Process integration provides the key to final product flatness

By Dan Miller

Customer demands for flat thin strip products have resulted in both suppliers and producers enhancing the capability of mills so as to achieve the tolerances required. This has occurred at the same time where the producers are operating their equipment at the engineering limits to achieve highly productive and efficient operations with minimal loss for scrap, vibration or for surface quality.

One problem resulting from running with higher reduction passes at higher speeds and producing down-gauged products, has been the common appearance of a flatness defect – the strip edge tightening significantly and the adjacent region near the edge becoming comparatively loose. The mechanical solution has been the enhancement of the conventional 4-high mill by additional actuators such as specially profiled work rolls, the insertion of intermediate rolls or the dynamic alteration of the backup roll pressure seen by the strip in the roll bite. A relatively new thermal actuator has been the provision of hot edge sprays, applying heated fluid to the work roll surface just beyond the strip width to counter the adverse thermal camber of the rolls. These have extended the range of possible control, and provided alternatives for the automatic flatness control strategies. A reputable supplier of a modern mill is therefore able to offer guarantees for flatness that fulfil product specifications.

However it is a frequent observation that, no matter how well controlled the strip may be while being rolled on the mill, the strip flatness observed in the next processing stage may well be poor. When this occurs at a processing stage within the producer's control, then at least a poor product can be prevented from being shipped (albeit at the cost of on-time delivery). However, if the next stage is at the customer's plant, then a rejection can result in a significant cost to the producer and may permanently damage their reputation.

The solution comes from an understanding of all the processes that lead to final product flatness. These processes occur within a producer's production path both by happenstance and by design and they also occur at the customer. How the customer treats and uses the strip affects its flatness and may demand very different supply criteria from the simple statement that the strip must be flat to within some mm of wave-height. Anything that bends or stretches the strip can potentially change its flatness (depending on the internal stresses in the product resulting from its processing route), as can non-uniform thermal treatment including coating, edge trimming or blanking the strip into shapes.

A critical but often overlooked process is that of coiling. The rolling pass is known to be important – hence automatic flatness control on mills – but the flat material is wound up under tension and this can irreversibly alter the strip flatness. In the steel industry modelling of this process was initiated to look at issues of coil collapse and telescoping, but especially in the non-ferrous industries these models provide insights and quantitative guidance on the changes in flatness that can occur.

Such models follow the build-up and changes to the stress and strain distributions that result from strip, of a given profile (non-uniform thickness over the strip width) and also having a non-uniform temperature over its width, being laid down under tension onto a spool or mandrel. Further changes occur once the coil is removed from the mill while the coil temperature equilibrates and decays to room temperature. Depending on the alloy properties, the strip profile & temperature and the winding tension, strip that was perfectly flat out of the mill bite will be predicted to be off-flat when wound off from the coil at room temperature. This is illustrated in Figure 1 for a soft aluminium alloy.

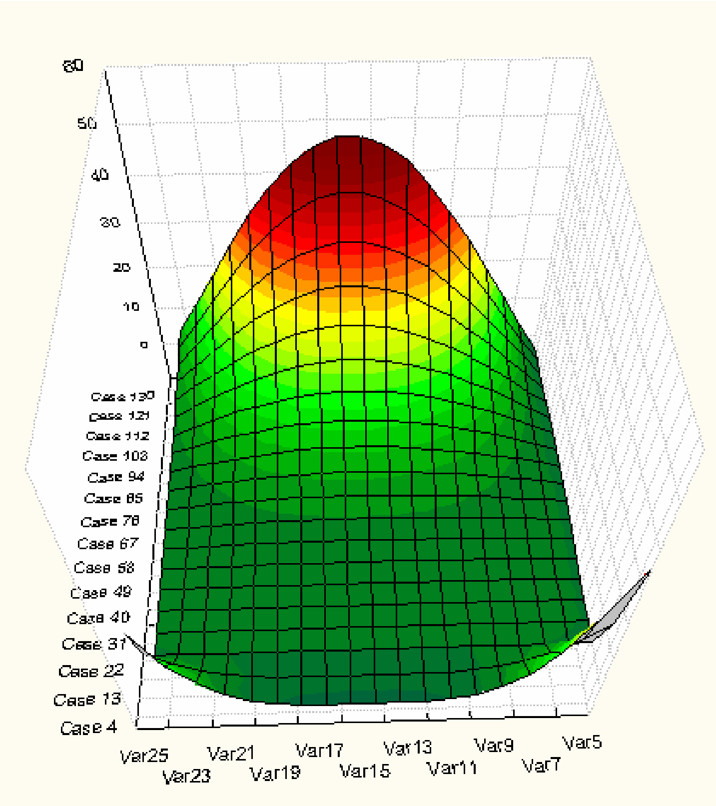

Figure 1: Predicted change in flatness for a coil of a soft aluminium alloy – note the change from spool end to outer lap

(X-axis is strip width; Y-axis is strip length form the spool [Case 1] to the outer lap [Case 130]; Z-axis is the change in flatness in I-units)

Just because changes in strip flatness occur in the downstream processes, this does not absolve the mill and control systems suppliers from providing the tools for good flatness control. What is required is a full integration of the process steps involved. Strip profile is essentially determined a long way from the final product delivery during the hot rolling stages, when lateral flow of the material in the mill bite is still significant. This key factor can seem quite remote from the impact at a customer. More obvious are the process steps between the last rolling pass and the customer using the material for a consumer product, each of which could alter the strip flatness. Some of those steps can be modified to control final flatness, but where this control is insufficient or unavailable, early processes have to be adapted to provide compensation for the flatness changes that will occur.

To achieve proper integration, process modelling and process knowledge is essential. For some of the larger companies, there may be some in-house expertise; others have to rely on external resources, such as those available at Innoval Technology Limited. The best outcome will always be when these resources are able to work in co-operation with a reputable, resourceful mill & control system supplier. Then, knowing something of the customers' requirements and their processes, a tailored controlled sequence of operations can be applied to satisfy the customer for every product.