Multi-faceted gauging systems for flat and long products

Recent years have seen the demand for defect-free materials increase while the prices paid for steel continues to decrease, so placing great difficulties on steelmakers. A family of shape measurement and gauging systems provides the basis for instruments incorporating highly advanced technology to address these issues.

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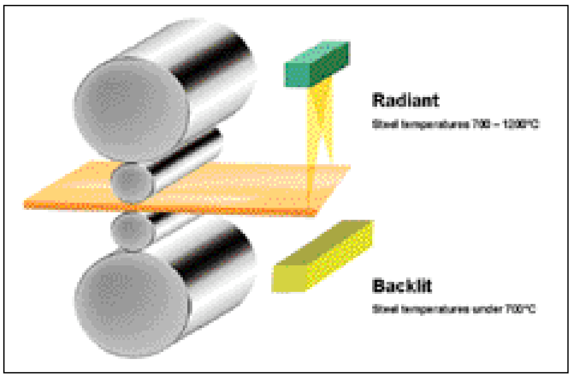
The Shape Technology strip gauging system
The CCD2040 system is based on sensitive, multisensor, high-resolution, linescan CCD (charge coupled device) technology which can measure width, centreline deviation, camber, manifest shape, thermal profile and bar-end shape for crop shear optimisation. Data is then available for use in mill process control systems and for QC purposes. There are now more than 185 reference installations world-wide, based on over 20 years' experience. The various functions will now be described.

Width measurement *Figure 1* illustrates a typical mill arrangement with the stereoscopic vision camera system on the exit side of the mill. The cameras are robustly built to withstand the harsh hot-strip mill environment and they can be installed in all locations from the furnace exit to the down coiler. Up to 2,000 width measurements per second are made, with an on-line accuracy of ±0.8mm (two sigma) and an off-line accuracy of ±0.4mm (two sigma). Various models are available, including a compact version for cold rolling and process line applications. The CCD2040 has been designed to be fully compatible with existing cameras to facilitate retrofitting/ upgrading.

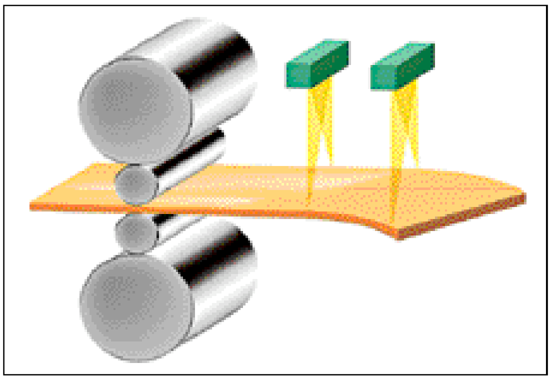
Camber measurement
This is achieved by introducing a second stereoscopic camera mounted approximately one metre from the principal width measurement camera (see *Figure 2*). The centreline changes between the two cameras are monitored by the CCD2040, and from this data the system calculates the camber produced at the roughing mill stand.

Manifest shape measurement
Flatness or manifest shape measurement uses a camera arrangement as in *Figure 1*. It is implemented using a combination of the stereoscopic principal of the CCD2040 with the installation of a laser lighting system capable of measuring the wave height of the sheet at each laser illuminated point across the sheet. *Figure 3* shows a typical operator screen output. The gauges are usually positioned just after the finishing mill or before the down coiler.

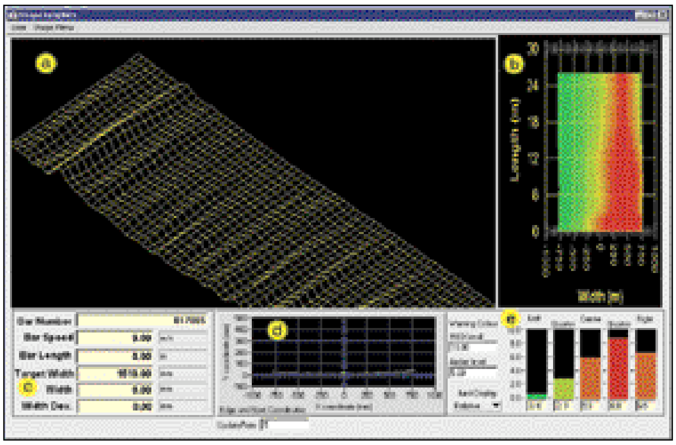
Thermal profile measurement
The CCD2040 OPC (OLE for Process Control) Server architecture provides a common software interface enabling access of the data within the system to the other computers on the same OPC network. This



