Extract from STEEL + TECHNOLOGY 2 (2020), issue-no. 5/6, page 66 – 68.

More accurate than demanded by the standards

New high-precision gauge for ultra-exact flatness measurement of heavy plate

nokra has recently commissioned a high-precision flatness gauge at thyssenkrupp Steel Europe AG's heavy-plate mill in Duisburg-Hüttenheim, Germany. In comprehensive tests and investigations, it has been demonstrated that the gauge measures with a much higher precision than that specified in the applicable standards and rules. This makes thyssenkrupp Steel the first producer of heavy plate able to measure that it can produce premium plate of exceptionally good flatness.

In its heavy-plate mill in Duisburg-Hüttenheim, thyssenkrupp Steel Europe AG produces plate for pressure vessels, truck-mounted cranes, ships and wind-power plants – in widths of up to 3,300 mm, lengths of up to 16,000 mm and thicknesses ranging between 4 and 150 mm.

At the end of the finishing line used by thyssenkrupp Steel to produce premium plates, cold-levelled plates are processed in a descaling and colour spraying (DCS) line, usually including the application of a primer coating.

The flatness requirements on premium plates – used in crane jibs, for example – are very exacting because these plates often need to be edged and welded for their final application. The increasingly higher strength of modern steels results in thinner plates being used in many applications. Therefore, flatness becomes an increasingly more important quality feature for the customers. In the past, only manual flatness measuring was available at the DCS line.

The flatness gauge is arranged at the end of the finishing line, behind the descaling and colour spraying line (Picture: thyssenkrupp Steel Europe)

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Highly ambitious targets

The thinner a plate, the greater the risk of out-of-flatness production becomes. Therefore, for this project the DCP line exit was chosen as the most suitable position to capture the complete plate topology, and assess and grade the flatness on the basis of measured centre and quarter buckles, wavy edges, and ski effect as part of the final quality inspection. Based on this evaluation, the plates would then be automatically separated into "good" and "bad".

In order to fulfill its customers' extremely exacting requirements, thyssenkrupp Steel decided to invest in a measuring system that would provide much higher precision in flatness measurement than specified in the applicable standards – DIN EN 10029 and ASTM A20. While DIN EN 10029 permits a ruler gap of 3 mm/m, the project team defined a target precision better than 1 mm/m – which would take precision of flatness measurements to the next level, enabling thyssenkrupp Steel not only to produce but also to verify premium quality.

Another objective of the project was to provide the possibility of capturing the length and width of the plates on the conveyor in order to check the identity of each plate.

The project team was convinced that only an optical measuring system would be able to fulfill these exacting tasks. The installation situation at the planned position, the slightly bright or primered surfaces and the plate temperatures of usually less than 70°C were ideal for an optical

The laser lines projected by the individual sensors are offset to avoid any misinterpretation of camera signals (Picture: thyssenkrupp Steel Europe)

gauge. However, the extremely high measuring accuracy to be achieved and its verification posed a great challenge. One essential requirement specified by the customer was to attest and verify in a suitable testing procedure the measuring capability of the system. This involved, among others, the referencing of the measuring results to a verifiable calibration standard.

In order to guarantee that the gauge would operate with the expected precision, thyssenkrupp Steel made it an essential part of the tender specifications that the supplier of the gauge would have to prove the reliability of the flatness measurement according to procedures 1 and 3 and in the presence of experts from thyssenkrupp Steel.

Experience with other flatness gauges in use in the mill had shown that such exacting measuring accuracies are achievable only if there is no significant up and down oscillation of the plate.

Therefore the project team decided very early on that the existing plate conveyor would have to be replaced – actually, before the installation of the gauge – by a new walking beam system with extremely small gaps between the individual beams. The overall success of the project would largely depend on the effectiveness of achieving a measuring situation in which plate oscillation during the measurement is reduced to an absolute minimum.

Several suppliers participated in the tendering process. thyssenkrupp Steel decided in favour of nokra last but not least because of the compact sensor design and the low space requirement of the complete system, and its high user friendliness. In addition, as nokra systems come with a pre-delivery calibration, they are very easy to set up.

