COST REDUCTION AND BETTER QUALITY CONTROL BY ON-LINE ROUGHNESS MEASUREMENT DURING CONTINUOUS STRIP PROCESSING - SORM3PLUS*

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Abstract

SORM 3plus (SORM = Superfast Optical Roughness Measurement) is a system enabling online measurement of roughness parameters during continuous strip processing. Increased requirements for new materials and more complex components call for ever increasing process safety. The roughness parameters are important quality features of uncoated and surface refined strips. The traditional method of measurement involves using a mechanical stylus based instrument. For this purpose the operator must stop the production line or samples are taken from the end of the coil and measurements are made offline in the lab. SORM 3plus, however, is a non-contact, online surface roughness measurement system that can be used for metallic and many non-metallic surfaces at strip speeds of up to 2400 m/min. The surface roughness data are stored in the system computer, displayed to the operator and if needed are fed into a higher-level network. The operator is alerted, if the limited values preset by him are exceeded or if any changes within the line will put at risk the production process. SORM 3plus calculates the roughness parameters as defined in the standards, such as the arithmetic average roughness (Ra) and the peak count (RPc).

Keywords: Optical roughness measurement; Quality improvement; Quality system Online surface roughness measurement.

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1 INTRODUCTION

SORM 3plus (SORM = Superfast Optical Roughness Measurement) is a 3rd generation system that enables the online measurement of roughness characteristics during continuous strip processing. The increased demands on new materials and ever more complex components require an ever greater process reliability. The roughness parameters are an important quality feature of uncoated and surface-refined strip material. The SORM 3plus system has been specially developed for use in high-speed production lines (e.g. process lines, skin pass mills, etc.).
SORM 3plus conducts online measurements of the surface roughness of a running strip within the production line. The SORM 3plus unit initially measures the microprofile of the surface using an optical scanning method. This surface profile can be compared to the profile which is detected by a tactile stylus instrument. The measured profile is then used as a basis to calculate the corresponding roughness parameters (Ra, RPc, Rz, etc.) according to the applicable standards (DIN / ISO / SEP).
The purpose of this paper is to explain basically how the system works and the main possible gains for customers.

2 FUNCTIONAL PRINCIPLE

The actual measuring principle of SORM 3plus is based on an angular measurement of the reflected stray light lobe (fig. 1). A laser beam is focused onto the surface of the material. The maximum diameter of the beam is 6 µm. The surface of the material consists of lots of small facets that are arranged next to one another.

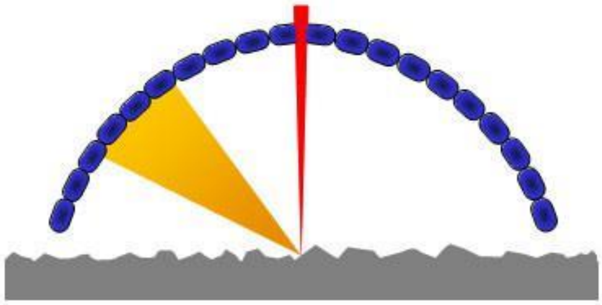

Figure 1: Measuring principle of SORM 3plus

Each facet reflects at least a small portion of the incident light in the same way as a mirror. As the measuring beam hits the surface at a right angle, it incorporates an angle with the focal point of the reflected stray light lobe, which corresponds to twice the gradient angle of the respective facet inclination (fig. 2).

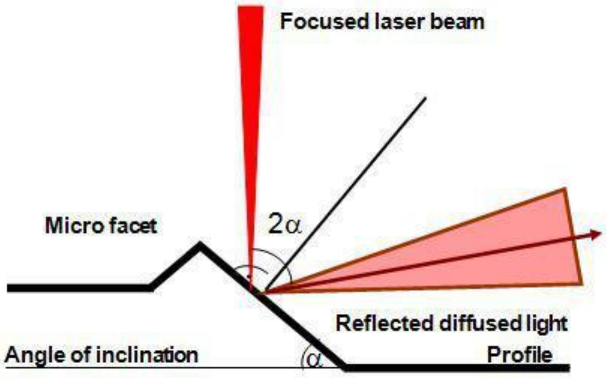

Figure 2: Angle of reflection as a function of the facet slope

An angle- sensitive sensor, which has an opening angle of 134°, receives the reflected stray light lobe and thus generates a signal that is proportional to the average reflection angle (fig. 1).

