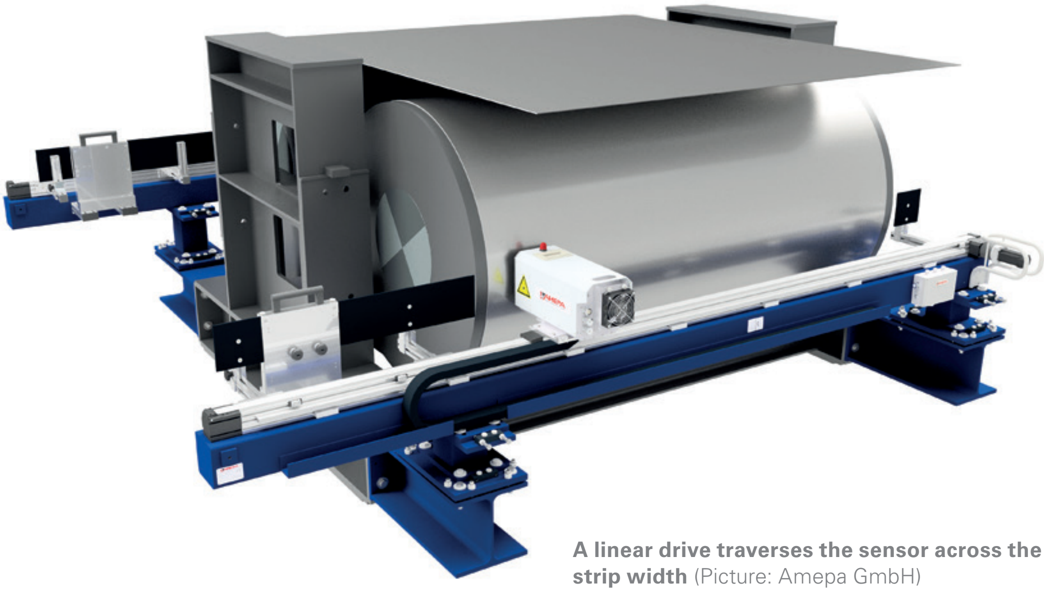

A linear drive traverses the sensor across the entire strip width (Picture: Amepa GmbH)

Towards filler-less painting

Inline waviness measurement of electrolytic galvanized steel strip

As automotive producers are placing increasingly quality demands on the surface area profile of electrolytic galvanized strip, there is a growing need for steel producers to measure the surface waviness, in addition to the surface roughness. thyssenkrupp Steel Europe AG has been using the waviness measuring system from Amepa in an electrolytic coating line. This line is the first worldwide that measures the waviness along the entire strip length and width inline during running production.

A growing trend in car body shell painting is to apply the final coating directly on the electrolytic galvanized zinc layer, without a filling layer. Consequently, surface area profiles of just a few µm have moved increasingly into focus. In addition to the roughness, the waviness determines the visual appearance of the painted surfaces of car body shells and the overall look of a car. The waviness may cause undesired effects, such as orange peel.

While reliable inline measurement of the strip roughness has been possible for quite a long time, the Wsa values, which measure the waviness, have been determined offline, randomly, and only via samples taken from the finished coils. The threshold between "good" and "bad" quality is often determined based on an indirect relationship between two parameters. To this end, the parameters roughness (Ra) and peak count (Rpc) are set within defined limits and controlled to achieve a Wsa value in compliance with the specification.

However, as automotive manufacturers increasingly demand low Wsa values, it can be anticipated that specific waviness values will soon become a binding requirement of orders from the automotive industry.

The aim

Therefore, thyssenkrupp Steel Europe (tkSE) was looking for a direct waviness measuring solution that would measure not just certain spots of the strip but also the entire surface over the entire strip length and width in real-time during production. A waviness measuring system should allow the operators to intervene immediately if certain tolerance limits are reached.

At that time, Amepa was just about to launch its new waviness measurement system. The system was developed based on Amepa's surface roughness measurement system (SRM system), which was already successfully in use at tkSE and other steelmakers' facilities. Therefore, it suggested itself to test the new system under operating conditions. tkSE's electrolytic galvanizing line EBA 3 in Dortmund was to be the company's first facility to use the new system.