The solution

After successful factory acceptance testing, nokra supplied a system of its alpha.fi series. Gauges of this series had already proved highly successful in various heavy-plate mills where standard measuring accuracies are demanded. The system's key component is a static measuring bridge equipped with sensors for laser light-section measurements.

These sensor units – developed by nokra specifically for the light-section method – project laser lines onto the surface of the plate. While the plate is travelling under the measuring beam, the cameras arranged at an angle within the sensor units capture their respective light lines. The height data, which is used to calculate the flatness, is derived from the angle at which the cameras capture the lines on the plate surface. nokra has set the measuring range of the sensors such that the required measuring capability of the system is achieved at a tolerance of 1 mm/m.

The narrow wavelength range of the laser and the use of interference filters on the receiver side ensure that the measuring results are not influenced by environmental light. The equipment has been approved by a publicly appointed and accredited expert, who attested it Class 1 laser safety. Thus operators may be present during operation of the gauge in the immediate vicinity of the gauge outside the protection fence.

As the latest generation of alpha.VR light-section sensors can take photos of the plate surface while measuring the surface profile, it is possible to also detect flaws, such as defects in the coating.

The measuring beam is safely protected by a casing against dripping water, dust and dirt. The columns of the gauge are bolted to the floor. Should there be a reason to remove the gauge from the line, the anchor bolts can be loosened and the complete measuring bridge lifted up by a lifting beam and placed next to the line.

The gauge operates fully automatically. It is integrated into the mill's production control system. Thus it receives both the values from the measurements and the flatness specifications from the higher-level production control system. After completion of the measurement it feeds the recorded data, including the results of the "good/bad" grading, back to the system.

The measuring record stored in the gauge includes a plate topography that can be rendered in a false-colour 3D view and in a plain view from above.

Additionally, the gauge is equipped with a database system for future retrieval and comparison of measurement data relative to individual plates or individual campaigns, for process optimization, for example.

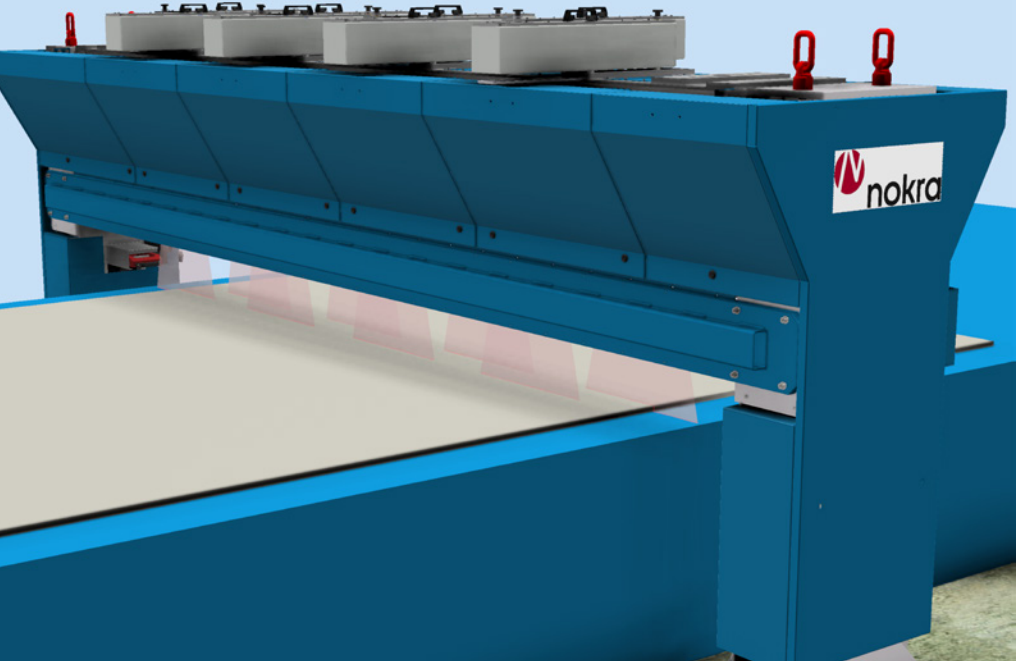
Control of the gauge and evaluation of the data are handled by an industrial PC accommodated in the electrical cabinet. This PC is also used to operate the gauge during service and maintenance activities.