The measurement of the facet slope is repeated every 1 µm (the scanning increment can be 1-5 µm and can be set via a parameter) over a defined number of consecutive measuring points (fig. 3, max. measuring length 300 mm). The changing surface structure of the material thereby generates a series of measured values that represent the surface roughness over an angular distribution.

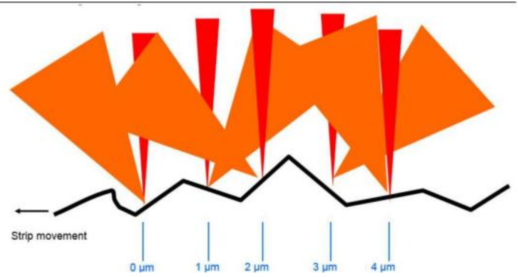

Figure 3: Functional principle for recording measured data.

From the measured angular distribution, the height profile of the material surface can be calculated at a constant distance between the individual measuring points:

tan (α) = dh / da

With:
α: Centre of gravity angle of the reflected stray light lobe (measured variable).
dh: Height difference between two measuring points
da: Scanning increment in the feed direction of the material (e.g. 1-5 µm (constant)).

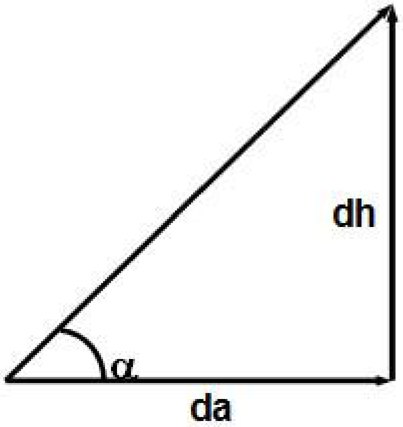

Figure 4: Angular distribution

This results in

dh = da x tan (α)

α relative height profile. The roughness profile is calculated by integrating the individual dh values (differential height difference between 2 measuring points) over the entire measuring length. The roughness parameters (e.g. Ra, RPc, Rz) are calculated from the ascertained profile in accordance with the standard (filter, algorithm, etc.).
Fig. 5 schematically represents the calculation of roughness parameters.

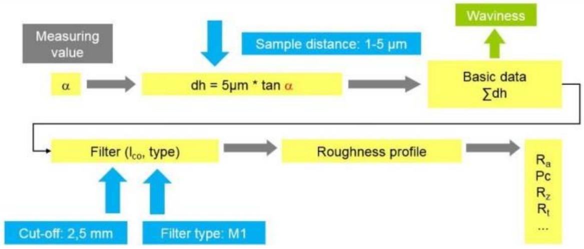

Figure 5: Block diagram for calculating the roughness parameters.

The measuring head is the main component and is used for recording measured data. The relative height profile and the roughness parameters are calculated on a standard industrial PC (IPC) within the control cabinet. The measuring heads are mounted on an electromotive traversing unit. The traversing unit is controlled via the digital control amplifier (EMG iCON®), which is also located within the control cabinet. The SORM 3plus measuring system is operated from the visualisation terminal, which is typically located within the control room. A graphical user interface (GUI) is used under the Windows operating system here. Communication between the visualisation PC and the components inside the control cabinet is conducted exclusively via bus systems (Ethernet or Profibus DP), meaning that the system can be setup almost anywhere.

