RECENT OPERATIONAL EXPERIENCE WITH THE DYNAMIC SHAPE ROLL ON ALUMINIUM COLD MILLS[1]

Phil Lawlor[2]
Greg Pack[2]
Jean-Paul Faure[3]
Wei Zhe Hua[4]

Abstract
Customer requirements are becoming ever more demanding in terms not only of product quality but also operational flexibility. The Dynamic Shape Roll (DSR®) is the most capable mill actuator currently available to meet these challenges. Recent experience has clearly demonstrated the benefits of the DSR®. Exceptional capability in terms of head end flatness performance and overall dynamic performance can be demonstrated. The ability to handle product width changes is unrivalled by any other actuator. The DSR® can easily be operated by correctly trained operators and mill technicians with a high degree of reliability.
Key words: Aluminium; Cold mill; Dynamic shape roll; Flatness control; DSR®.

[1] *Technical contribution to the 50th Rolling Seminar – Processes, Rolled and Coated Products, November, 18th to 21st, 2013, Ouro Preto, MG, Brazil.*
[2] *Siemens plc, Industry Sector, Metals Technology, Sheffield, UK.*
[3] *Siemens VAI MT, Montbrison, France.*
[4] *Siemens Limited China, Beijing, China.*

1 HISTORY

The DSR has its origins back in the paper industry with the NIPCO roll from Sulzer Escher Wyss. Paper mills have always tended to be much wider than mills in the metals industry. This means that the length to diameter ratio of the rolls is large and thus a number of problems arise such as roll stability, the bending effect being concentrated at the roll ends and so on. To overcome these issues the NIPCO roll was developed to give improved control under these conditions. Siemens have taken this technology and extended it into the metals rolling field.

2 DSR OVERVIEW

The DSR is a replacement for one of the back-up rolls (usually the top one). It consists of a hollow shell rotating about static beam that has been mounted between two back-up chocks. An arrangement of hydraulic pads generate load on the inside face of the shell and this transfers through to the workroll to generate the rolling load. The clear advantage of this is that the load can be applied directly where it is required and not simply at the roll ends, as in either a conventional four high or six high (Figure 1).

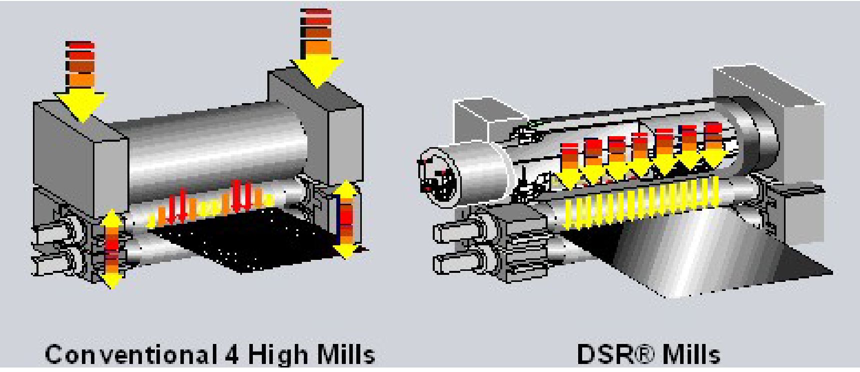

Figure 1. Load Distribution.

This clearly enables the load distribution to be controlled more directly, thus helping flatness and threading.

Figure 2 shows the main components within a DSR. Note that the servos are mounted at the ends of the beam and are easily accessible below removable covers.

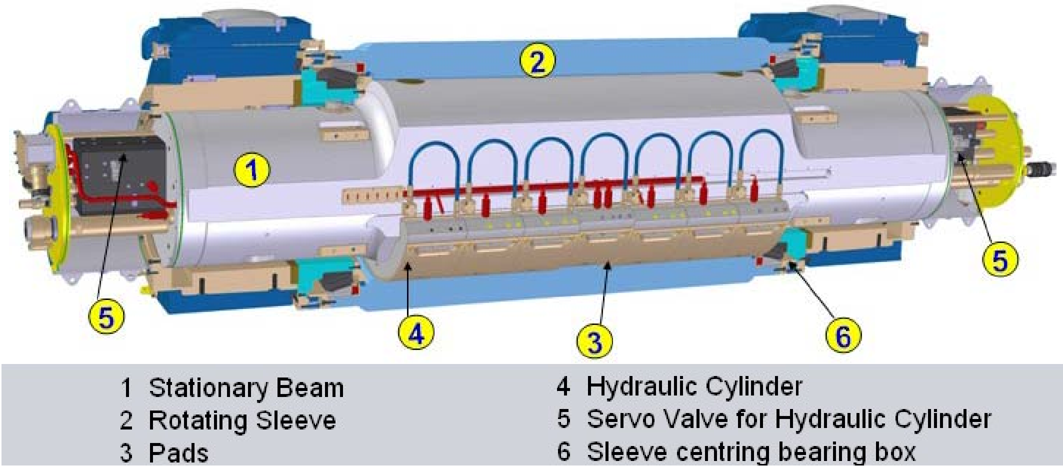

Figure 2. DSR Sectional Diagram.