For high-precision flatness measurement over the complete surface it is essential that all sensors refer to a common Coordinate Reference System. The sensors are adjusted to this CRS by means of a motorized adjusting device travelling in automatic mode under all of the sensors, when there are no plates on the walking beam conveyor.

Should one of the sensor units – which are made up of a projector and a camera – have to be replaced, this can be accomplished by the maintenance staff within only 30 minutes. When the new sensor is in place and the sensors have been re-calibrated, the gauge is immediately ready to perform measurements with the same high precision.

The results

nokra installed and commissioned the new gauge within just a few days after the new



The principle: the sensor units project laser lines onto the plate surface. Cameras capture the height profile of the lines (Picture: nokra)

conveying system had been put in place. The gauge has been operational since the beginning of 2020 and has been working very reliably ever since the operators were trained on it in February 2020.

On account of the extremely exacting demands in terms of measuring precision, thyssenkrupp Steel's project team had subjected the gauge to comprehensive testing, with special emphasis on proving the system's measuring capability.

Here the focus was particularly on two aspects: first, how far do the measured values spread out. This spread is given as the Cg value determined in procedure 1. And, second, the Cgk value, which indicates how far the measured values deviate from the true values (reference values). A measuring system is generally considered accurate when both values are higher than 1.33.

The plate topography is rendered in a false-colour 3D view or a plain view from above (Picture: thyssenkrupp Steel Europe)

The Cg value represents the repeatability of measurements. This value was fairly easy to determine by means of successive measurements of different inhouse-produced plates. Determination of the CgK value, on the other hand, involved a much greater effort. Usually, the use of a calibration standard of which the exact dimensions are known would have been required – for the case at hand, this would be a very accurately measured plate. However, for a heavy-plate mill it is not viable to keep and use such a calibration plate. Even if there were such a plate, it would very likely deform during the transfer by crane or when placed on the walking beam conveyor.

From these constraints resulted the idea to construct a profile measuring beam equipped with a tactile sensor, which would measure the height profile of any available plate over a length of 1,500 mm with maximum precision. The solution was to measure the same segment of a plate first with the tactile sensor and then with the optical system. In this case, the height profile measured by the tactile system would represent the "true" values. Given a measurement uncertainty of approx. 10 µm, these values can serve as a calibration reference.

For this to be acceptable as a proof of measuring capability, it was necessary to have the properties of the calibration reference accredited by an official attestation body – similar to the international prototype meter for length measurements. Consequently, the measuring uncertainty of the tactile system was determined on a hard-stone measuring surface in thyssenkrupp Steel's calibration lab. As far as the author of this report know never before had a flatness measuring gauge been subjected to such rigorous testing ... a challenge nokra was pleased to accept.

The results were extremely positive: in many instances, both the Cg and CgK values were much better than the values specified as minimum for the tolerance field T = 1 mm.

Bottom line

All project objectives have been achieved: The new system enables thyssenkrupp Steel to exceed the requirements specified in the applicable international standards. It achieves a three times better measuring accuracy than specified in the standard that allows a ruler gap of 3 mm/m.

Also checking the identity of each individual plate based on the length and width data generated as part of the sensor data evaluation has proved highly successful in avoiding any misallocation of data.

Especially the intensive dialogue between thyssenkrupp Steel, nokra and the supplier of the plate conveyor system during the planning and installation phases has been key to the success of the project.

Combining high-precision inline flatness measuring with inline surface inspection has resulted in thyssenkrupp Steel's DCP line being one of the world's first finishing lines in heavy-plate production where both the flatness and the surface quality of each individual plate are – gaplessly and over their complete surface area – measured, evaluated and documented.

A viable scenario for the future is to use the images taken by the sensor cameras during the measurements for evaluations of the plate surfaces at a later point in time.

For thyssenkrupp Steel, the fact that the gauge even today performs much better than the specifications in the two above-mentioned standards, commonly used to assess the flatness of plate products for the American and European markets, means that the company is optimally prepared for probably even further growing requirements in the future.

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