3 MAIN COMPONENTS

3.1 MEASURING HEAD

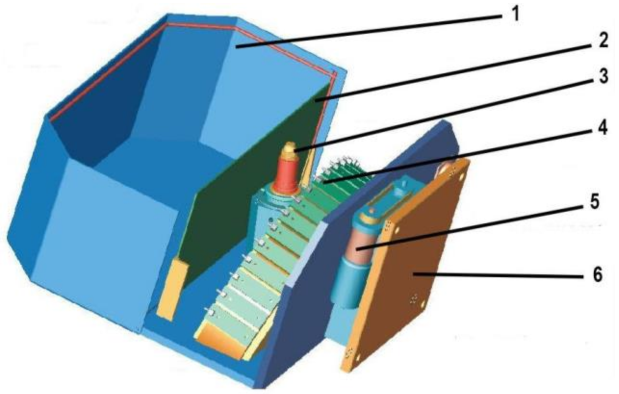

Figure 6: Mechanical design of the measuring head

1	Folding housing cover
2	SORM 3plus motherboard (SMB)
3	Measuring laser (pre-adjusted,exchangeable)
4	Lens array with photoreceiver (individually adjustable)
5	Autofocusing unit (sensor, DC motor, mechanics)
6	Mounting plate

The measuring head is enclosed via a folding housing cover. All of the functional elements can be freely accessed when the housing cover is open. The SORM motherboard (SMB) accommodates all of the electronic units (autofocusing control, A/D converter, FIFOs (for intermediate storage of the measured data), communication control (CAN, Ethernet), laser control and monitoring, analogue/digital I/Os).

The measuring laser is a 22 mW semiconductor laser with an output wavelength of 660 nm.

The laser is operated and monitored via special driver electronics.

The distance to the material surface is checked and corrected, if necessary, prior to each measurement. The measuring process is conducted using an integrated triangulation sensor (laser protection class 2). Fig. 7 shows a cross-section through the lens (consisting of the distance laser, lens rim and measuring laser). The lens rim is composed of 20 individual lenses which are glued together. A board with a photoreceiver and evaluation electronics unit is mounted behind every lens. This enables an offset to be set for each receiver (hardware adjustment) and the amplification to be set (via software). The measuring laser operates in an uncooled manner and consists of the laser diode, collimator optics and focusing lens.

The measuring laser is adapted to the measuring head via a spacer ring, which is set and fixed from head-to-head during assembly. This means a laser can be replaced without conducting any further adjustments.

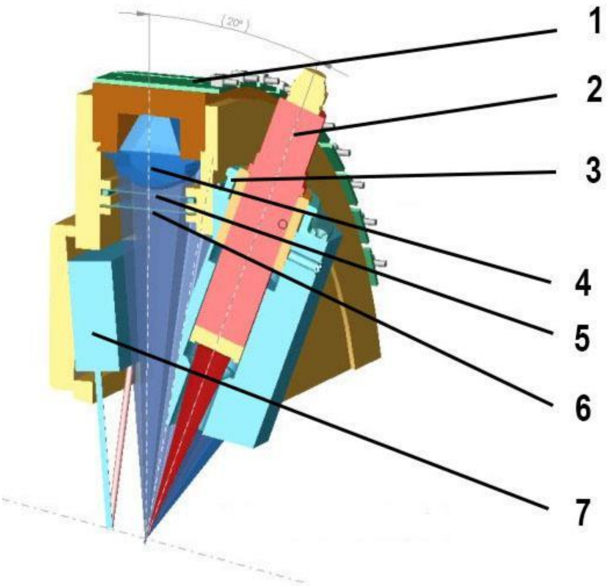

Figure 7: Mechanical design of the lens

1	Photoreceiver (elements can be individually adjusted)
2	Measuring laser
3	Spacer ring
4	Lens
5	Diffusion disc
6	Makrolon protective film
7	Autofocusing laser

The angle between the path of the beam and the measuring laser is 20°. The lenses are protected from damage and contamination by an easily replaceable Makrolon film. The protective film should be replaced approx. once a month (application on a hot-dip galvanizing continuous annealing line), whereby the correct function of the measuring head is automatically monitored with a module for test equipment monitoring (optional) 3 times every day. The distance between the focal point of the autofocusing laser and that of the measuring laser on the material surface is approximately 15 mm.

