Industrial online surface roughness measurement of strip

Rising sheet surface quality demands by the automotive industry make it necessary to control continuously the roughness of strip steel. Moreover, the optimisation of the deep drawing process requires tight tolerances in the tribological behaviour of the material to achieve higher production rates. High strength steel and aluminium sheet can only be deformed without defects under optimised conditions and homogeneity of the surface. Roughness is an important factor to reach the best product. The AMEPA SRM online roughness measurement system is an established tool for better production control of these properties.

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The appearance of a finished painted product has high value for the end user. Not only are the demands on surface brilliance rising, but also, due to cost and environmental reasons, paint layers are becoming thinner and even the filler layer is now being omitted prior to painting. This means that the structure of the base material is becoming ever more important to the appearance of the final product. All this increases the need for a better control of the topography ie, the roughness of the steel or aluminum sheet.

Currently, surface roughness is manually measured with a mechanical stylus on samples taken from the head or tail of the coil. This measurement does not give a representative value for the roughness distribution over the length or width of the coil. The necessary samples are also cut near the coil join welds where the rolling force and speed are reduced when the weld passes the skin pass.

The immediate availability of roughness data allows the direct correction of process parameters if the quality of the surface roughness is out of its tolerance range. This avoids a cost and time intensive second milling of the product.

To continuously control and so improve the surface properties, a surface roughness measurement system (SRM) has been developed by the Center for Research in Metallurgy (CRM), Liège, Belgium and industrialised by AMEPA to measure online the strip surface roughness. The measurements are taken along the whole length of the strip, with the possibility of positioning the sensor over the width of the coil to obtain valuable information about roughness distribution across the strip.

**SRM MEASURING PRINCIPLE**

Although a more detailed description can be found in [1], the AMEPA system basically uses two-dimensional triangulation, also known as light-section measurement. A
laser line is projected at a certain angle onto the surface and, due to the surface topography, this line is distorted if it is observed under a different angle to the projection. This distortion allows a direct calculation of the surface profile and hence the surface roughness. Figure 1 shows the laser set up and Figure 2 a typical output, namely the distorted white line on a galvanised surface created with electron beam texturised (EBT) working rolls.

The sensor consists of a diode laser system for line projection and a microscope with a high resolution CCD camera for the observation of the distorted line and strip surface. An additional laser is used for background illumination, enabling a direct inspection of the microscopic image of the strip surface, which can be done normally only in a laboratory.

Background illumination is not necessary for the measurement, but gives the user the chance to validate the result. Even the fine structures of the zinc layer can be resolved by the distortion of the laser line.

The AMEPA SRM system is not affected by the investigated surface, its roughness, coating or texture, therefore no calibration is required.

Online roughness measurement systems use a laser spot for the roughness measurement that is influenced by strip vibrations and depends on the movement of the strip to achieve data in the second dimension. Therefore, these devices are only able to measure parallel to the rolling direction. The light section principle however, as used by the AMEPA SRM, allows an arbitrary orientation of the line and so roughness can be measured perpendicular or in 45° to the rolling direction as SEP 1940 and DIN EN 10049 demand.

The other advantage of the line projection is the fixed correlation between all points of the line. Also, when the exposure time is short enough, the system is not affected by vibrations or the velocity of the strip.

The photographs in Figure 3 show the wide range of optical properties of coated and uncoated steel sheet which can be measured by the SRM. The system adjusts automatically to the different reflectivity of, eg, galvanised (highly reflective; Figure 3b) or galvannealed (perfect...
This is very important because both products are manufactured on the same production lines. The displayed examples show surfaces milled with electron discharge textured (EDT) and EBT working rolls.

The laser system is maintenance-free so a long lifetime is guaranteed. The lasers are equipped with special driver electronics that enable not only the control of the pulse energy, but also the variation of the pulse duration. The typical pulse length of 20ns enables measurements even at speeds up to 1,500m/min without reduction of image quality. With this system a pulse length down to 8ns is possible. These short pulses freeze any movement of the strip and hence the system is very tolerant to vibrations. Velocities of 3,000m/min are possible with the minimum pulse duration and should have no effect on the result of the measurement itself. The other advantage of such electronics is the ability to set the illumination of the laser diodes to the optimum point for each sheet surface with very different scattering properties, from nearly black to highly reflective.

A very high resolution and magnification of laser line and image is necessary to measure surface structures in the micrometer range. The small depth of field of the required microscope objectives leads to high demands in the positioning accuracy of the sensor. To match this task, the sensor is equipped with a precise distance sensor which triggers the lasers and the image acquisition process when the strip surface is within the focus of the microscope. The sensor is placed above a roll where the strip is held in a defined position.

For the necessary adjustments of the optical system fully motorised stages are used. This means the settings for installation or corrections can be changed whenever necessary. No production stop is required and installation at nearly inaccessible locations is also possible. These properties guarantee a high availability and a flexible operation.

