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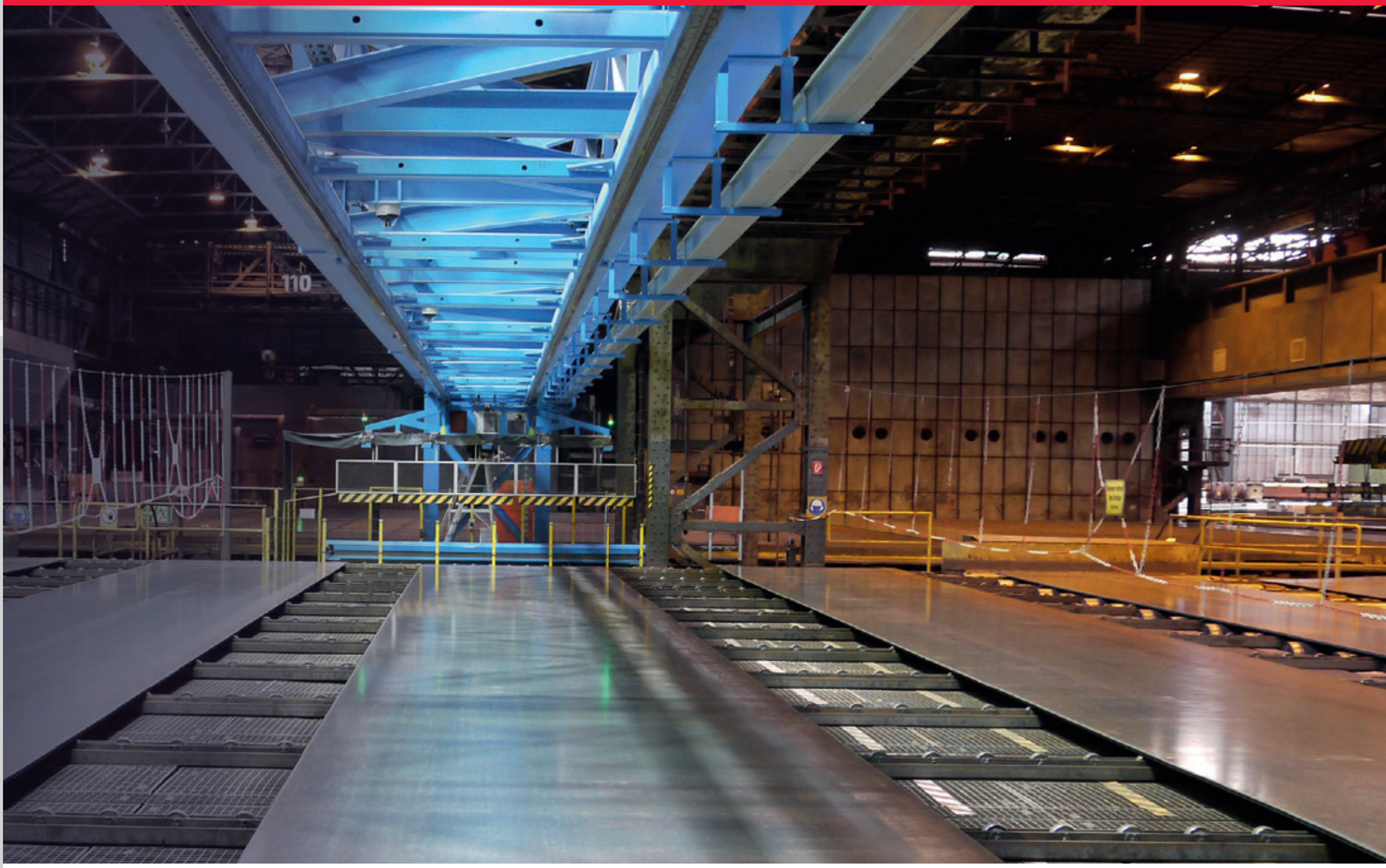
Optical contour and flatness measurement with the new nokra system



The application in the heavy plate mill of Salzgitter Mannesmann Grobblech GmbH (SMGB), based in Mülheim an der Ruhr, Germany.

