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Quality management

New high-precision flatness measuring system at heavy plate manufacturer Ilsenburger

At Ilsenburger Grobblech GmbH, a system from nokra measures and documents the flatness of fine-levelled plates. The nokra system ensures that all plates shipped fulfill the special tolerances on flatness specified in EN 10029. To achieve the high measuring accuracy required for this challenging task, the almost 30-m-long facility uses laser light-section sensors of the most advanced design and performs the flatness measurements on the static plate.

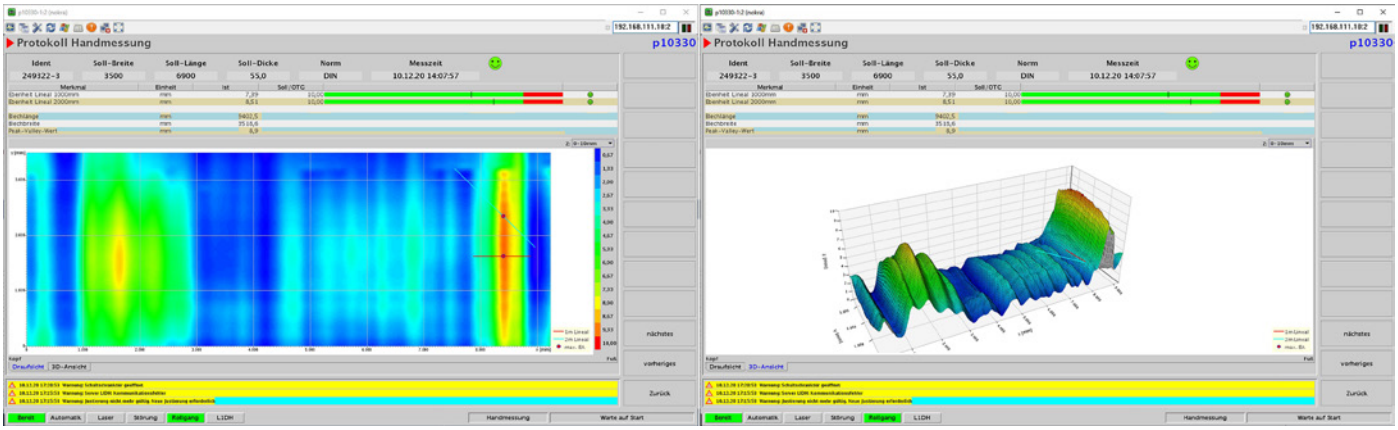
With its new, recently commissioned heat-treatment line, Ilsenburger Grobblech GmbH (ILG) has strengthened its position as supplier of high-strength, fine-levelled plates. These products are used in truck-mounted telescopic cranes, for example. For these applications, special high-strength properties are needed to guarantee that the cranes are safe even when they are working at maximum payload. At the same time, the plates must be of impeccable flatness to ensure smooth extension and retraction of the telescopic jib. Up to 24,500 mm long and 3,550 mm wide plates of thicknesses ranging between 5 and 175 mm are heat-treated and levelled in a newly built production hall, which covers an area of about 31,000 square meters.

Installed downstream of the leveller, an automatic, high-precision measuring system from nokra documents the flatness of the plates before shipment. The system measures the height profile of each individual plate with ultrahigh precision, evaluates the flatness based on the criteria specified in EN 10029 and generates a test certificate.

EN 10029 specifies the maximum allowable deviation from flatness for fine-levelled plates based on the distance measured between the plate placed on a flat surface and a straight edge. For a straight edge of 1,000 mm long, the maximum allowable distance is 3 mm, for a 2,000 mm straight edge, it is 6 mm. To be on the safe side, the project team of Ilsenburger Grobblech specified a maximum allowable deviation from flatness to be measured by the new system of only 2 mm for the 1-m straight edge and of only 3 mm for the 2-m straight edge. Another essential factor in the decision-making process was that the supplier would have to conduct MSA type-1 and type-3 studies to provide proof of the system's capability to measure within these extremely tight tolerances with sufficient accuracy.

