Improving Rolling Plant Performance

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INTRODUCTION

It has always been a concern to most flat rolled product (FRP) manufacturers that their products and standards of production should be best in class, and that the equipment they have bought to achieve this is being well utilised. Most aluminium rolling companies will be trying to improve their performance by increasing their asset utilisation, improving their product quality and reducing their operating costs, for example by reducing their energy consumption. Finding a balance between these aspirations requires a careful approach combined with a deep understanding of the products being rolled and the rolling process itself. It is a relatively easy exercise to calculate theoretical rolling mill capacities based on the product mix and maximum mill powers & speeds, but achieving this theoretical productivity can be a much more difficult task.

Innoval Technology have expertise in conducting technical audits to assess the rolling and finishing processes and the products being produced. Careful study of the operations and material flow results in an assessment of how existing equipment is being used and highlights where practices can be improved and where the purchase of new capital equipment makes economic sense.

Good mill design can help maximise productivity by reducing the non-productive times of coil handling and maintenance. Also, removal of constraints such as vibration or fear of strip breaks in cold rolling can be used to achieve the designed mill speeds and hence maximise productivity. Optimum mill performance can occur only when the mill capabilities, process understanding and coil sequencing are dynamically linked. Examples of how improvements in productivity can be achieved and standards be raised without the need for large new capital outlay will be discussed below.

INCREASING ASSET UTILISATION

Understanding Mill Capacities

The key production facilities in FRP plants are the rolling mills. Product volumes together with powers, speeds and pass schedules can be used to calculate capacities both for existing mills and for potential upgrades or new mills (the mill output can be used to define ancillary equipment such as furnace capacities and is the basis on which finishing equipment can be specified). This often is used as the engineering limit for asset utilisation, but there are at least two problems with this: (i) there can be constraints which prevent operators from achieving the design speeds or desired passes and (ii) the capacity models are normally based on a uniform product mix. With mills provided by the better suppliers, such as the Danieli Diamond

Mills, there is at least certainty that the stated speeds and passes will be achieved without running into mechanical constraints such as vibration issues. However, many quality dimensions are not included in the scope of equipment manufacturers and may impose limits on productivity. Furthermore the capacity models use average or assumed values for key parameters such as handling time or yield while in practice the variation in product mix and even the sequencing of coils through a mill may have a significant impact on the real plant productivity. This is demonstrated in Table 1. Understanding why capacities might change is one factor that has to be considered when optimising plant performance.

Varying parameter	Base case	Average exit gauge	Product yield	Mill speed	Average handling time	Units
Av. exit gauge	0.59	0.49	0.59	0.59	0.59	[mm]
Yield	85	85	80	85	85	[%]
Mill speeds	100	100	100	90	100	[% of expected]
Handling time	5	5	5	5	7	[min]
Capacity	**119**	**99**	**112**	**95**	**94**	kt/year

Table 1: Sensitivity of cold mill capacity to various parameters

Plant Metrics

Most plants will have data on output which is required for the financial statements and will track the progress of orders to ensure that the delivery to their customers is properly monitored. However, the detailed engineering data needed to evaluate performance of machine centres, and the plant as a whole, is often incomplete and frequently stored in separate databases. So while metrics of productivity (tonnes/hour), utilisation and yield may be available, the lack of rigor in data collection reduces the value of the numbers. For example, what is included into up-time and down-time for a machine centre can vary from plant to plant even within the same company and calculations of scrap weight may be done purely on the basis of what is needed to balance metal in and metal out of a plant. Two of the most important tasks in improving asset utilisation are the careful definition of the metrics and the identification & understanding of where the data come from. It is important that the metrics are as independent of the product rolled as possible in order to avoid, for example, showing that wider products give a higher tonnes/hour than narrow products. With robust definitions, it then also becomes possible to compare plant performance within a company and with world-class performance metrics, identifying differences that are sometimes associated with equipment usage and sometimes with the skills of the operators and managers of a plant.