2.1 The Oil Film

In Figure 3 we show a cross sectional view of the shell, beam, piston and pad.

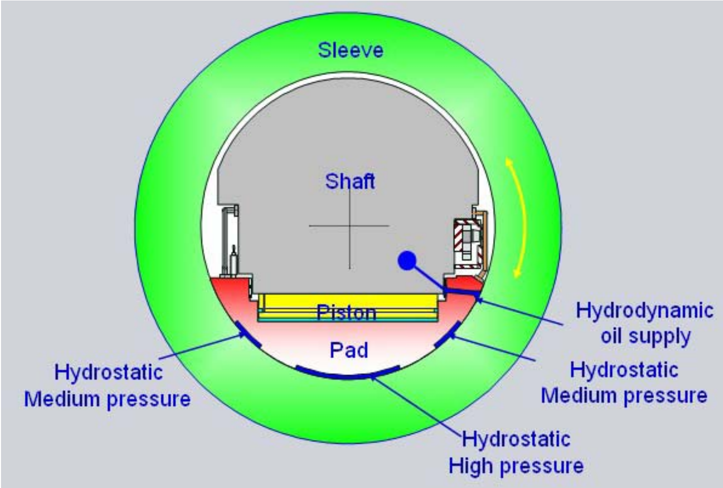

Figure 3. Oil Film Generation.

Two types of oil feed supply oil to the interface between the pad and shell. There are three pockets in the pad that are supplied with high-pressure, low-flow oil. These are the hydrostatic feeds. At the leading edge of the pad a high-flow, low-pressure feed is also applied. This is the hydrodynamic feed.

At low speeds the hydrostatic flow provides the majority of the support. As speeds increase the contribution made by the hydrostatic feeds decreases and the hydrodynamic effect comes to the fore.

The force distribution within the DSR is varied by changing the pressure in the DSR pistons. The flatness control software generates force trims and these are applied to the piston pressures to achieve the desired flatness.

The pistons run from the normal roll load power unit and the hydrodynamic and hydrostatic flows are supplied by dedicated system using 220cSt oil.

2.2 DSR Control Range

A four high mill with DSR has a larger control range than either a CVC equipped mill or a six high mill.

Flatness errors come from two main sources – mechanical effects such as the stack deflection, roll flattening and so on and localised effects such as local temperature or material differences. Mechanical actuators such as the DSR are used to address the distributed effects, local errors being left to differential spray control.

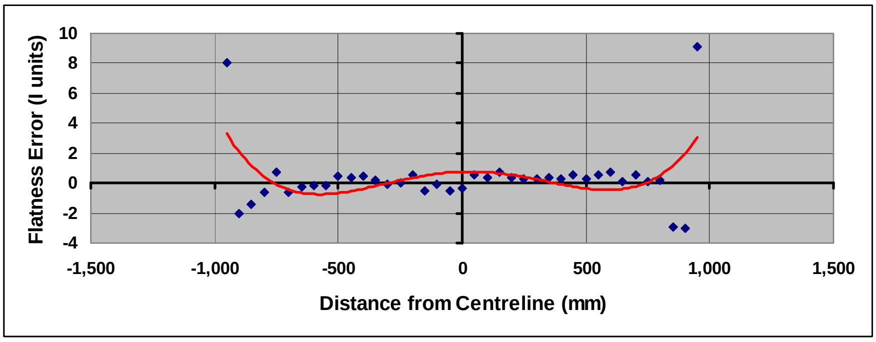

Figure 4. Flatness Error.

