With larger coils less time within the overall production is spent changing coils and accelerating and decelerating. Out of tolerance material generally occurs at the start and end of pass when the mill is not in steady state conditions. With larger coils these lengths form a smaller part of the overall production.
When we need to increase coil diameters a lot of equipment has to move and this often requires novel solutions. In Figure 6, below, we can see that we moved the coiler heads by inserting large 'C' frames bolted to the side of the housing to take the coiler heads. This maintained operator access from the side for threading etc.
Diameter and speed increases often require the operating capability of the coiler/uncoiler drives to be checked – will the reel motors still be within the tension speed envelope at all coil diameters? Do we need to change the gearing? In this case we were still within the operating window but that is not always the case.

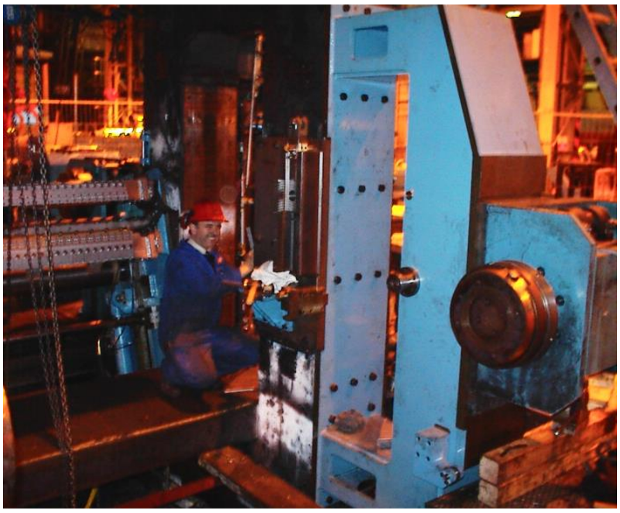

Figure 6 – Coil Diameter Increase – New Coiler Mounting

9.2 HEAT REMOVAL & ADDITION

The rolling process generates significant amounts of heat. This has to be removed in an effective way by spraying the rolls. In a typical single stand aluminium cold mill the heat removal could easily be in the 250 to 500 kW range – often more.

Rescheduling the mill by rolling faster, or with shorter delays between coils, or the rolling of new, harder products often requires work on the spray system.

Effective heat removal requires a carefully designed spray pattern that maximises sprayed area and accounts for roll diameter changes, see Kotrbacek [5].

Primetals use the knowledge of extensive laboratory testing in our own works to guide this work.

We use our proprietary spray valve, the ISV (Integrated Solenoid Valve), shown in Figure 7, below, for roll cooling.

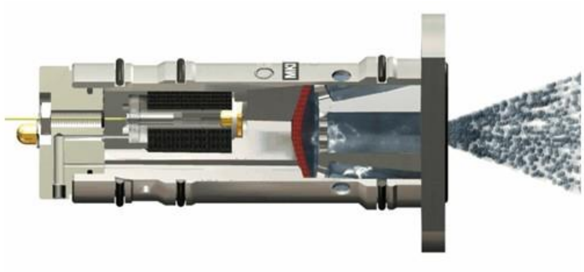

Figure 7 – Primetals ISV Spray

Meech et al [6], [7] discuss cooling and spray control in detail.

Heat is added to the rolls outside the strip edge to modify the thermal profile. This helps to minimise edge flatness errors – tight edges, and enable higher rolling speeds.

Today this is now typically done using edge induction heaters rather than hot sprays to heat the workrolls. The effect of these can be seen in Figure 8, next column.

