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# Inline Measurement of Surface Roughness and Oil Film Thickness – Smart Press Shop Uses Decisive Parameter Data in Galvanized Strip Forming

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Surface roughness and oiling condition of incoming coils are two critical quality-parameters determining the friction between blank and deep-drawing die in galvanized strip forming, in particular the flow behaviour of the blank pressed around die edges. AMEPA commissioned a unique tribological system at Smart Press Shop in Halle/Saale/Germany, a Joint Venture between Porsche and Schuler Pressen. The inline system measures surface roughness and oil film of galvanized strips for body in white parts. It is integrated into the Schuler Track & Trace system. Press parameters are adjusted to each coil processed based on inline measurements, ensuring perfect forming. An inline Surface Roughness Measurement System (SRM system) uses a light-section method. The OFM system measures reflection and absorption of infrared light projected onto the strip and calculates the oil film in $g/m^2$. If values are not within tolerance, systems trigger a warning for operators to take immediate action. A key aspect is the system's capability to adjust press line parameters so that parts otherwise graded as out-of-spec could leave the press line as OK products. Thus, a poorly oiled strip that normally would fail in the forming process can be turned into a "good" strip by re-oiling.

***Keywords:*** *Galvanized strip, Roughness, Oil film, Press shop, Track & Trace*

## 1. Introduction

Oil film characteristics and surface roughness of coils delivered to a press shop are two parameters essential for the quality of the forming process. The practice of oiling galvanized strip for the automotive industry has fundamentally changed. In the past, it was common practice to cover the strip before shipment with anti-corrosion oil at the cold rolling mill. That oil had to be removed again before the strip could be formed at the press shop. Today, the strip is often delivered to the press shop with its surface already covered with forming prelube oil – in the amount appropriate for the subsequent press forming process. This is usually performed as early as at the steel producers' strip processing lines. This procedure saves costs and supports the environment because no anti-corrosion oil has to be applied, removed and disposed of. However, it may occur that the oil film thickness changes with time, for example, when the coils are stored over longer periods and the oil is pressed out towards the edges.

This provides the risk of the oil films becoming inhomogeneous. Consequently, their thickness has to be measured before strip forming at the press shop. In the past, the oil film thickness was usually checked either visually – and thus subjectively – by experienced operators, with random measurements using hand-held oil film measuring devices (OFIS) or with gravimetric methods. All these methods may fail to recognize oil film issues altogether or may recognize them with considerable delay.

To ensure perfect forming, it is essential to measure the entire oil film of the coils delivered – at every spot of the surface from head to tail and across their entire width – before they run into the press line. To also take into account the surface roughness, which is another important parameter in strip forming, Amepa has developed a combined system that measures both the oil film and the

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roughness in an inline process and provides the presses with data that enables them to adapt to the specifics of the next strip processed.

This system saw its very first implementation at the Smart Press Shop located at the German city of Halle on the River Saale. Smart Press Shop is a joint venture between Porsche and Schuler (Fig. 1) that produces high-quality bodyshell parts for the automotive industry. With its high-tech components, the innovative press shop built by the two JV partners sets a new standard in terms of forming technology that represents the future of metal forming.

## 2. Track & Trace: The Product Becomes Smart

The Schuler track & trace system plays a pivotal role in production control and quality assurance (Fig. 2). It interlinks each individual product with the associated

**Fig. 1. The laser blanking line at Smart Press Shop in Halle/Saale with the Amepa systems installed behind the leveller**


**Fig. 2. Throughout the forming process, every bodyshell component is related to its specific measured data**

material and production data and tracks every meter of strip downcoiled at the laser blanking line throughout the entire production process until it leaves the press line as a blank.

Each blank is laser-marked on the fly with a specific ID code to be able to identify the blank at any time as it proceeds through the various production stages. All relevant product information is stored in a data base. This makes it possible to check at any time what coil each individual product originates from and what material properties it possesses.

The track & trace system acquires and stores process parameters as it has direct access to the process control system. The resulting process transparency makes it possible to forecast production issues and adapt the press parameters to avoid forming issues before they occur. Thus, the track & trace system plays an important role in minimizing waste and guaranteeing high-quality products.