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Optical measuring system for the plate mill of Salzgitter Mannesmann Grobblech GmbH

New system for contour and flatness measurement of heavy plate

A new optical measuring system from nokra has been installed in the heavy-plate mill of Salzgitter Mannesmann Grobblech GmbH. This system measures not only the contour, but also the flatness of the plate with highest precision, delivering data that assures optimum cutting of individual plates from the mother plates with minimum waste. It is the first system in the world to be arranged above a cooling bed, not above a roller table.

In its heavy plate mill, Salzgitter Mannesmann Grobblech GmbH (SMGB), based in Mülheim an der Ruhr, Germany, produces heavy plate in widths of up to 4.80 metres and lengths of 24 metres. In the hot rolling mill, slabs are rolled down to rough plates according to the customers' specifications. The dimensions of these plates used to be measured manually on the cooling bed, by operators taking the length and width with a tape measure at several positions of the plate. However, that manual method was not suited to measure and document complete plate contours.

The objectives

One of the project targets was to minimize the cutting waste for each customer order by measuring – in a fully automatic process and with high precision – the complete contours of the raw plates and calculate the optimum cutting pattern for each one of them. Another task to be performed by the new system was to measure the plate flatness.

In the context of production digitalization, SMGB wanted to be able to capture and store the complete geometrical data of each individual plate and generate a grey-scale image of each plate surface. This would enable the company to review the production process at any time in the future and assure 100% traceability of each individual product.

Another feature expected from the new system was to enable systematic analysis of the measured contour and flatness data, and on the effects the various parameters concerned may have on the contour and flatness of the plates. The results from these analyses would be used to continuously optimize the rolling process.

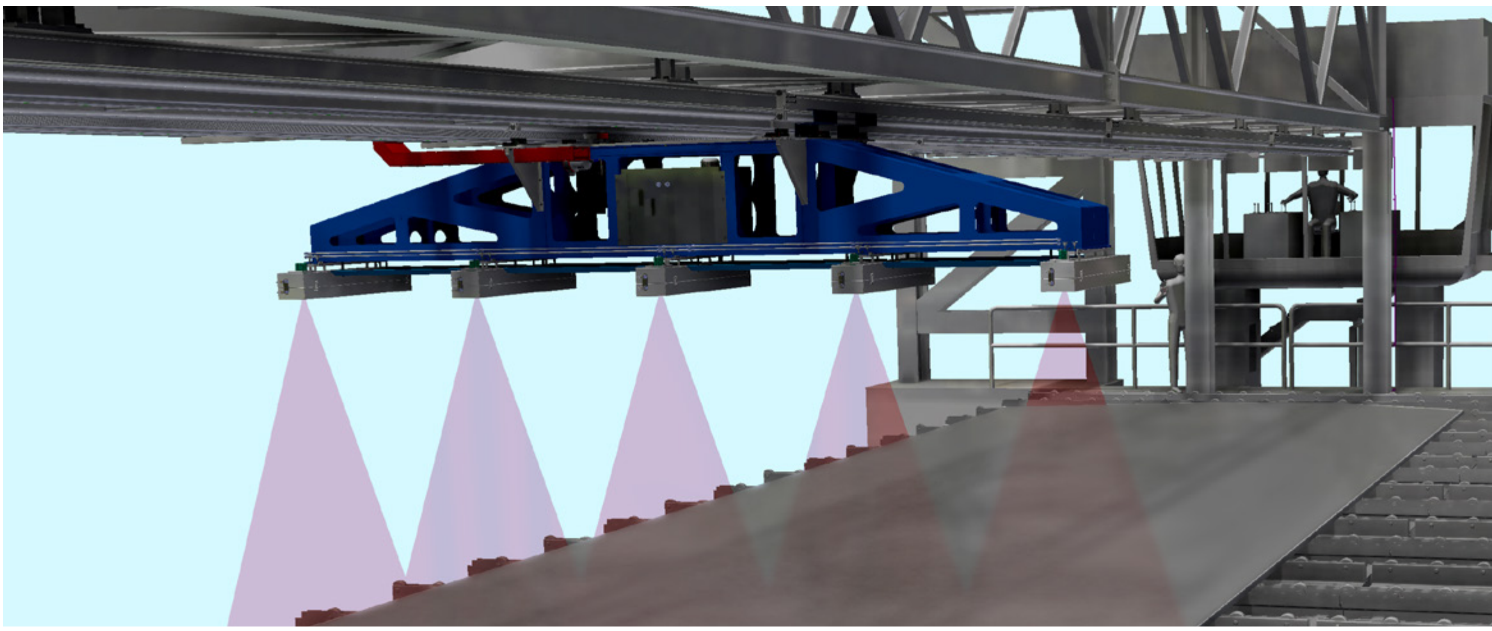

Figure 1. The measuring beam suspends from a steel structure that stretches over the complete length of the cooling bed (Picture: nokra)

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Hence, the overall goal was to establish an automatic measuring process that would not only measure the complete contour of each plate, but also each plate's topology – including product height data – in 3D, store all this data and make it available online to downstream processing stages and the various departments involved.