SYSTEM VALIDATION

To validate the measurement principle, hundreds of sheet samples were measured in a laboratory with the SRM and a stylus system. The results show a very good correlation (see Figure 4). The investigated samples cover a wide range of roughness, but also stochastic and deterministic textures (EDT, Pretex, EBT) and different surface qualities (cold rolled, annealed, galvanised, galvanealed and electrolytic galvanised).

This collection of samples was measured with the same optical setup and identical software settings. This means that there are no texture-specific settings necessary. The only parameter which had to be adjusted is the laser intensity to avoid over- or under-exposed images due to
the very different reflectivity of the surfaces — and this is automatically controlled by the system.

For most samples, the deviation was less than 5%, which is in the same order of the deviation of stylus measurements done by different operators with different stylus systems [2].

ONLINE MEASUREMENTS

The first online evaluation measurements were done by the Rolling Annealing Finishing (RAF) group of Arcelor Research at the continuous annealing line at ArcelorMittal Flat Carbon Steel, Ghent. In Figure 5, the mechanical offline and optical online roughness measurements of one production day are shown. The complete product range was evaluated [3,4].

For the mechanical roughness, three stylus measurements were done at the end of each coil at the strip position where the optical sensor was installed. The optical measurements were saved in the plant database and the mean value of the last 10% of the coil was calculated for the comparison with the stylus results.

The SRM system received no information about texture or material qualities that were produced. This means all different surface qualities are measured and analysed with the same set of parameters.

RESPONSE TIME

To evaluate response time, an SRM sensor was installed inside a tandem mill directly after the last stand. To stabilise the sheet surface to take focused images of the texture the support of the flatness measuring roll was used. With this configuration, the SRM was able to measure EDT strip at speeds up to 1,450m/min. In Figure 6, the result of a step test is shown, where a coil was rolled in the tandem mill with decreasing/increasing rolling forces in the last stand of the mill. Afterwards, the roughness was also measured manually in the inspection line with a stylus.

Even at these high speeds the measured roughness signal follows very closely (delay of 20-30m) the change of the rolling forces showing the ability of the SRM system to be used in a closed loop to control the product’s roughness. Online results between online measurement and stylus on a galvanised EBT surface are shown in Figure 7, indicating good repeatability of online measurements of +/-5%.

GALVANISING LINES

Production of automotive exposed sheets requires a high level of quality, therefore the SRM system is used mainly for production and quality control on hot dip, galvannealing and electrolytic galvanising lines. Figure 8 shows a schematic 3D layout of a system...
installation, including traversing unit with optional service panel for manual control, safety bar and protected service area.

**USER INTERFACE**

The control software offers a simple to use, but very informational, interface. *Figure 9* shows the layout of the main screen where all coil related information is displayed in the upper half. Measured values are available as statistical values as well as a schematic to give a quick overview of the product quality of the last coils. The lower half of the screen is dedicated to the individual images which give the operator direct access to the applied surface texture. A special feature is the information about the width of the strip. The software includes an easy to use tool to configure and select different scanning modes to place the sensor on different positions over the width of the coil. This enables the operator to control the homogeneity of the roughness, especially to correct the adjustment of the skin pass mill in case of high deviations.

The system uses a database for storage and analysis of the measured data. Line managers and quality control staff get an efficient tool to visualise and analyse the measured roughness parameters. Individual coil data, as well as an overview on daily production, can be checked with interactive diagrams and using statistical information.

Access to the database is done via a web front end which makes the system data available from any PC inside the company network. Production management and quality
control can access the online data as well as the stored history data of the system from their desks.

INSTALLATIONS
Today, the system is used in daily production by a number of European companies including ArcelorMittal, Salzgitter Flachstahl, TKS and voestalpine. Systems are also installed in China at Shougang Cold Rolling Co, Ltd and Shagang Group on continuous galvanising and annealing lines as well as in a skin pass mill.

CONCLUSIONS
- The AMEPA SRM is an industrial online strip surface roughness measurement system that delivers roughness information over the length and width of a coil, unlike other optical systems which calculate the roughness from a limited number of intermittent measurements only in the rolling direction, or manually offline by stylus on a very limited number of coil end samples.
- The measurement method is based on the principle of 2D-triangulation whereby a very thin laser line is projected on the surface and the surface relief is determined by analysing the deformation of the line.
- This measurement principle comes closer to the mechanical stylus reference measurement than any other optical measurement device, and has a correlation between SRM and stylus within +/-10%.
- The SRM is installed on various production lines in Europe and China, covering the whole range of strip steel products manufactured today, many of which are difficult to measure with other optical systems.
- Because SRM provides a measurement over a significant part of each coil, it could be used for more complete documentation of this important product property, for tighter production tolerances and as a more precise tool to identify the need for a texturing roll change. 

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REFERENCES