The Benefits of Modelling Rolling Processes

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Many of the processes required to produce aluminium sheet are done out of sight where measurements of important process parameters are impossible. For example, during the rolling of sheet the strip thickness reduction and other dimensional changes which determine product quality occur in a tiny volume of the roll bite. This volume is only about 0.26 cm$^3$ metre width when producing 45 micron foil.

It is important to understand what is happening in this small volume during rolling so that reasonable estimates can be made of rolling loads, torques, current drawn by the motors and the resultant strip temperature and profile. These factors are needed for the improvement of rolling practices and devising new schedules. This is best done by mathematical modelling and an example of some output from the Innoval Rolling Model is given below. Figure 1 shows the result of modelling a pass in a hot finishing mill rolling can end stock

![Pressure and material flow stress graph](image)

Figure 1 Modelled roll pressure and material flow stress with through-thickness strip and roll temperatures at the bite exit rolling a pass of can end stock

This shows the pressure distribution on the roll in the roll bite (the so-called friction hill) and forward slip, together with the through-thickness temperature variations for both strip and roll surfaces just as the strip leaves the bite. The heat from the strip into the rolls is determined not just by the conditions in the bite itself but also by the thermal conduction into the roll surface. The temperature gradient in the roll surface limits the heat transfer. There is an increasing use of rolls with low thermal conductivity, for example high speed steel rolls, which can have a profound effect on the heat flows in the rolling process. This sort of effect would be very difficult to identify without a physics-based model.

Figure 2 is a screen shot of an abbreviated version of the Innoval Rolling Model output. The user can select any range of output parameters to view or print.
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Figure 2 Sample output from the Innoval Rolling Model

This model can be used to design new rolling schedules for an existing mill, and to estimate the maximum productivity from new mills before they are built or even fully specified. The proper use of a model of this kind can save many hundreds of hours of lost time compared with the use of less sophisticated approaches.

Ingot pre-heating is another example of a process where important parameters are hard to measure; in this case, the temperature deep inside the ingot. It is important during pre-heating for all parts of the ingot to reach the target temperature in order to achieve proper homogenisation. However, it is also important not to exceed the safe temperature on any parts of the ingot. This compromise can best be achieved by using a calibrated model. In this way, accurate temperature control can be achieved with a minimum time in the furnace.

Ingot pre-heating is the most energy-intensive part of the aluminium rolling process and models can be used to devise heating schedules for minimising the energy loss and also for identifying furnace defects. Figure 3 shows an output from the Innoval Ingot Preheating Model.
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Figure 3 Output from the Innoval Ingot Preheating Model

This one shows the temperature profile of a single ingot progressing through the furnace. The ingot leading and lagging temperatures are plotted. These are the hottest anywhere and the coldest anywhere within the ingot, so all other parts lie between these two. Also shown are the set point temperature and the air temperature onto and off the load. The model is able to predict, in this case, that near the beginning of the cycle the heating source is insufficient to maintain the air temperature at the set value. This happens when heat is being absorbed by the ingots and furnace structure at the highest level. This model includes a calculation of the energy absorbed by the furnace structure itself, and so can distinguish between hot and cold starting conditions. It is also possible to plot the energies for both the heating source and the fan used to circulate air round the furnace. This is useful for assessing the efficiency of the process, including that of the furnace itself.

Many other key processes are conducted “out of sight”. A further example is the continuous annealing or solution heat treatment of sheet. The temperature profile of sheet in these processes is critical to the final product quality, but it is very difficult to measure on a production basis. An invisible parameter in these processes is the heat transfer coefficient between the hot air and the strip and how this varies with the impinging air velocity. The transparency of the process can be greatly increased by modelling using a physics-based heating and cooling model, and then calibrating this against one-off temperature measurements in the plant. Such models are immensely useful in optimising the processes so that maximum productivity is achieved without prejudicing product quality. Innoval Technology has many years experience of both creating and applying this type of model. Furthermore, the company has recently launched five new models covering (in addition to those mentioned above) mill vibration, spray impact and coil heating/cooling. All are available to purchase under a license agreement from Innoval Technology.