Equipment Efficiency

A thorough analysis of data from machine centres enables objective assessment of the various components of efficiency, which includes not only process productivity rates but also machine utilisation, delivery performance and quality controls.

There are many techniques that consider both the process efficiency during rolling of a coil (up-time) and the time between coils (down-time). Overall Equipment Efficiency (OEE) is a method that captures the most important sources of manufacturing productivity loss and converts them into metrics that provide good indicators of current status of the plant performance as well as how the processes can be improved. OEE analysis addresses both process productivity and the production quality aspects, recognising that there is little merit to producing faster if that leads to increased rejections. By focusing on under-utilised equipment, the dead time during normal production and by either reducing passes or increasing process speed it is possible to make considerable improvement in the speed of work and line availability. This needs to be done while still accounting for delivery and quality parameters. An example of successful application is shown in Figure 1.

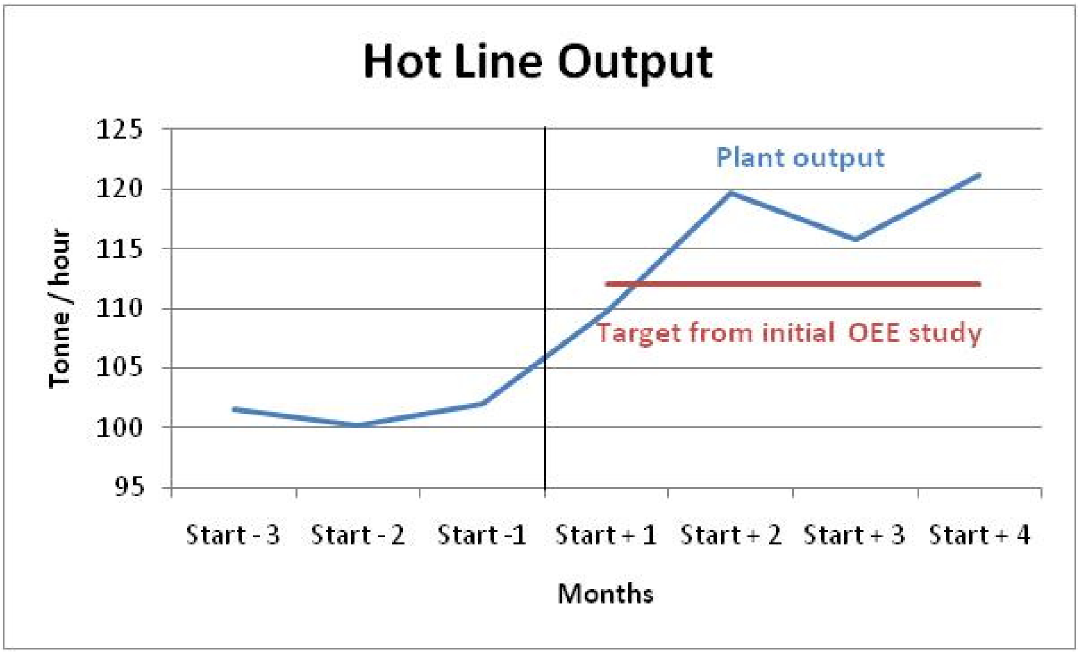

Figure 1: Improvement in hot mill output following OEE study

The variations that can be observed after the project start are caused by the natural changes in the product mix for each month. Understanding this prevents plant personnel from reacting to data variation whose cause is not related to the way the hot mill is run.

Similar approaches can be adapted for cold rolling mills, even though the balance between contact time and non-contact time changes. Analysis of plant data helps to identify and prioritise the activities of plant personnel. Backed up with good process knowledge, the action plans can be implemented quickly and improvements made without the need for large capital expenditure. Innoval has facilitated and led several such initiatives: the result from one is shown in Figure 2.