With almost 30 meters in length, the flatness measuring system installed downstream the new RM 5 levelling machine is the largest measuring system ever built by nokra (Picture: Ilsenburger Grobblech GmbH)

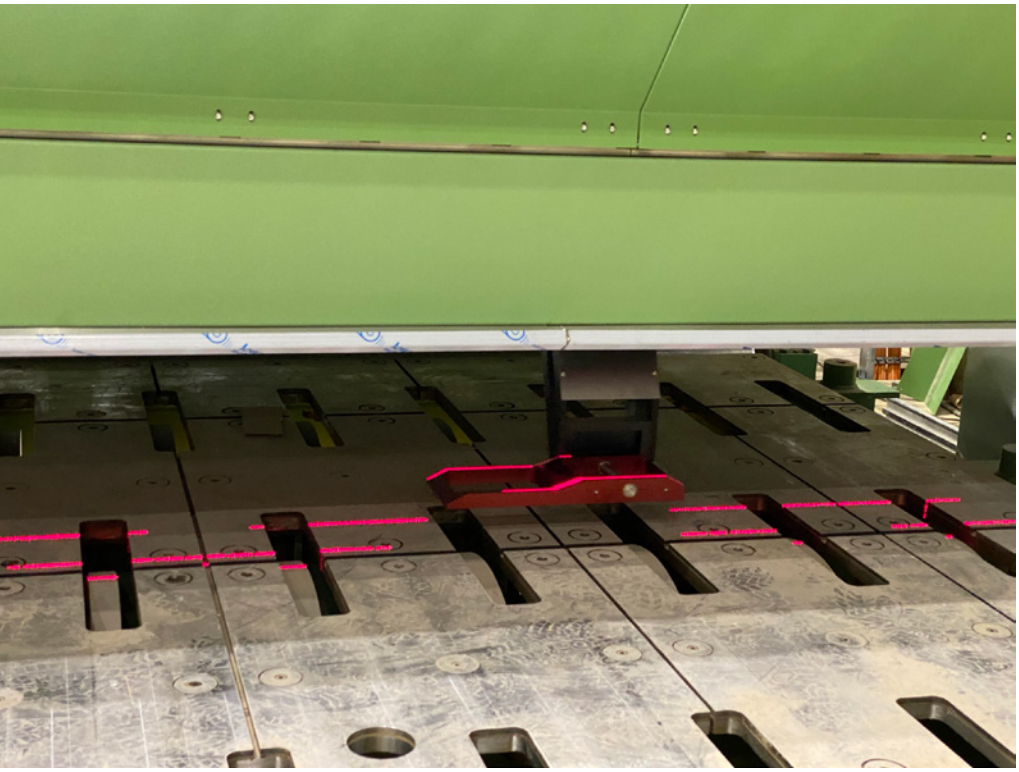
Rolf Simon, project engineer, Ilsenburger Grobblech GmbH, Ilsenburg, Germany; Günter Lauven, managing director, nokra Optische Prüftechnik und Automation GmbH, Baesweiler, Germany – Contact: info@nokra.de



In the control room, the flatness distribution is visualized as a 2D view (left) or 3D view (right) as well (Picture: Ilsenburger Grobblech GmbH)

The selection process

These were the main reasons why the project team had generally ruled out a solution based on manual measurements. Manual measurements are prone to errors, very time-consuming, based on random checks only and, last but not least, would have been very costly. Consequently, optical measurements were the only viable choice. The ILG project team had examined various systems based on laser triangulation. Most of these systems operate with a stationary measuring bridge arranged above a roller table, taking the measurements while the plate is travelling below. Even when complemented by additional measurements, these systems would have been unable to compensate the plate's oscillations on the roller table with sufficient precision. None of these systems would have been able to pass the MSA tests for the tolerances specified. In addition, the fact that the measuring system was to be installed close to the leveller posed another challenge. Therefore, the system would have to be able to compensate the vibrations resulting from the levelling process. Therefore, ILG was looking for a system that would perform the measurements on still plates and would use a measuring table decoupled from the vibrations of the levelling machine.