Figure 4 shows a randomly selected flatness error. The trend line shows the fourth order polynomial that can be fitted to this error. Note that even with an actuator that can easily address fourth order defects there will still be residual errors that have to be addressed by differential spray control – and maybe even hot sprays.
A useful method for assessing the range of an actuator is to look at how the actuator can address the various components of the error. This is illustrated in the following two pictures. The diagrams show the combination of the x^2 and x^4 components of the flatness errors that can be corrected in each example.
Figure 5 shows how the DSR compares to workroll shift type solutions - CVC or SmartCrown. The DSR has an operating region where it can dynamically address the x^2 and x^4 components within 30ms, whereas the CVC operates at various fixed and pre-selected points along a line – the preset being set at the beginning of pass based on the pass data (width, thickness, alloy, load and so on).
Figure 6, shows how the DSR has a larger range than the 6-high, even with workroll and intermediate roll bending.

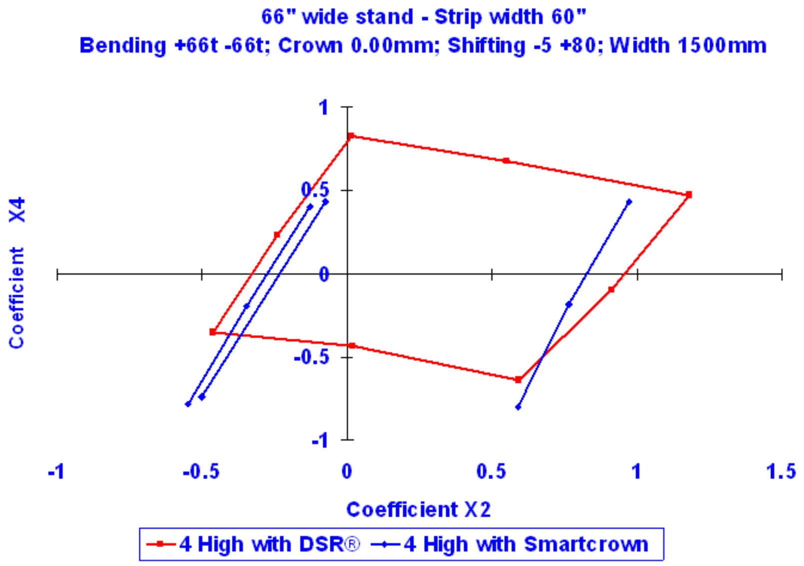

Figure 5. Control Range – DSR vs. SmartCrown.

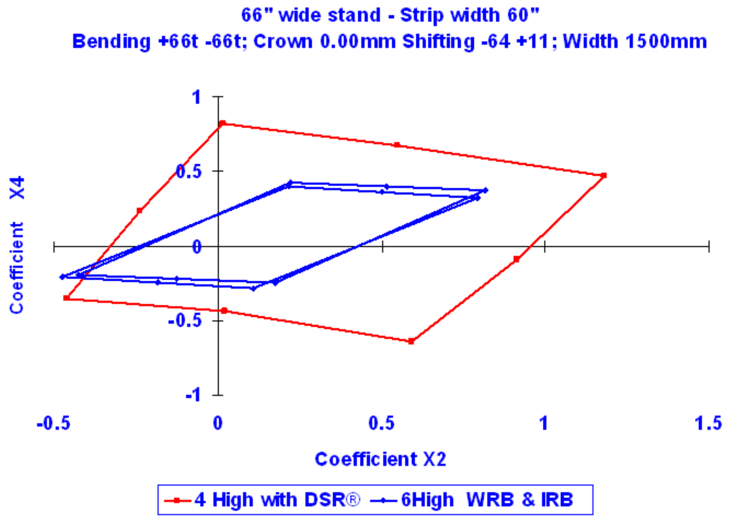

Figure 6. Control Range – DSR vs. Six-High.

Note also that a DSR will extend the effect of the roll bending by 20 to 30%.

2.3 Operational Benefits With the DSR

The benefits of a DSR can be summarised under four main headings: overall flatness performance, cold starting ability, head and tail end flatness, and ability to handle width changes.
Each of these improves yield. These are now considered in turn.

2.3.1 Overall Flatness

Overviews of the logged data indicate that the flatness is more consistent when the DSR is in use. This can be seen by the fact that we can consistently get a larger percentage of the coil to within a very small residual error as illustrated in Figure 7. This improvement is due to the combination of: a better control range, improved dynamic response and the ability to address fourth order errors.