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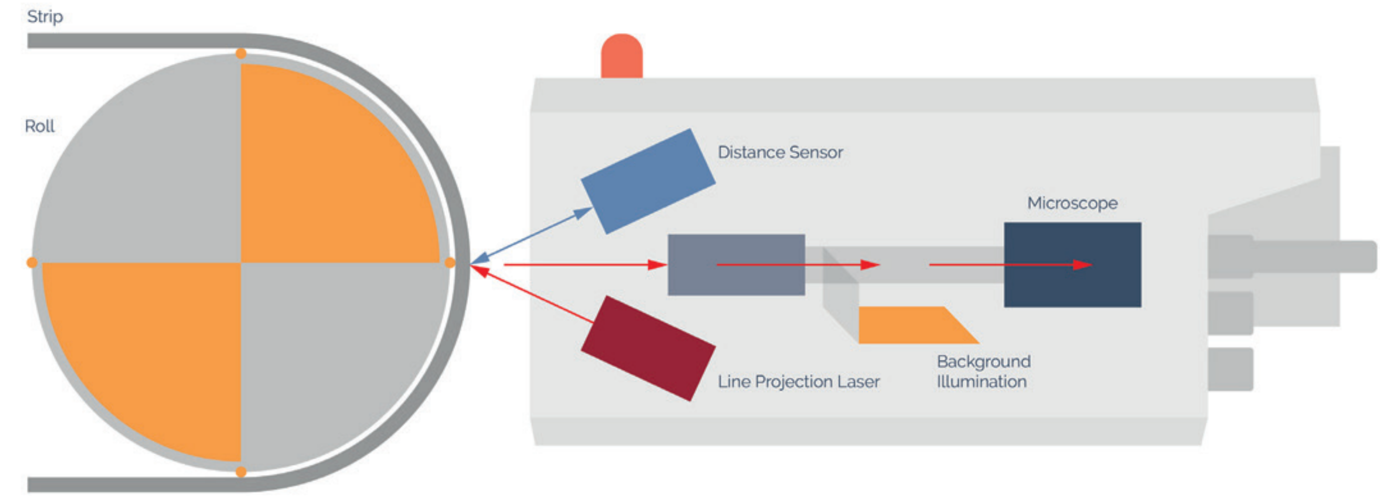


The laser (red) projects a line onto the strip. The line appearing on the strip surface is captured by the camera (black) with microscopic resolution (Picture: Amepa GmbH)

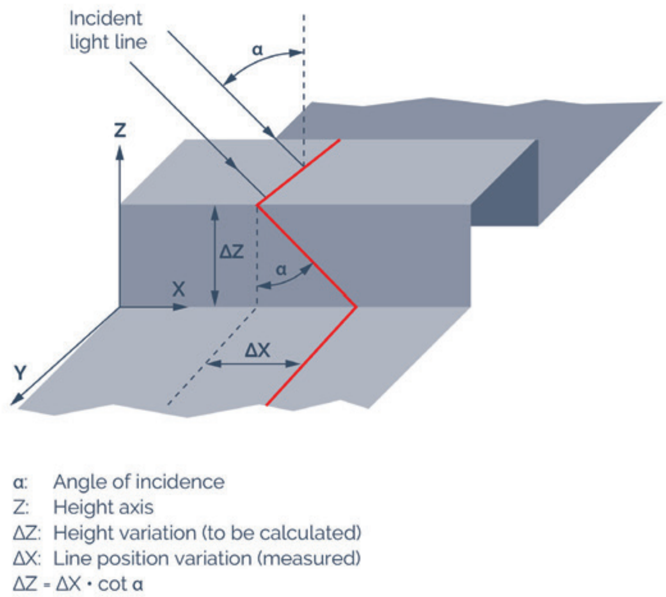
A main reason for this decision was the fact that the data measured by the new system could be directly compared with the roughness control data from the downstream process stages because the roughness measurement (Ra) and the peak count (Rpc) systems are already in use, operate on the same basis, and use compatible data formats. This paved the way for a holistic approach to quality control based on objective data, taking various processing units along the production chain into account.

From roughness to waviness

For developing the waviness measuring system (WMS), Amepa expanded its optical roughness measurement system SRM with a waviness measurement feature. The new system can now simultaneously measure the roughness and the waviness with one common sensor.

The inline roughness measurement with the SRM system is based on the laser light-section process, a two-dimensional laser triangulation method. In this non-contact process, an extremely thin laser line is projected onto the strip surface at a specific angle. This line is captured by an integrated camera with microscopic resolution. From the line's contour, image processing algorithms calculate the surface profile.