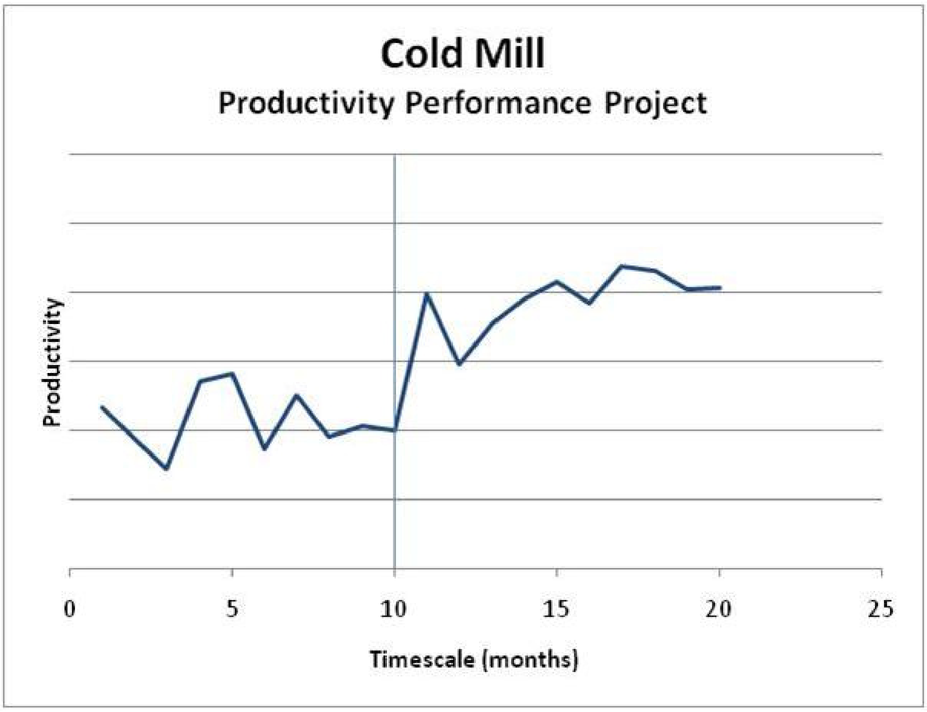

Figure 2: Improvement in cold mill productivity following OEE study

In this example, the data analysis showed that there was a lack of consistency in the process and the first action plan was drawn up in order to achieve stable operation. Once the practices were standardised, it then became possible to realise permanent improvements in productivity as can be seen in the right hand region of the graph. Of course there is still process variation reflecting ongoing changes in the product mix through the plant.

IMPROVING PRODUCT QUALITY

Product quality can be categorised in terms of dimensional properties such as thickness and flatness, surface properties and mechanical properties.

Quality has two dimensions that need to be addressed: the quality as measured directly on a machine centre and the impact that control of key parameters at that machine centre have further downstream in the same plant or at the end user. The former is self-evident and a good example of the latter is the impact of profile (the thickness variation across the strip width) on downstream quality performance.

For example, when multi-slitting a product such as Finstock into narrow reels, some reels will be prone to collapse due to loss of tension if the strip profile is allowed to exceed certain limits. However, profile is determined upstream at the hot mill, and the profile that can be achieved relates to the thermal state of the hot-mill and the type of product being rolled so the sequencing of coils being hot rolled becomes important.

Figure 3 shows the change in crown value (a key measure of strip profile) due to a width change in the product sequence. Other changes in product features also change the profile, essentially because of transient thermal conditions that occur on product changes.