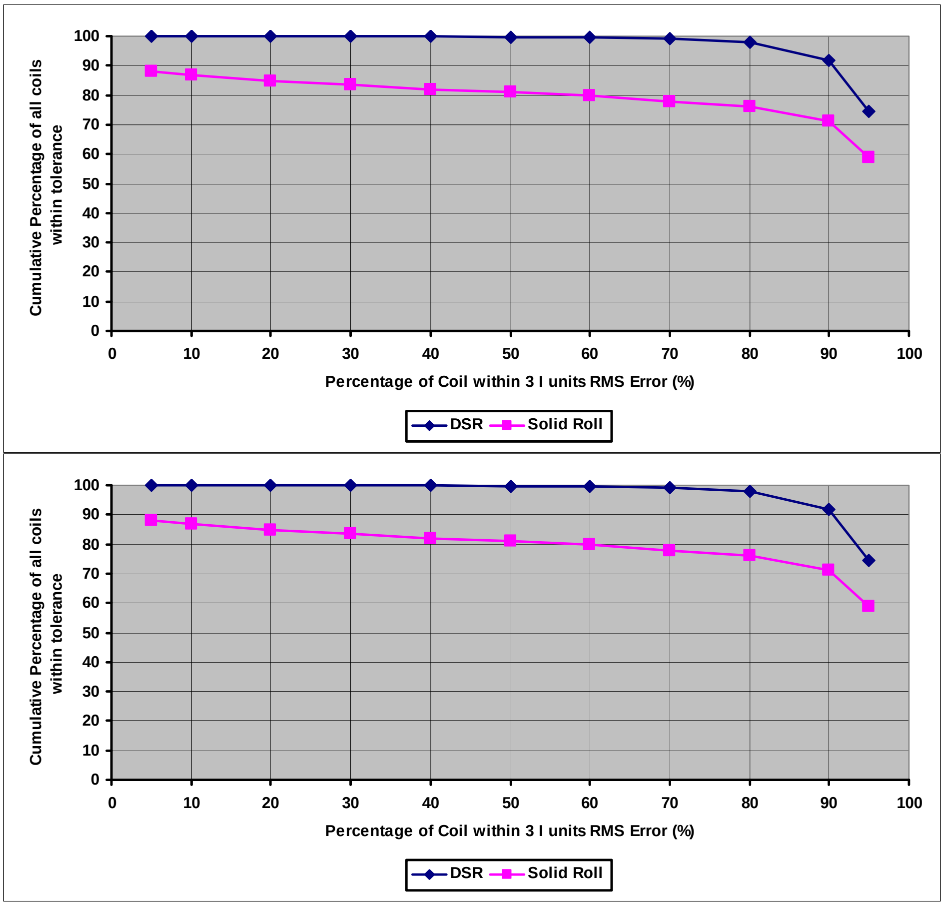

Figure 7. Overall Performance.

The X axis shows the percentage of the coil that has to be in an arbitrary evaluation tolerance and the Y axis shows the cumulative percentage of all coils that are actually in this desired tolerance.
In this example we are looking at an RMS flatness error of 3 I units – a very small error. We show that if we wanted 80% of each coil to be within this tolerance then we would only expect under 76% of coils rolled with a solid back-up to achieve this target but 98% of coils rolled with the DSR would get at least 80% of the coil within the 3 I unit RMS threshold chosen for this illustration.

2.3.2 Cold Starts

These are particularly impressive with a DSR. Figure 8 shows a mill start after a prolonged stoppage of sixteen hours on 0.447mm strip at 1,870mm strip width. Note how the peak flatness error is below 20 I units at just over 90 metres rolled and the operator feels confident enough to go to a rolling speed in excess of 1,000 mpm straight from thread speed.

Figure 8. Cold Start on Thin Strip.

2.3.3 Head & Tail Flatness

A more consistent head end performance can also be achieved with a DSR compared with a solid roll as can be seen from Figure , below. This shows the cumulative percentage of the length required to get the peak error within tolerance at the start of the pass. The peak error can be reduced quickly with a solid roll but the performance with a DSR is more consistent -to get the last fraction of performance the DSR is required.