Unique challenges

Stationary optical contour measurement systems are in use in heavy-plate mills the world over. Those systems operate with sensors arranged above roller tables. The plates are measured while passing underneath the measuring bridge.

A key requirement specified by SMGB had been to be able to receive the measuring results at the earliest possible stage of the production chain in order to make maximum use of the results in downstream process steps. This meant that the only suitable position of the new measuring system in the Mülheim heavy-plate mill was at the head end of the cooling bed.

As the plates are placed transversely on the cooling bed, an arrangement with the plates travelling underneath a stationary measuring system was not feasible. Consequently, the solution was to design a measuring beam with sensors that would be travelling above the complete length of the plates while these were lying still on the cooling bed. These considerations led to the new measuring system for the heavy-plate mill of Salzgitter Mannesmann Grobblech GmbH being the world's first to not employ the traditional roller-table design.

Compared to measurements performed on roller tables, this innovative arrangement provides a series of benefits: The plates are not moving while being measured. Every measurement can now be related exactly to the position of the plate length where it was taken, based on the position of the measuring beam. Additionally, flatness measurements can be taken while the plates are perfectly still. Therefore the measurements are not influenced by any motion of the plate – not even at its head and tail ends. These benefits have resulted in an overall very high measuring accuracy.

The solution

The core elements of the system are nokra's pre-calibrated laser light-section sensor units. Each unit comprises one line laser and one camera. Consisting of five sensor units mounted on the measuring bridge, the system captures approximately 10,000 pixels over a width of 5 m (**figures 1 and 2**), resulting in a resolution of 0.5 mm transversely to the longitudinal plate axis. The measuring range for the height measurements taken to determine the plate flatness is 340 mm above the cooling bed, at a measuring uncertainty of ± 0.05 mm.

A high-precision position encoder system, consisting of a 30-m-long magnetic band fitted along the rail and a measuring head with a spatial resolution of 10 µm, measures the position of the sensor beam along the plate length with an accuracy of ± 1 mm. This data forms the basis for the length measurement of the plate. The thermal expansion of the rail is measured with thermocouples and any deviations in the measured length values due to temperature variations are compensated automatically.

Combined measurement of contour and flatness

The sensor units developed by nokra for the light-section process project laser lines onto the plate surface, each one covering a width of 1,150 mm. While the measuring beam is travelling above the product to be measured, the cameras arranged at an angle within the sensor units capture their respective light lines. The plate edges are determined based on the images taken by the cameras and the position of the measuring bridge along the plate length at the time each image was taken. From the measured width and length values, the software calculates the contour.

In the system installed in the Mülheim heavy-plate mill of SMGB, nokra uses lasers of different wavelengths (red and infrared) in two adjacent sensor units. This eliminates the need to offset the lines, makes the equipment more compact and exploits the full length of the cooling bed.

The height information, which is used to calculate the flatness, is derived from the angle at which the cameras capture the lines on the plate surface.

Figure 2. The system as seen by the operator at the pulpit (Picture: Salzgitter Mannesmann Grobblech)