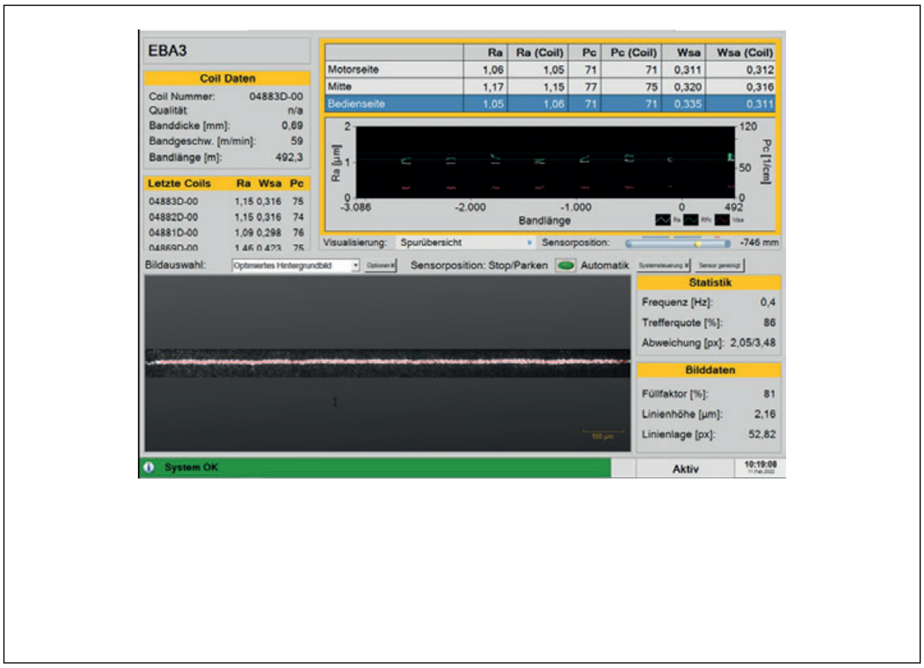
The measuring sensor is much smaller than the head of comparable roughness measuring systems because it contains only one camera on the receiver side. The measuring principle works with any surface condition. The head is arranged next to a deflector roll over which the strip runs. To ensure correct evaluation, the algorithms take into account the roll diameter.



The light section principle: The laser light hits the strip surface at a certain impingement angle. The camera captures the laser line's offset (Picture: Amepa GmbH)

While for a roughness measurement, the laser line usually runs transversely to the rolling direction, the laser line for the waviness measurement runs lengthwise in the rolling direction.

The high-speed camera takes 30 to 50 microscopic images of the laser line in rapid succession. It combines the individual images one after the other with a small overlap into an overall picture of the height profile. The rate at which the pictures are taken is synchronized with the strip speed. Thus, the individual images can be precisely assigned to the positions on the strip. In this way, a virtual laser line is created on the strip surface. The line covers several stretches of the one to five-millimeter-long waves. From this, the height profile in the rolling direction, and thus the Wsa value, can be derived. Another important aspect is that those picture elements have a fixed reference point to one another. This ensures that indefinite or missing data points can be interpolated.



Both the Ra and the Wsa values are displayed on the control screen
(Picture: Amepa GmbH)

The sensor is arranged in the run-out section of the electrolytic galvanizing line
(Picture: thyssenkrupp Steel Europe AG)

The project

A sensor was arranged in place of an existing coating thickness measuring system facing a deflection roll in the line run-out of EBA 3. The existing structure was modified to accommodate the new traversing unit and decouple the system from the line vibrations. The new system was officially commissioned in October 2021. Since then, the system has been operating with great reliability. This makes EBA 3 the world's first electrolytic galvanizing line operating with an integrated inline waviness control system.

At the same time, the system still delivers the data needed for roughness control. All of the acquired data is continuously recorded and visualized on the control screen. If a roughness threshold is reached, process intervention is instantly triggered. Since December 2021, the roughness values have additionally been used to support ship/no-ship decision-making.

The reliability of the roughness control is verified by daily manual tactile measurements of samples taken from the strip and compared with the inline measurements of the corresponding strip locations. To verify the waviness measurements, a procedure for the analysis of the samples and the comparison with the inline data is currently being developed in cooperation with a certified testing lab in Dortmund.

First experience

The new system has considerably enhanced the effectiveness of quality assurance: The random analyzes in the downstream lab are now complemented by continuous inline quality control. If necessary, corrective action can now be taken immediately, without having to stop the production process. It is possible to influence the surface roughness and peak count, for example, by adjusting the dissolution conditions of the zinc anode.

According to the quality assurance personnel, the new system is "a gift". In addition to facilitating daily work, it also helps in quality decision-making. Even now, the Ra value is used for target/actual comparisons to support coil quality assessment and ship/no-ship decisions.

The availability of additional information about the roughness and waviness distribution over the entire strip length and width provides a host of new possibilities for further surface quality enhancement and making the strips suitable for filler-less painting. The new data form an essential building block to the digital, smart coil because more data is now available about an important surface quality parameter.

The future

Even now, it is evident that waviness specifications will become a standard requirement of customer orders in the years to come. Very soon, more and more orders from automotive producers will include a guaranteed specific Wsa value for the strip producers to comply with. Inline control of the waviness will then be indispensable. Thanks to the new measurement system, tkSE has what it takes to comply with this requirement.

The move away from random offline checking of the Wsa value to a continuous inline process provides many more important benefits: It is now possible, for example, to correlate the waviness values with the conditions in the various process stages, such as the cold rolling mill, the continuous annealing line and the EBA 3 itself. This will make it possible to provide answers to many open questions: How do certain conditions in the downstream process stages interact? Do they lead to positive effects, or do they aggravate negative effects? Do they complement each other, or do they have a neutralizing effect?

Thus, the WMS opens up a range of new opportunities for the examination of root causes for variations in surface waviness. Knowing the influencing factors along the process chain means that it will be possible in the future to precisely control the waviness – based on objective data, not on subjective judgment.