## 3. “Trial and Error” Has Become a Thing of the Past

Both the oil film and the surface roughness of the coils delivered to the press shop determine the friction acting between the blank material and the deep-drawing die, in other words, how the blank material flows around the forming die edges. The aim of the “surface roughness and oil film measurement” project was to make it possible for press shop operators to immediately react in the event coil material running into the line features properties other than expected. This was to be achieved by relating the strip data measured to the respective blanks and predicting their behaviour during downstream press forming. Based on this information, it would be possible to adapt the pressing process accordingly, for example, by making adjustments to the setting of the oiling unit before the press line entry. In the event that oiling issues, such as dry stripes, are identified at the blanking line entry, additional oil can be applied where necessary as the material is entering the press line. Therefore, it was decided to integrate a system at the blanking line entry capable of measuring the strip thickness, surface roughness and oil film layer in one inline process.

Based on these measurements, the parameters of the press can be optimally set to ensure that only “OK parts” are produced. So far, adjusting the line to the surface roughness and the oil film condition used to be a matter of “trial and error” and depend to a large degree on the press operator’s individual skills. With the track & trace system, it is now possible to use data science to be able to take more precise and objective decisions that additionally are of much higher accuracy of repetition. This avoids out-of-spec production and is a significant cost-saving factor. The resulting smaller scrap rate has also a direct positive impact on the carbon footprint.

## 4. Two Parameters Within One System

Schuler and Amepa can look back on many years of cooperation and many successfully completed joint

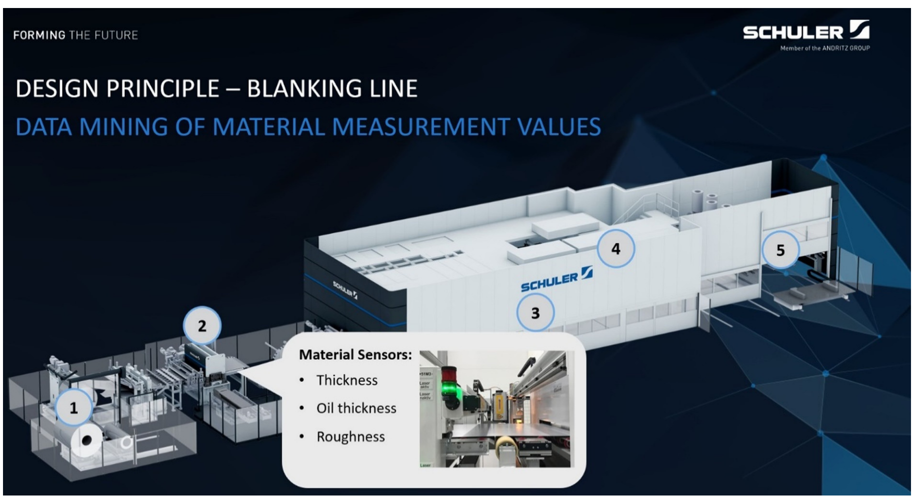


**Fig. 3. The roughness and oil measuring systems are arranged after the leveller of the press line**

projects. One area of cooperation is preparing blanking lines supplied to customers for the subsequent integration of measuring systems.

Amepa proposed a combined tribological system of a worldwide unique layout, suitable to measure the surface roughness and oil film of steel and aluminium strip (Fig. 3). Several factors were decisive for Schuler to decide in favour of the Amepa system. Excellent measuring accuracy in both measuring modes was of course one of them. In addition to this, Schuler was looking for a company that would be able to supply both systems within a harmonized solution and have the necessary expertise to implement the electrical and data interfaces according to the specifications formulated by Schuler to ensure smooth integration into the existing line. In November 2020, the JV awarded Schuler the order for the supply of the new system.

The inline strip roughness measurement unit uses the laser light section method, a two-dimensional laser triangulation technique patented by CRM Centre de Recherches Métallurgiques, Liege, Belgium, for inline roughness measurements. The technique was scaled up for industrial use by Amepa GmbH. 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. Various measurements can be combined to make the method DIN EN ISO 10049-compliant. The roughness sensor measures transversely to the rolling direction. This is of relevance particularly for mill-finish-grade aluminium strip. In addition to the Ra value, other statistical values, including RPc and Rz can be calculated.

Traditionally, oil films on metal strip surfaces are measured by gravimetric offline analyses in a laboratory. However, these offline measurements of just a few random samples are not suitable to give a true picture of the layer thickness and the distribution of the lubricants on the entire surface of a coil or blank. As a result, oiling issues are often recognized too late or remain undetected.