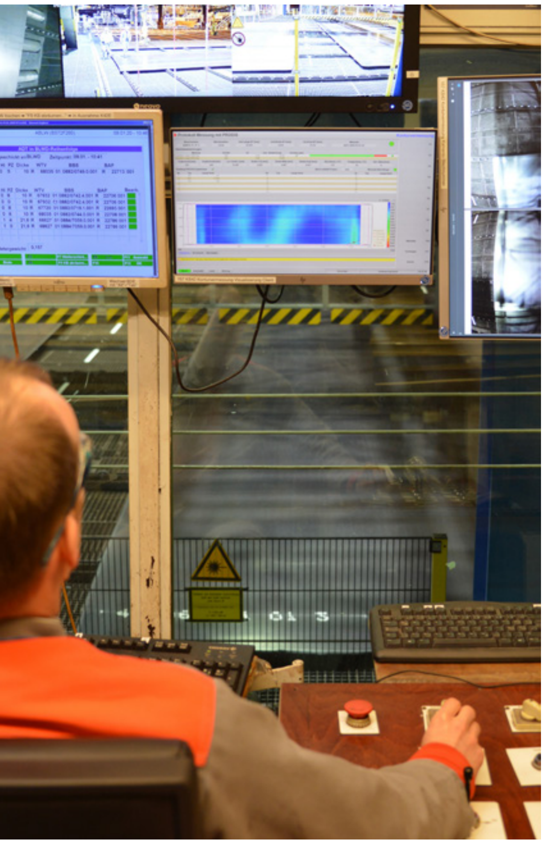

Figure 3. At the control screen, the plate contour and the grey-scale image are shown, in addition to the measured geometrical data (Picture: Salzgitter Mannesmann Grobblech)

An encapsulated housing shields the optical equipment from dust ingress. Narrow-band filters in the receiver optics prevent the system from being influenced by extraneous light. The lower side of the measuring beam is protected by heat shields. Excessive heating-up of the laser light-section sensors is prevented by an active cooling system. These precautions enable the measuring system to operate at plate temperatures of up to 150°C.

The nokra system requires no compressed air and no external cooling water. This provides a distinct cost advantage over competitor systems – with regard to both capital and operating costs.

nokra also implemented the safety concept – including CE marking and the integration of the system into the production process – developed in cooperation with the consulting institute BIT e.V.

The system was installed during scheduled downtimes. Consequently, there was no interference with regular production. As nokra supplied the system with the laser source and the camera firmly connected within a common housing and in a pre-calibrated state, no calibration effort was required. This saved much on commissioning time.

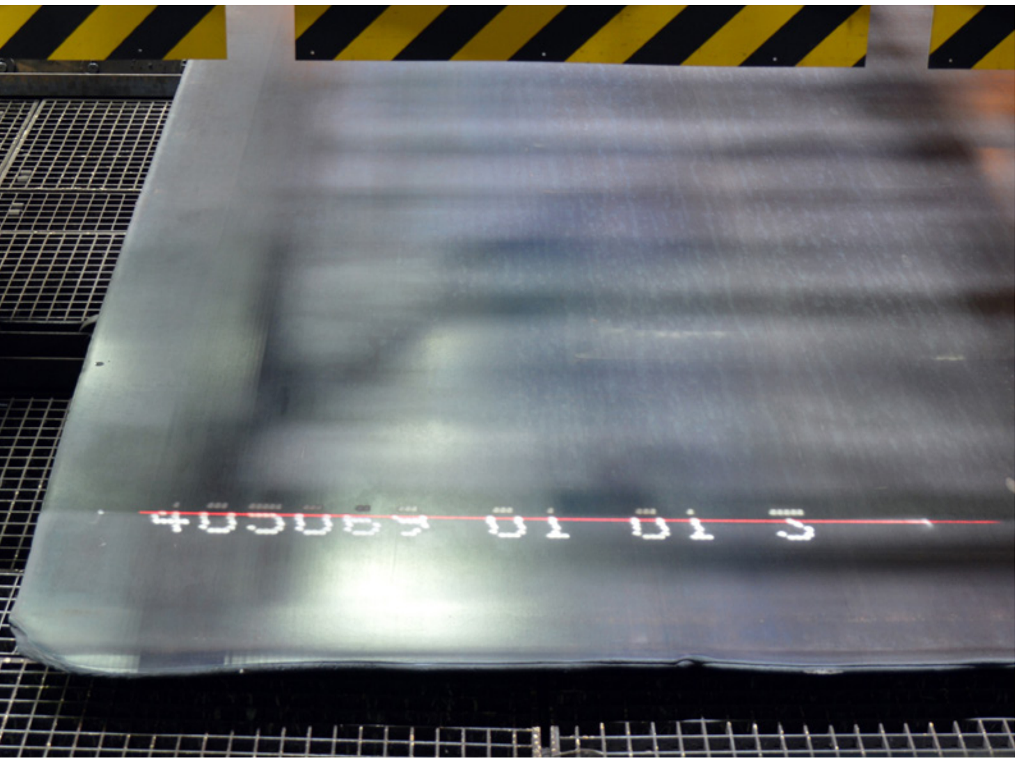

Figure 4. While the measuring beam is travelling above the plate, the laser line becomes visible on the plate surface (Picture: Salzgitter Mannesmann Grobblech)