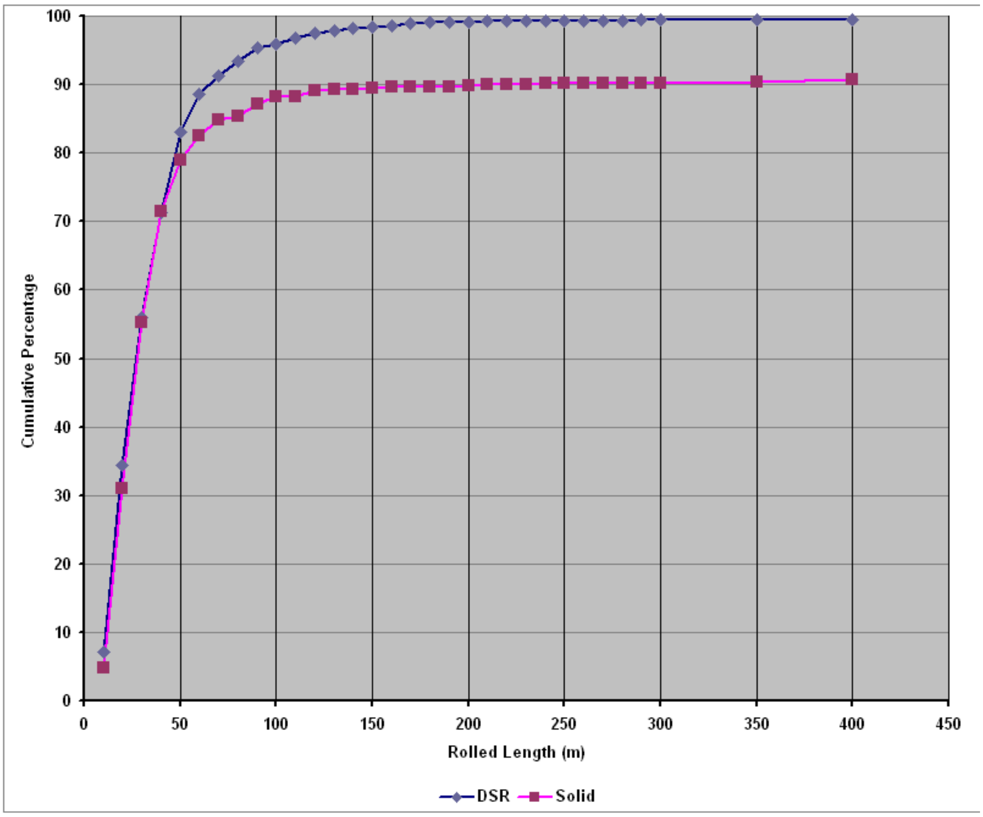

Figure 9. Head End Flatness.

At the tail end the DSR also yields noticeable benefits, as shown in Figure 10.

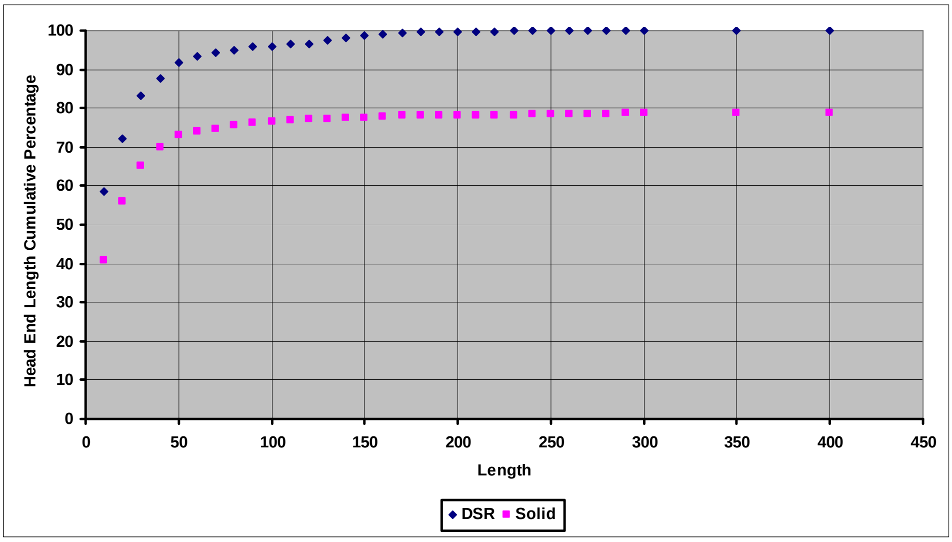

Figure 10. Tail End Performance.

2.3.4 Width Changes

It has been found that with the DSR it is possible to switch rolling widths by considerable amounts (in excess of 600mm) and to still achieve excellent flatness without any warm-up (transition) coils. This is a considerable benefit for mills where there are frequent product changes (Figure 11).