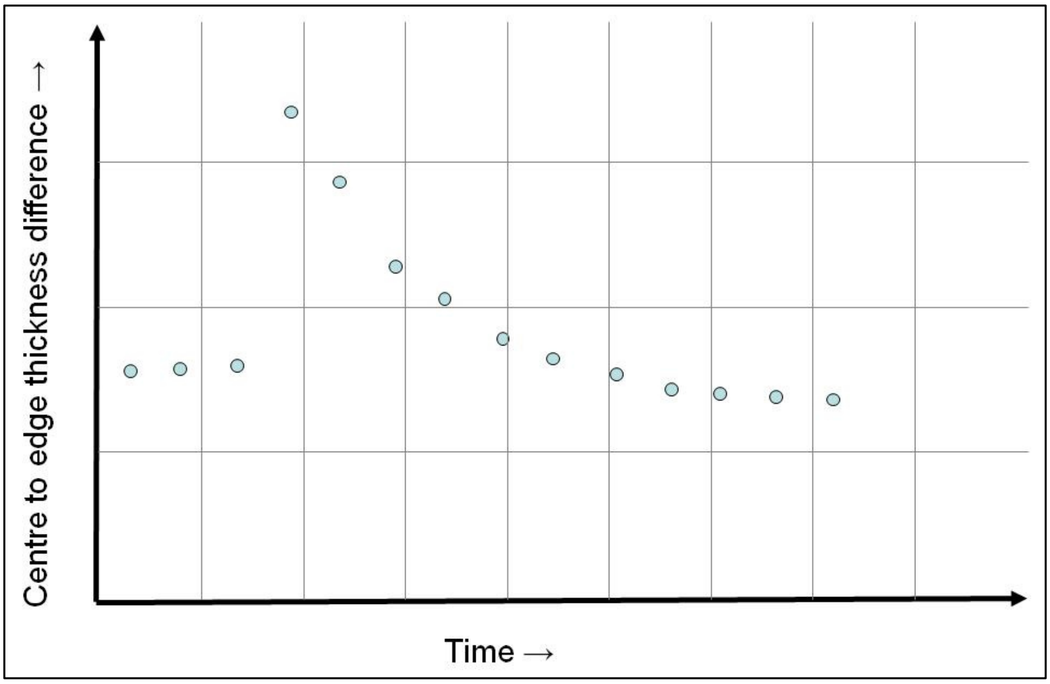

Figure 3: Crown change in a hot mill when a batch of slabs has a width change

As the sequencing of coils depends on the schedulers, it is often the case that the schedule for the mill will be based on width changes and of course on expected delivery dates. Each product change can cause an error in the expected profile and Figure 4 shows an example of a series of measured profile errors. With a more complete understanding of the way product changes can influence the profile, an alternative product sequence could have been determined and rolled. Figure 5 shows a computer model prediction of the reduced profile errors resulting from an optimised sequence of the same products.