nokra's exceptional know-how and longstanding experience as a supplier of optical measuring systems for the steel industry were paramount for the success of the project. This is demonstrated, among others, by the sturdy mechanical design of the steel structure. nokra was also extremely flexible and supportive in customizing the system to the constraints and specific circumstances in the plate mill, and ready to accept the responsibility for the complete project, including the travelling steel structure and the integration of the system into SMGB's infrastructure.

The test run of the nokra system went very smoothly. Since the end of November 2019, the system has been operating as a fully integrated asset of the plate production process.

Operation with the newly integrated system

The plate transfer within the Mülheim plate mill is handled by a warehouse management system. When a plate is placed on the cooling bed, the system enters the plate ID number to assure reliable material tracking during the contour measuring process. The operator at the cooling-bed control station selects the plate to be measured on his screen and sends the specific plate data to the system (**figure 3**). Additionally, in order to rule out the risk of mixing up material, he doublechecks the plate number via images taken by two cameras mounted on the measuring beam (**figure 4**). As soon as the plate has been properly positioned within the measuring area, the plate data is transmitted to the system and the operator starts the measurement with the push of a button. The system starts automatically. While moving along the length of the plate, it measures the complete plate geometry. It stops immediately as it recognizes the plate end and returns to its parking position.

As soon as the measuring process has been completed, the software calculates the plate geometry, length, width and the cropping cuts at the plate head and tale. The complete contour is graphically displayed at the control pulpit (**figure 5**).

Then the measured data is transmitted to the higher-level product data and information system "PRODIS", which calculates the cuts, taking into consideration safety allowances, sample cutting and the plate sizes specified in the customer order.

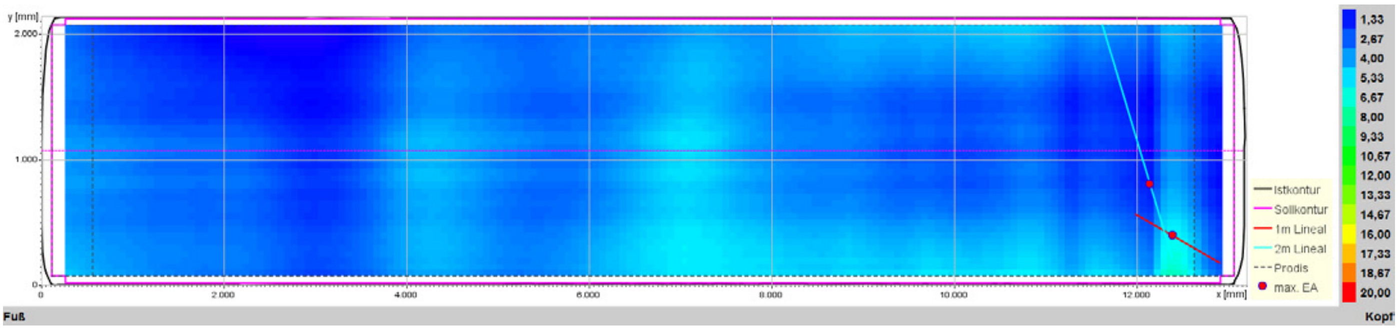

Figure 5. The plate flatness is visualized as a 2D image (Picture: Salzgitter Mannesmann Grobblech)

First experience and conclusions

The new system fully complies with the requirements specified by SMGB and has been performing as guaranteed by nokra. The outside contours of the plates, i.e. width and length, are measured with an accuracy of 3.5 mm and 5.0 mm respectively. The accuracy of both the contour and the flatness measurements is definitely up to expectations. The employees greatly appreciate the way the contours are visualized – how the cutting lines, the safety allowances and the sample cuts are indicated. They immediately accepted the new system.