● **Figure 1** ***Width gauge***



● **Figure 2** ***Camber measurement***



● **Figure 3** ***Manifest shape, operators screen***

feature is exploited in the thermal profile measurement option by making temperature calibrated camera data available to an external temperature profile system. The output from the CCD2040 camera can be combined with other sensors used by the thermal profile system to give complete thermal profile data for the rolling process. *Figure 4* shows a typical screen output with coloured graphics and data.

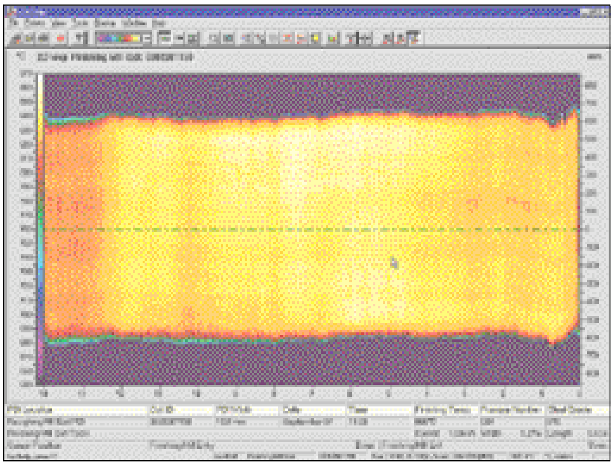
Edge defect detection

The Shape Technology SafeEdge automatic detection system provides 100% inspection of coil edges during the rolling of fast moving, cold strip products, with a defect resolution of 0.25mm. SafeEdge detects, records and classifies both edge tears and nibs, providing the operator with a severity rating. The system then provides the operator with the faults, categorised by size, for the current and previous coils, enabling them to make immediate quality judgements.

Two cameras are positioned on slides above the strip edge, using stepper motor drives. The strip is viewed in silhouette against a back-light system and vision software tools are used to find and inspect the strip edge. Information about defects, including the defect size and position along the coil are stored and displayed in the system.

With a camera height of 1,500mm and a line speed of 800m/min, the minimum detectable defect size is 1.0mm. At slower speeds the camera can be positioned closer to the strip, with a consequent improvement in detection capability, while at faster speeds the camera has to be positioned higher with an increase in the minimum detectable defect size. For example, at 1,200m/min the cameras would be 2,250mm above the strip and the minimum detectable defect size would be 1.5mm. The camera height and associated system resolution are fixed for each installation.

SafeEdge can offer a return on investment in as little as one month; an undetected strip break in a continuous process can stop the mill for up to 12 hours and SafeEdge can prevent this loss of yield, productivity and efficiency.



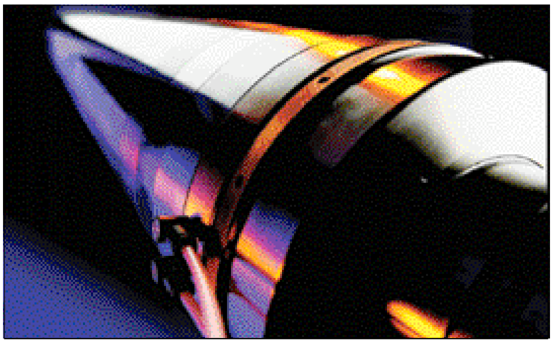
● **Figure 4** ***Thermal profile measurement***

Air bearing shape measurement

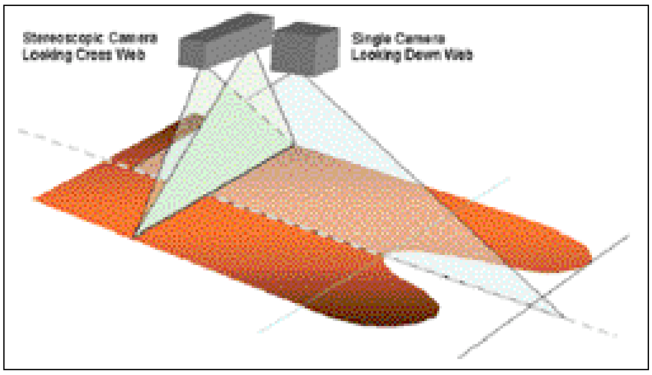
The Air Bearing Shapemeter (see *Figure 5*) is designed to provide continuous data on the flatness of materials at the exit of the cold rolling process. Modular in construction, the instrument can be tailored to meet each customer's specific application requirements without compromising any of its design strengths. Each rotor across the width of the strip is supplied with air from a common plenum chamber in the centre of the arbour. The differential pressure from each rotor is measured and the outputs compared to provide an evaluation of the shape of the strip. The stationary signal outputs provide continuous, fast, highly accurate readings that are independent of mill speed.