3.2 TRAVERSING UNIT

The traversing unit is used to guide the measuring head over the strip width, thereby enabling a roughness profile to be recorded online over the length and width of the strip. Fig. 8 shows the installation for a typical application. The measurement should be conducted on a roll in order to minimize the effect of fluctuations in strip height. The traversing unit essentially consist of (fig. 8):

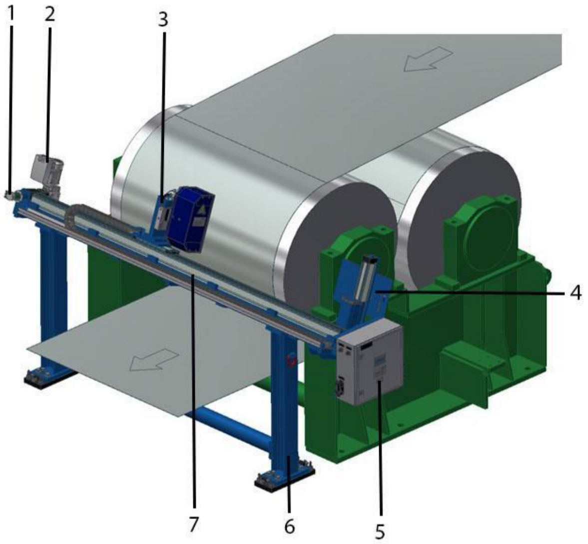

Figure 8: Design of the traversing unit

1	Digital position sensor
2	AC spur gear motor with integrated frequency converter
3	Infinitely variable adjusting unit (rotate - tip - tilt) of the measuring head with adapter plate
4	Module for control of inspection, measuring and test equipment (option)
5	Intermediate terminal box
6	Mechanical basic design
7	Linear unit with belt drive

The measuring head is installed using a special template, which ensures the correct alignment of the measuring head to the roll. The measuring head is connected to the traversing unit with an adapter plate. After the alignment process has been conducted the measuring head can be dismantled and mounted without requiring any readjustment.

The traversing unit can be optionally provided with a module for control of inspection, measuring and test equipment. This module for test equipment monitoring is used to check the SORM 3plus measuring head, e.g. to meet the requirements for monitoring measuring equipment.

The module for control of inspection, measuring and test equipment consists of a sample holder, whereby the sample is stored in a special protective housing and is only subjected to environmental influences during the test run. The sample holder is moved by a linear unit and an AC motor. An incremental position sensor is used for position detection. This ensures that the distance between two measuring points is constantly 1 µm. The number of measuring tracks and the measuring length can be configured via menus in the visualization software. An automatic and a manual inspection mode are both available.

3.3 DATA SOFTWARE PACKAGE

The EMG SORM - Data visualisation software serves as a graphical user interface

(Graphical User Interface, GUI) and is installed on a Siemens industrial PC, which is typically housed within the main control room.

The GUI displays the roughness parameters on a monitor. The measuring sequence, the traversing program and the test equipment monitoring cycles are configured according to customer specifications via the EMG SORM – Data software. This is operated in a typical Windows manner by using a mouse and menu navigation tools. The program is created in the LabVIEW programming language (National Instruments) and supports various options for remote maintenance. Data is archived in ASCII format, meaning it can be exported into various programs (e.g. MS Excel).

Figure 9 shows the main screen of a SORM 3plus installation. Various roughness and process parameters are displayed.

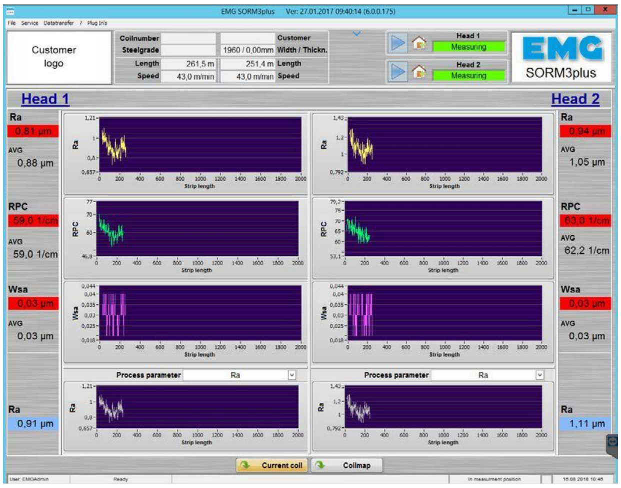

Figure 9: Main screen of the SORM GUI. Display of Ra, RPc and WSA.

Fig. 10 shows the result screen for the testing unit. The data relating to the inspection can be displayed offline.