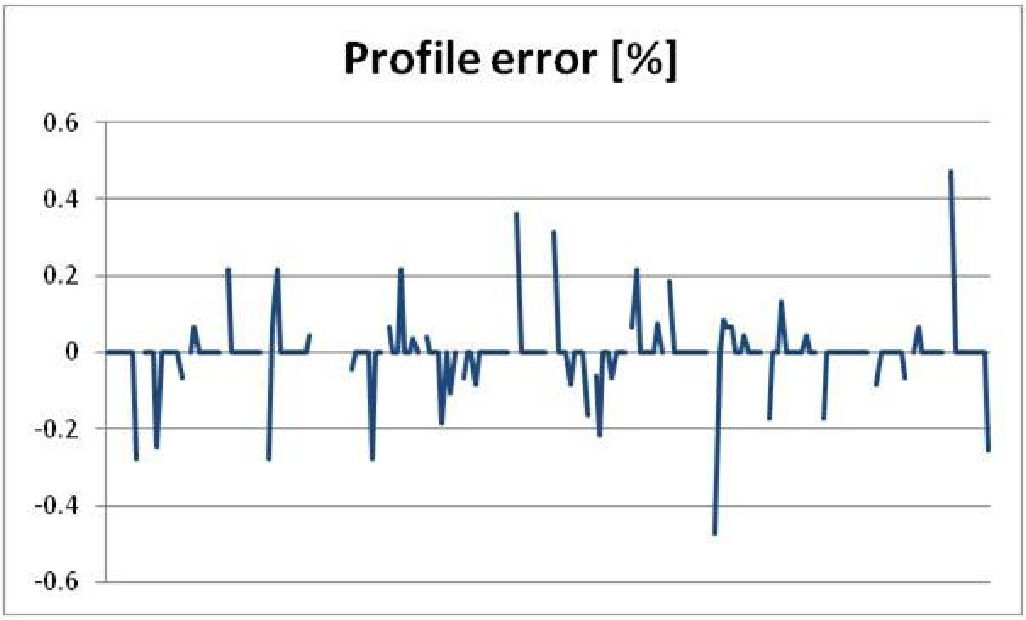

Figure 4: Measured profile errors for a sequence of coils rolled on the hot line

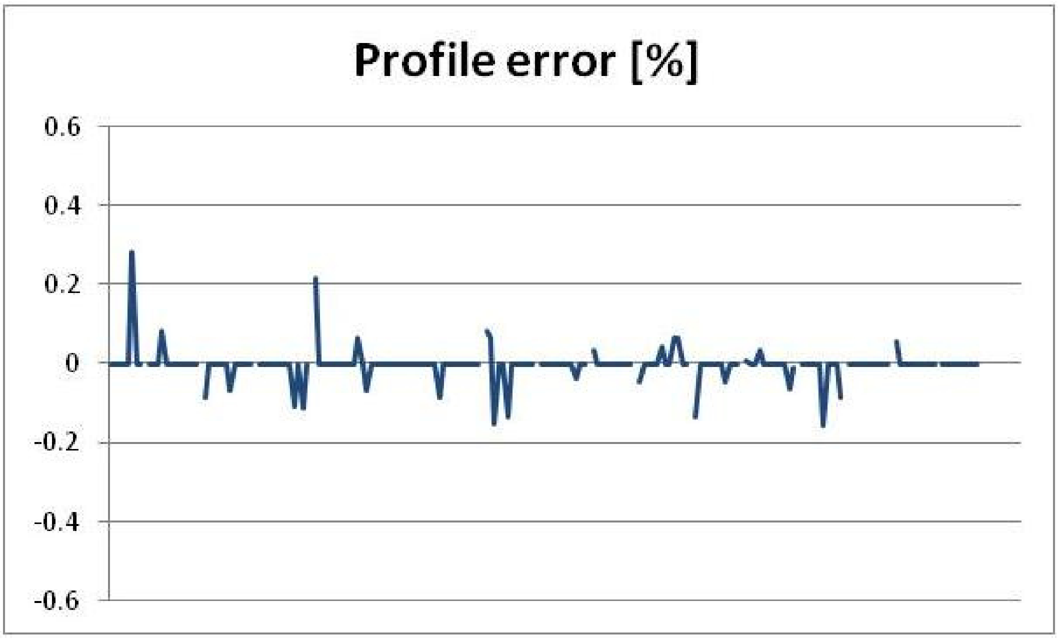

Figure 5: Predicted profile errors if the same coils on the hot line had been processed in a different order

By setting a series of rules and constraints and by weighting the relative importance of process efficiency parameters it is possible to schedule a fixed stock of incoming material for the line to minimise profile errors and so avoid downstream quality issues. Where process interruptions are unavoidable, whether scheduled or as a result of a breakdown, the impact of these interruptions on final product quality can be minimised by incremental process delays instead of one large and significant event. After all, the hot line process is one where the contact time is comparatively short but the thermal time constants are long and so it is important to manage the thermal condition of the hot line.

REDUCING OPERATING COSTS

The cost of energy is a significant component of the overall operating cost of a rolling plant. The largest contributors to the energy consumption during the production of aluminium sheet are the metal melting and ingot pre-heating processes. These processes use significantly more energy than the rolling process itself. Therefore if energy consumption is to be reduced, these metal heating processes should be the first ones to be examined.

Significant savings can be achieved by careful control of the DC ingot preheating process utilising the understanding of the metal temperature distribution within ingots during the heating process and an evaluation of the energy lost to the environment. This allows higher initial furnace air temperatures to be used without over-heating any parts of the ingot, leading to shorter cycles that potentially increases furnace availability. The approach is to use a mixture of computer modelling and experimental calibration. Innoval have considerable expertise in this approach.