Crop shear optimisation

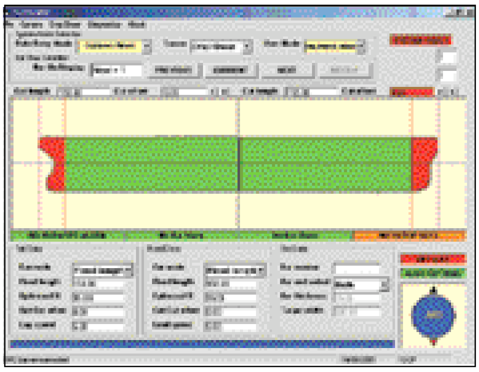
There are two parts to the crop shear system: bar end shape measurement with cut point determination, and shear synchronisation and control. Optimisation is achieved using additional speed measurement and synchronisation sensors such as laser speed devices,



● **Figure 5** ***Air-bearing shape meter***



● **Figure 6** ***Bar end shape acquisition***



● **Figure 7** ***Operator display. Bar end shape measurement and cut point determination***

single line scan cameras and hot metal detectors. The sensor inputs are used to map the bar end shapes and calculate optimum cut points for the head and tail ends of the bar consistent with product type (see *Figure 6*).

The crop shear system provides information which is used to synchronise the operation of the shear to achieve the optimum cut point, either using the CCD3030 crop shear control or using an external crop shear control system. *Figure 7* illustrates the bar end shape display and cut point.

A CCD3030 system was installed at AvestaPolarit, Sweden, in 2003 which provided the necessary product reliability, functionality and customisation capabilities (see *Figure 8*). The project was delivered on time, taking less than six months from order including site specific requirements. The installation was completed within one week and initial commissioning completed within two weeks. At the start the system was run in parallel with existing equipment, which was subsequently decommissioned after four months. The expected benefit of a 0.4% yield improvement was quickly achieved.

Shape measurement for process lines (ProLAB)

The ProLAB is similar in operating principle to the air bearing shapemeter. The instrument has been designed as a cost-effective solution to measure continuous data on material flatness in operations downstream of the cold rolling process, such as process lines. The ProLAB shapemeter has been engineered to suit the budget of process lines without compromising measurement performance. As with the air bearing shapemeter, this unit measures the differential pressure from each rotor and compares the outputs to provide an evaluation of the strip shape.

Interstand flatness roll (IFR)

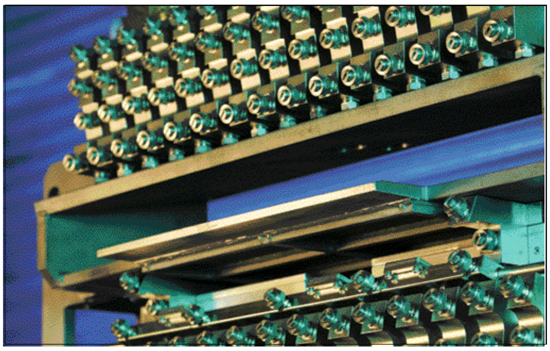
The IFR provides a major breakthrough in strip processing technology. It enables low-resolution online shape measurement of rolled metal sheet 'interstand' early in the rolling process on multistand mills. The IFR comprises a fixed central shaft supporting a single precision machined rotor mounted on high precision bearings. Internal sensors measure the deflection of the rotor relative to the central shaft from which analogue outputs are used to calculate parabolic shape and steer errors used for bend and tilt control. The IFR can be installed at any one or more points after stand one.