After the flatness measurement of the calibrated reference part, the current position of each laser sensor is calculated and recorded in a common machine coordinate system (Picture: Ilsenburger Grobblech GmbH)

The solution

nokra GmbH soon recognized that a fundamentally different approach was needed and proposed a system based on the use of laser light-section sensors. Such a system, which nokra had implemented before at several other plate rolling mills, would be able to reliably measure plate flatness within the tolerance range specified by the customer. While conventional stationary systems measure the moving plate, the nokra system would use a travelling measuring unit that would scan the plate lying still on a precisely aligned gauging table. With this system arrangement, nokra was able to demonstrate in an MSA that the system was qualified to perform the flatness measurements with the necessary accuracy.

In April 2018, SMS group, as general contractor for the heat-treatment line project, awarded nokra the order to supply and commission the measuring system that was to be installed downstream of the new RM 5 levelling machine. With almost 30 meters in length, this was to become the largest measuring system built by nokra so far.

A special challenge of the project was that the system had to be operational at a rather early stage of the project to be able to provide the flatness measurements necessary to conduct the final acceptance

tests for the new levelling machine. Those tests were to be based on results from 500 plates. This, too, would have been unfeasible for a manual measuring method.

The technology

The nokra system is based on the laser light-section process. It uses sensors developed specifically for this application. These sensors are integrated into a gantry-type frame which moves down the complete length of the plate on high-precision rails embedded in the foundations.

Nine light-section sensors of nokra's alpha.VR series project laser lines onto the surface of the plate. The laser lines run across the complete width of the gauging table. nokra delivered the system with pre-calibrated sensors. Therefore, the system was ready for use without on-site calibration. The measuring range of the sensors assures that the system can provide the required measuring accuracy for the specified tolerances. To rule out any interference between adjacent sensors, the sensors are arranged with an offset of 150 mm.

While the gantry is travelling along the plate, the cameras arranged at an angle within the sensor units capture their respective lines projected on the plate surface. The height data, which is used to calculate the flatness, is derived from the angle at which the cameras "see" the lines on the plate surface. To obtain a complete height profile, a magnetic sensor captures position data of the gantry as it moves along the plate.

The plates discharged from the leveller run on height-adjustable disc rollers onto the gauging table. The perfectly level gauging table guarantees that the measuring precision of the system is not affected by any unevenness of the table. Laser tracker measurements have confirmed that the system is able to reliably measure deviations from flatness below the maximum allowable deviation of 2 mm. Given the thus confirmed measuring capability, the flatness of the gauging table can be verified at any time simply by having the gantry travel down the empty table and measure its flatness. The software is programmed to automatically skip the apertures and slots for the disc rollers in the table.

When the plate has reached the measuring position, it is stopped and the disk rollers are lowered to deposit the plate safely on the gauging table. For the measurement, the gantry travels down the complete length of the plate scanning its height profile. The sensors in the gantry recognize the plate end and automatically stop the measurement. After the gantry has travelled back to its starting position, the disc rollers are moved upwards to discharge the plate from the gauging table.

The gantry travels at a speed of 0.5 m/s. Thanks to this fairly high speed, the measurement of a 24-m-long plate takes just 50 s. The sensors measure at a frequency of 200 Hz. At 0.5 m/s, the system generates a complete transversal height profile every 2.5 mm of the plate length.

Rolf Simon, Project Engineer Electrical Systems, Ilsenburger Grobblech GmbH
(Picture: Ilsenburger Grobblech GmbH)

The new heat-treatment facilities at Ilsenburger Grobblech are accommodated in a complex of three new buildings covering an area of 31.290 square metres
(Picture: Ilsenburger Grobblech GmbH)

The sensor equipment

The system is designed for plate temperatures of up to 500°C. The lower side of the gantry-type measuring frame and the components on the frame are protected with heat shields made of stainless steel. The laser sensors are mounted in encapsulated protective housings, which are actively temperature-controlled by means of a heating/cooling unit. The system uses ambient air to cool the cooling circuit back down.

Ambient air is blown between the heat shields and the laser sensors across the complete width of the gantry to minimize the effect of heated air rising up from the plate and the gauging table. At the same time, this reduces the ingress of debris and dust into the gantry equipment. Narrow-band filters protect the optical equipment against extraneous light effects.

While in the parking position, the gantry is safely protected against collisions, for example, with the bay crane, by a garage of very sturdy design built by SMS. Also while in this position, the sensors are protected by heat shields against thermal radiation from below.