The cutting pattern data derived from the measured values can also be viewed and used in the downstream processing stages. The availability of digitized geometrical data enhances statistical process control and is extremely useful in performing detailed evaluations and achieving process optimizations (**figure 6**). It is possible to systematically analyze the effects of certain materials or geometries on the production process. Also in-depth analyses of historical data can help to further optimize the production process. It is possible to analyze the effects of individual material grades on the rolling process, for example, or whether certain plate dimensions may require special attention.

To enable high-precision alignment of the coordinates of the five sensor units, a calibration block in hard stone has been installed at the parking position of the measuring bridge in front of the cooling bed (**figure 7**). It has proved useful to perform an alignment once per shift and whenever the ambient temperature changes by a specified value. For the alignment, the laser lines are measured relative to one another and automatically adjusted, if necessary. The alignment is an entirely automatic process.

The measuring bridge is completely encapsulated. Therefore, apart from occasional removal of dust, the optical equipment does not require any other cleaning measures. The maintenance staff greatly appreciates the fact that the parking position of the system is next to – not above – the cooling bed. This means that the measuring bridge is easily accessible even during running production.

In the event of a power supply failure, the control computer of the measuring system is buffered by a UPS system (**figure 8**). It shuts down automatically after a few minutes without power, and reboots and restarts all necessary programs – also fully automatically – as soon as power is

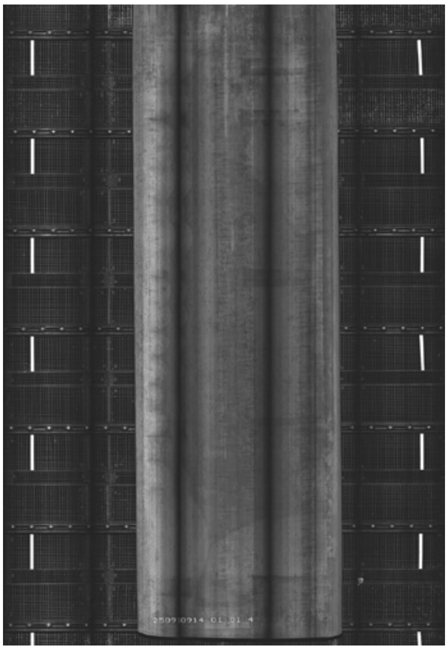

Figure 6. Grey-scale image of a plate (Picture: Salzgitter Mannesmann Grobblech)

Figure 7. The measuring beam – with the five sensor units – in the parking position. Installed below is the calibration block in hard stone (Picture: Salzgitter Mannesmann Grobblech)

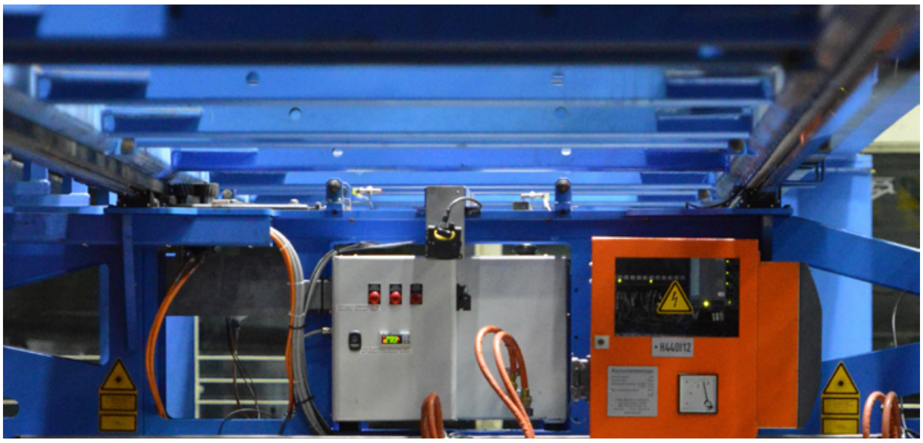

Figure 8. The electronical equipment is fitted below the measuring beam (Picture: Salzgitter Mannesmann Grobblech)

back up. All this takes place without any intervention by the maintenance staff.

The first months of productive operation have shown that the contour and flatness measurements of the individual plates work extremely reliably. Availability of the system has been excellent. These results prove that it was the right decision to employ a system that uses a measuring beam that travels above the plates while these are lying still on the cooling bed. Also the algorithm that calculates the cuts has proved highly successful in maximizing the yield and minimizing waste.