Figure 6 shows typical results from the modelling of a preheat furnace. The graphs show how the initial use of a higher than expected air temperature (brown line) achieves a shorter heat-up time. The highest temperature and the lowest temperature at any point within the ingot, at any time, are given by the red and dark blue lines, respectively. This approach also highlights an opportunity to reduce losses from the furnace as the energy required to heat up the ingot (green line) is only a fraction of the total energy used (light blue line).

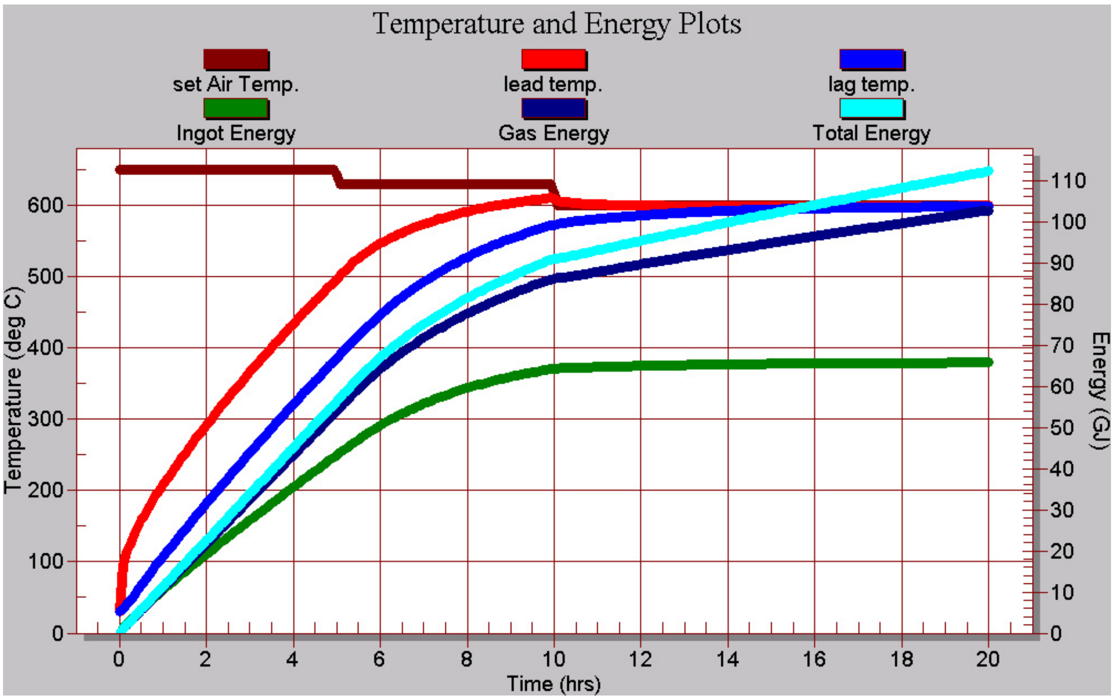

Figure 6: Ingot leading and lagging temperature and energy consumed during a typical pre-heat cycle with higher initial set-air temperature

CONCLUSION

It is important that rolling plants get the most from their existing machine centres to maximise the financial performance of the plant and certainly before considering the purchase of new capital equipment. Using approaches such as OEE analysis and removal of constraints, the utilisation of existing assets can be significantly increased in plants with both old and recently purchased equipment. This can be much more cost-effective than new capital spend.

It is also important to consider the impact of process changes on downstream product quality and to avoid any local optimisation of one process step at the expense of the final product quality. What is needed is a methodology that gives rigour to the analysis yet maintains the balance between choice of equipment, skills, productivity, delivery and quality.

Finally a method to reduce energy consumption has been described which both reduces the cost of operations and the carbon footprint of the rolling process.