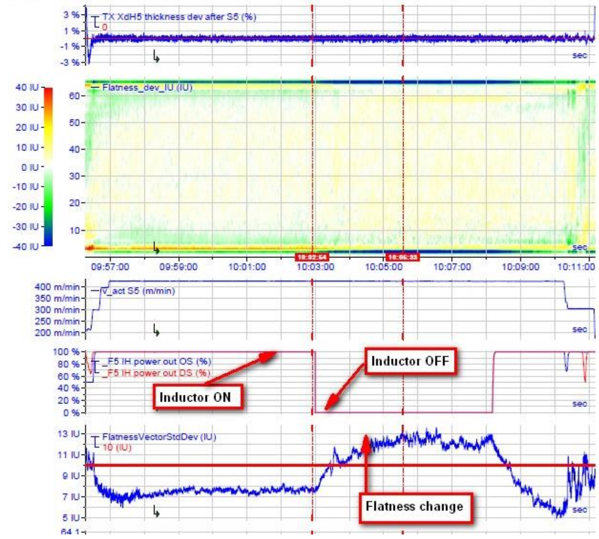

Figure 8 – Influence of Edge Inductors on Flatness

Flatness changes at the strip edge of 25 I units can easily be achieved with induction heating – but at less than 10% of the power required for hot sprays – a clear efficiency saving.

9.3 INTERSTAND COOLING

One of the difficulties with driving a mill harder is that the strip temperatures increase and that can lead to undesirable outcomes in some cases – mainly associated with metallurgy.

With too high a temperature we might experience higher levels of recovery/recrystallisation than are desired.

Furthermore, the process rules may say that the coil temperature must be lower than some threshold for the next operation. The higher the temperature the longer the coil has to spend in storage until it can go to the next process step. This increases work in progress and goes against the lean philosophy that is common in these just-in-time days.

As a result, the introduction of interstand cooling is becoming common on aluminium cold tandem mills. The mill can therefore either be driven faster, or run at the original speed with a lower finished coil temperature. Interstand sprays been found to decrease coiling temperatures by ten degrees C or more.

10 PROCESS OPTIMISATION

Speeds can often be increased by optimising the process. In this example we increased the speed by optimising the foil mill strip stresses, since speed is highly influenced by stress in foil rolling. Here the foil stresses, as set by the customer, were unusually high. The graph in Figure 9, below, shows a clear way of increasing speeds.

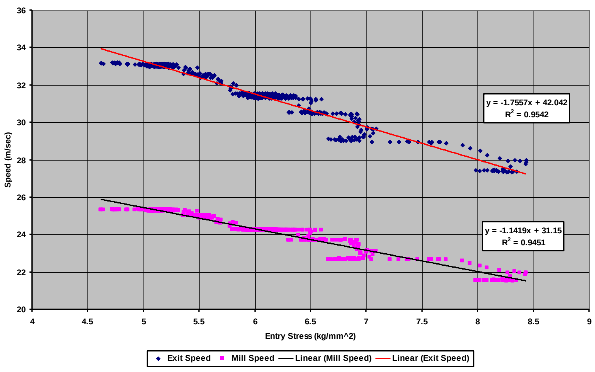

Figure 9 – Foil Mill Speed Optimisation

Note how both mill speed and forward slip increase with decreasing stress – so a gearing effect on rewind speed is obtained.

11 REALISING THE BENEFITS

All the examples discussed above give potential benefits – to achieve the expected benefits we need to take steps to actually realise them.
For example there is little point in achieving a reduction of out of tolerance material if the same amount as previously is cut off at heads and tails at the next step – the prime material needs to be easily identifiable. The logging needs to identify to the operator or the supervisory system where the prime material is. Log, record and make available the: length, diameter and number of laps where the strip came in and went out of tolerance for example.
To achieve this the logging system often needs to be improved to log more signals, store in an accessible manner and so on.

12 MAINTAINING THE BENEFITS

To maintain the benefits of any optimisation we need to ensure that the mill remains in a good condition. This requires a thorough maintenance program coupled with appropriate condition monitoring.
As part of any automation system Primetals can incorporate appropriate monitoring - servo null leakage currents for example to monitor servo condition.
Logging should not be restricted to just logging the rolling process. Logging of mill test and calibration routines is an important part of condition monitoring. For example mill zeros, spray tests and such routines should be monitored.
It is important to remember that the IT hardware and software will require its own maintenance routines, such as backups and archiving of logged process data after a certain time period.

13 CONCLUSION

In this paper we have demonstrated that a thorough understanding of the rolling process is required to optimise a rolling mill.
The process of cold mill optimisation is complex and wide-ranging, and involves a combination of theoretical knowledge of materials and equipment and practical experience of engineering innovation.
A multi-disciplinary approach is required.

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