One Shape Technology customer has installed two IFRs on a 5-stand mill; one between stands three and four and one between stands four and five. An installation between stands one and two would provide information to assist the operator in reducing the risk of breaks and buckles. Installation between later stands in the mill provides the operator with low resolution parabolic flatness measurement and valuable information regarding tight or loose edges. In most applications, the IFR is designed as a direct replacement for the existing tension roll.

Integral solenoid valve spray coolant system (ISV)

The ISV is a well-proven spray valve, having been supplied to the rolling industry for many years. The main function is to provide zone cooling to the work rolls to remove residual flatness errors and control the temperature of the mill during the rolling process. This

● **Figure 8** ***Crop shear system at AvestaPolarit***



● **Figure 9** ***ISV coolant spray system***

is achieved by the 'pulsing' of coolant (mineral oils and water based) through individual valves matched to each zone to control the thermal profile of the work rolls. The ISV coolant spray system is designed specifically for automatic flatness control (AFC) systems which demand a fast control response for mill thermal control, while providing high reliability and simple maintenance (see *Figure* 9). However, it can also be used as a stand-alone device with a PC from which the operator may select individual spray levels or a fixed spray pattern. Each system is modelled specifically for each customer, its application and product range.

Hot edge spray system

Control of strip shape at the strip edges, mainly on lighter gauge rolling mills, is difficult due to the problem with the steep temperature gradient at the strip edges. This has been addressed by using hot fluid (90°C water or mineral-oil) to simulate a wider strip than is actually being rolled. The system incorporates hot spray nozzles which are set in a horizontal adjustable carriage fitted with displacement transducers to enable precise positioning for varying strip widths.

The positions of the nozzles along the carriageway are pre-programmed according to the product width but can be manually overridden by the mill operator if more positioning flexibility is required. The optimum temperature of the hot spray is normally 50–60°C above the normal coolant temperature. Hot edge sprays have been observed to improve edge conditions by 10–15 I units on aluminium mills under normal operating conditions. This can lead to the potential for speed increases, possibly by up to 10%.

Orbis and Orbis^e non-contact rod and bar gauges

The Shape Technology range of Orbis gauges provides continuous profile measurement of hot wire, rod, bar and billets from 4mm to 310mm in diameter. The Orbis gauge can also be used to measure and display the cross-section of rounds, squares, flats, angles and hexagonal rod or bar and re/de bar. The operator screen provides the major dimensions of the sections.

The optical rotating principle works by passing a beam of light across the moving rod or bar as it passes along cast iron guide tubes through the gauge head. The sensing camera(s), located directly opposite the light source, detects the shadow image cast by the moving bar, giving an accurate and complete profile of the diameter of the bar. The return on investment is short; an Orbis gauge can pay for itself well within 12 months of installation. Annual savings of up to £400,000 have been achieved, with rejects dropping from more than 4% to just over 1%, and yield loss falling from 3.6% to 2.5% in just two years.

Reflex Laser profile gauge for sections

The Shape Technology Reflex Gauge provides online profile measurement of hot-rolled steel sections. The gauge measures steel as it is rolled and provides the operator with early detection of out of tolerance products, such as structural sections, beams, locomotive rails and the simpler shapes of flats, squares and rounds.

The return on investment is short; a Reflex Gauge is a vital component in achieving close tolerance product, high yield and high production efficiency. The amount of rejected product is greatly reduced as the Reflex indicates immediately when any section goes out of tolerance.

The requirements of measuring a re-entrant profile call for a system that will be able to 'see into' the section and measure the web and flange thickness as well as the overall section dimensions. The Reflex uses a modular, structured-light imaging system consisting of lasers and area-scan cameras. Four lasers project narrow lines of the profile, the ends of which are linked to give a complete coverage of the cross-section under inspection. Each laser stripe is then viewed by an obliquely mounted camera, and four such 2D images are recorded. Profile images from the product are captured and manipulated in 3D virtual space, to produce a profile map of the section surface. A digitised line profile of trueform shape is then produced. Parallel pipeline techniques of processing give real-time, rapid measurements.

The measurement data is transferred to the system processor where the real-time on-line display provides the operator with a clear warning when the quality limits are being approached. Corrective action can then be taken to prevent costly faults and ensure the product remains within tolerance. The operator can also view historical production parameters that can be analysed on screen and printed to provide a permanent record for quality and production purposes. This record also acts as a Certificate of Conformance to satisfy the requirements of the end user.

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