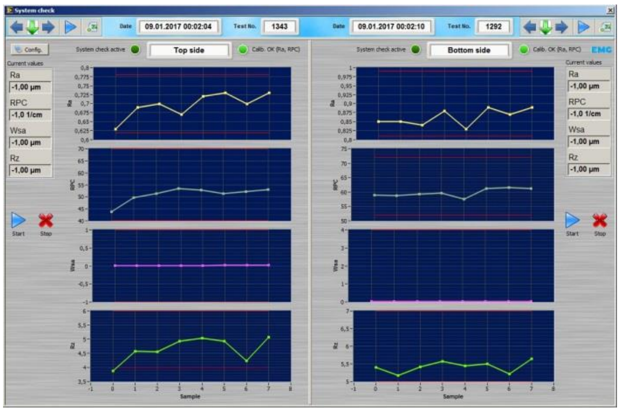

Figure 10: Results of the testing unit

4 CUSTOMER’S BENEFIT

4.1 POSSIVILITY OF ONLINE REACTIONS AT THE PRODUCTION LINE

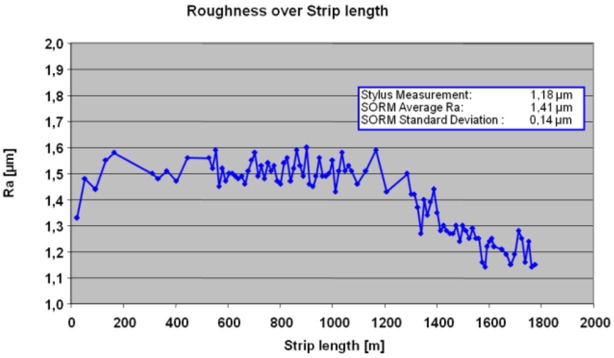

Figure 11: Skin-pass deviations can be detected.

The stylus instrument measures according to the sample position 1.18 or 1.35 µm. SORM shows cross section of the whole roughness range as well as the standard deviation and a direct course.

4.2 AUTOMATIC SKIN PASS CONTROL

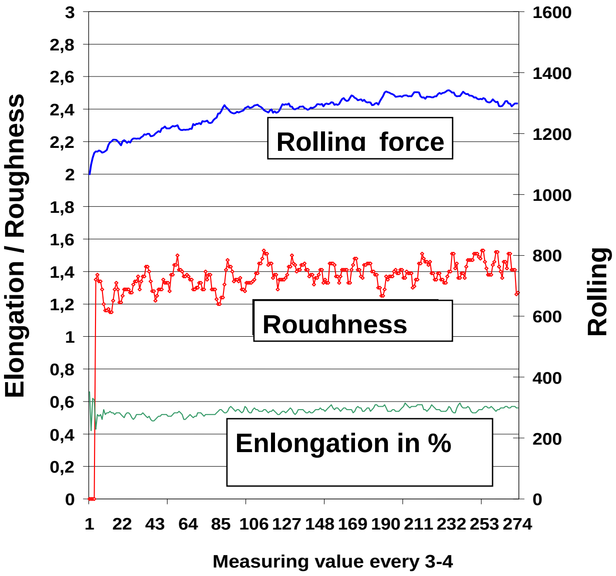

Figure 12: Automatic control is possible.

The desired value of Ra = 1.4 µm is achieved without over swinging.
The deviation over strip length is less than +/- 0.2 µm.
In regular operation deviations of the desired value at a mill force of up to 200 kN occur without swinging events.

4.3 APLICATION OF SORM IN CGL FOR SKIN PASS CONTROL

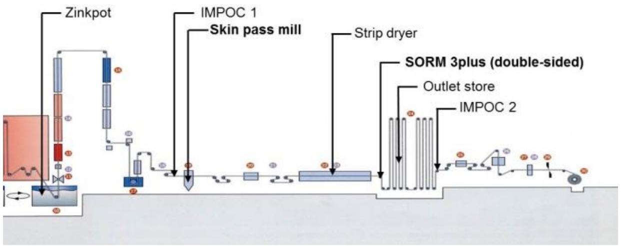

Figure 13: Positioning of equipments

Another possibility to control a skin pass mill to minimize the roughness variations is the combination with IMPOC. In this case the IMPOC system detects the skin pass force starting value before the skin pass mill. This value is needed to achieve the desired skin pass degree as soon as possible. An integrated roughness control avoids an exceeding of the desired roughness values. The second IMPOC is used to control the quality.