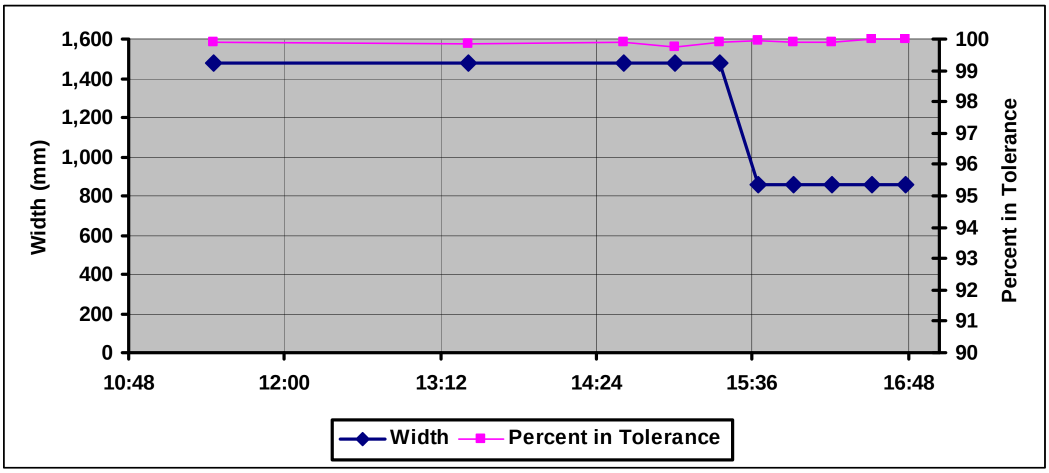

Figure 11. Width Changes.

3 OPERATIONAL EXPERIENCE

3.1 Threading

The fact that the load is applied directly where it is needed makes threading with a DSR equipped mill very straightforward. The operator is equipped with two simple potentiometer type controls by which he can adjust the force distribution by adjusting the quadratic and quartic components of the force distribution. With these, and the ability to thread in force control, the head end of the strip can be threaded very easily, even down to the thinnest gauges.

3.2 Grinding

The grinding interval of the DSR is similar to if not slightly longer than a conventional solid back-up. When grinding a DSR a slightly smaller amount of material is removed compared with grinding a solid back-up. Experience in steel plants indicates that approximately two and a half times as many tonnes of material can be rolled per millimetre of DSR turndown compared with a solid roll.
Note that on all the recent DSR cold mills only one ground camber has been required for the work rolls – something that considerably simplifies operations for the roll shop.

4 ECONOMIC BENEFIT OF THE DSR

Based on a review of a typical new large cold mill producing around 100,000 tonnes per annum we have estimated potential benefits upwards of well over US$5 million per year. This of course does depend on the product mix. The savings are approximately evenly divided between the benefits from improvements to the head and tail performance and the ability to minimise out of specification material at width changes.

5 FUTURE CONSIDERATIONS

Four trends have emerged recently in the rolling industry. The first is a growing demand for automotive bodysheet. The second is renewed demand for maximum production flexibility to minimise work in progress and thus hold down working capital requirements. The third trend is for increased strip widths – mills of just over three metres wide have been discussed during recent proposal activity. The fourth trend is for the operating range of mills to be extended – many cold mills for example now extend into what was previously a thin strip mill region. This places considerable demands on the mill actuator capability and the controllability of the mill. The DSR is well positioned to face all of these challenges.

Car makers will demand the ultimate in flatness. No other actuator has the range of the DSR or its dynamic response. Six-high mills have to have the roll offset adjusted from the Level 2 model prior to rolling thereafter the roll offset is not dynamic in any meaningful sense. It has been said that the sideshift can be adjusted at 1/2,000 of the rolling speed but Siemens are not aware that this is actually done in practice. The DSR pads have a dynamic response of around 30ms and it is this fast dynamic response that provides the capability of addressing head end flatness issues as shown above.

A further consideration with autobody sheet is that it generally has its final pass on EDT (electro discharge textured) rolls. This is similar to the process in steel where shot blasted rolls are used in the final stand of a tandem mill to generate the desired surface finish for steel autobody sheet. Whether it is steel or aluminium these passes are typified by very light reductions. This means that the mill will run cooler and differential spray control will have little to work with. In such a situation a DSR will prove invaluable; given both its greater control range compared to other actuators and the fact that the DSR increases the bend range.

In this paper we have also shown how width changes can easily be accommodated – clearly demonstrating how the DSR can play its part in maximising production flexibility. Further we have shown how the DSR has the largest control range of any currently available actuator.

Finally let us consider the question of strip width. At greater than three metres wide will actuators such as six-high still have a meaningful operating range? Or as we tend towards the widths encountered in the paper industry is the actuator that has its roots in that industry the way ahead?

Considering things in the round Siemens are confident that the DSR offers a capability that provides the best possible current mill performance and is well placed to address the challenges of the future.