Alignment

The system's measuring precision is verified at regular intervals. This is done by means of an automated procedure during which a calibrated reference part made of anodized aluminium is moved through the measuring ranges of all the sensors. Once this procedure is completed, the current position of each laser sensor is calculated and recorded within a common machine coordinate system.

The alignment check is part of the automated measurement procedure: when there is uncertainty about the accuracy of the alignment, the nokra system sends out a corresponding notice which triggers the process control system to perform an alignment check before the measurement of the next plate starts.

Installation and commissioning

Factory acceptance testing at the nokra facilities in Baesweiler together with ILG and SMS was conducted with the system operating along a several meter long measuring path. The system was accepted without reservation. During the tests, the

machine also demonstrated that it is "steelmill proof".

Installation of the system at Ilsenburg progressed smoothly with acceptance testing of the measuring equipment in cooperation with ILG und SMS starting as early as at the end of 2020. Final acceptance was granted soon thereafter at the beginning of 2021. The performance criteria for the final acceptance, including MSA type-1 and type-3 studies to confirm the system's measuring capability, were fulfilled at the first attempt. For the MSA studies, eight measurement tracks distributed over the plate surface were defined and the respective flatness values compared.

In the MSA type-1 study, the repeatability of measurements, expressed as the Cg index, and of the systematic deviation, expressed as the Cgk index, are determined. For the calculation of the Cgk index, the values measured by the system along the defined tracks were compared with the corresponding values measured with a laser tracker and verified.

For the 1-meter straight edge, a Cg index above 2.94 and a Cgk index above 1.75 were determined. For both indexes, minimum attainable values of 1.33 had been specified by the customer. For the 2-meter straight edge, a Cg index of 4.39 and a Cgk index of 3.07 were determined. Also in this case, the minimum attainable values specified had been as low as 1.33.

In the MSA type-3 study, which is used to determine the system's repeatability and reproducibility (%R&R), 25 plates from production were measured two times each along the previously defined tracks. From these results, the repetition and reproducibility of the measurements, expressed in percentage, were calculated. While the value specified by the customer was <30%, the actual value achieved by the system was just 6.79% with the 1-meter, and 7.09% with the 2-meter straight edge. Thus, it could be proved in both studies that the measurements are clearly within the allowable tolerance ranges.

The process

nokra designed the HMI to the customer's specifications. The standard view for the operator in the control room is a 2D display of the flatness distribution. In accordance with EN 10029, the values for the 1-meter straight edge are shown as red, and for the 2-meter straight edge as blue lines. In both cases, the position of the greatest deviation from flatness is marked as a red dot. If the operator wants to get a more detailed view, he can simply switch to a 3D display.

nokra has also implemented a traffic light system, as requested by ILG. This enables the operator to see at a glance whether plate flatness is within or outside the allowable tolerance limits.

In the event that a plate does not meet the required tolerances, it can be reversed back into the levelling machine and re-levelled, provided that the microstructure is suitable for immediate re-levelling. Otherwise, it will first be heat-treated one more time.

Bottom line

The measuring system was fully operational and the FAC issued several weeks ahead of the tests for the final acceptance of the levelling machine. Thus, the performance tests could be conducted as planned on 500 plates.

The flatness measuring system has been in automatic three-shift operation since early February 2021, when the new quench became operational. It is linked with the process control system, which transmits the operating signals to the measuring system and receives the measured data as feedback. There has been just one issue ever since the measuring system came on stream. It could be quickly resolved by replacing an existing sensor with a pre-calibrated new one.

The system has proved extremely maintenance-friendly. Lubricating certain mechanical drive components and changing filters in the heating/cooling circuit are the only regular maintenance activities required. The alignment of the system is a fully automatic process performed without any manual intervention.

Outlook

For the future, it is planned to implement direct feedback of the measured flatness values to the levelling machine to enable the automatic setting of the levelling parameters in the event a plate must be levelled a second time. In addition, the stored flatness data will be used to optimize the overall levelling process. Based on the good experience with the new measuring system, ILG plans to install a second one in the existing No. 1 finishing shop.