4.3 REDUCTION OF THE LABORATORY CHECKS (AUTOMATIC CONFIRMATION)

Due to the automatic roughness measurement via SORM

Table: estimated costs for a laboratory measurement
(Source for the values is a customer from Germany)

Costs	Cut off 0.8	Cut off 2.5
Staff (€)	4.25	4.25
Measuring device (€)	1.4	2.0
Assembly machines (€)	0.4	0.4
Total costs (€)	6.05	6.65
Average costs Ra per month 2010 (€)	1133.94	8655.45

4.3 OTIMIZATION OF WORK ROLL USAGE

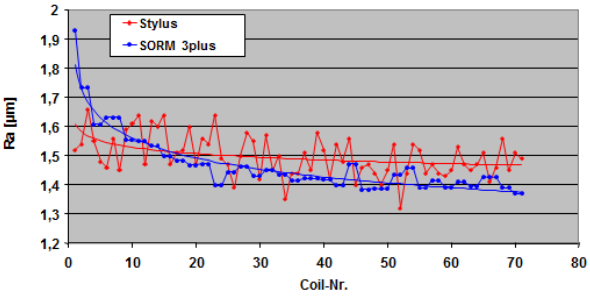

Figure 14: Comparison between SORM and Stylus

New textured mills can have a higher roughness in the beginning, which evens out after 3-4 coils.
This effect is achieved through the mill handling whereas fine points can exist which are worn off after some coils.

So called finishing mills don‘t have this behaviour any more, they are polished before the first use.

The mill has to be changed after a certain life time. This moment can be optimized with an online roughness measuring system.

4.4 PRODUCT DEVELOPMENT AND REDUCTION OF EFFORTS/WORKS.

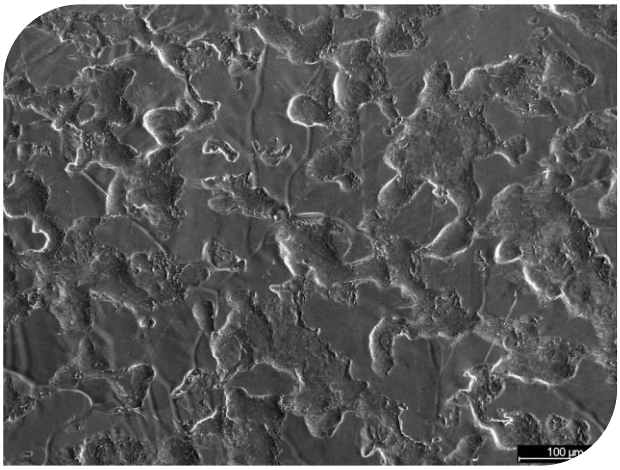

Figure 15: Example material

With SORM 3plus changes in the production and process can be detected and valued directly within the line.

This is true especially for special research and development departments of the steel manufacturer.

In this way experiments with new roughness textures can be valued directly for example.

A texture is the structure on a mill which can possess different micro structures.

5 CONCLUSION

All the points discussed in the previous topic are positive aspects that follows the implementation of the SORM system, however each production line is very specific and therefore very difficult to accurately quantify all the gains with the solution implementation.

In general, with SORM, the certainty about the quality of a coil is made available immediately and online, so operation teams have detailed roughness information on 100% of the processed material. In addition, trends along the length and width of the coil are available, which is crucial for the improvement of the production processes and subsequent processes, as well as for the handling of materials. The availability of SORM data allows relevant gains that, in individual cases, can go beyond the examples shown here.

These gains are mainly based on the online observation of the results, the reduction of the inspection effort and the material saved. In addition, there are positive influences not implied throughout the production. Besides the directly controlled intervention in the production processes, the immediate availability of the data on the conditions of the whole strip mainly allows the creation of more favorable and lasting conditions that, finally, allows the production of higher quality materials.

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