In contrast, the Amepa system operates inline, by measuring the reflection and absorption of an infrared light beam projected onto the strip surface. The system calculates the oil film thickness in g/m$^2$ by comparing the measured values with calibration data previously determined with high-precision balances in a laboratory. Calibration measurements are made of the materials processed – steel or aluminium, for example –, of different textures and types of dry and fluid lubricants.


**Fig. 4. Mounted on motorized traversing beams, the sensors can move across the entire strip width**


**Fig. 5. Moving across the entire width of the strip, the sensors measure the oil film (left) and the surface roughness (right).**

## 5. The Project

One and a half meters of space in the strip run direction was available behind the leveler of the blanking line for the new measuring system (Fig. 4) – sufficient for the Amepa solution thanks to the fact that the roughness sensor is of a particularly compact design. The sensing units of both systems can travel and capture data across the entire strip width (Fig. 5).

The systems were installed in August 2021 and commissioned in October 2021. As they were running without a hitch, Schuler issued the FAC as early as in November 2021.

All the data from the strip measurements are sent via a data interface to the track & trace system that interlinks them with the respective blank data. An interpolation algorithm developed by Schuler makes it possible to generate a complete, gapless measuring profile. All measuring systems installed are fully integrated into the control and visualization environment of the line. This makes operation very user friendly: The line operators have all the measurement and control data available at a glance.


**Fig. 6. The measured values are graphically displayed in a clearly structured form by meter of strip**

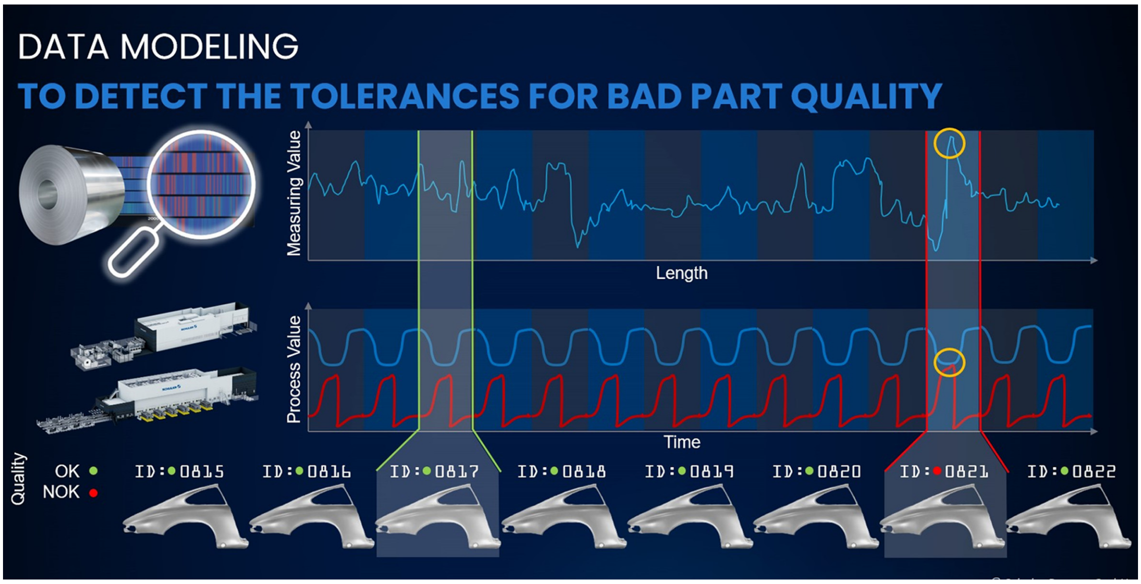


**Fig. 7. The data model indicates potentially critical bodyshell components that should be closer examined**

## 6. Information Instantly Available

For every coil in the line, the track & trace system sends material and lubricant data via an interface to the Amepa systems. The systems then retrieve the respective calibration data from the database and compare them with the measurements.

If any of the measured values are not within the allowable tolerance range, the systems immediately trigger a warning. Thus, the operators can instantly take the necessary corrective measures (Fig. 6).

If the measurements reveal major quality issues of a coil, that coil can be removed from the line without processing and returned to the coil supplier. Likewise, the system can identify out-of-spec sections of a coil and avoid that these sections are further processed (Fig. 7). Let's take as an example a strip section that is poorly oiled and, at the same time, features too rough a surface. This combination may lead to tearing during forming in the press line. In this case, the plant operator will remove the torn component from the line. The part will be automatically graded as "not OK".

In fact, the most important aspect is the system's capability to actively influence the forming process. By adjusting the press line parameters based on the measurements taken of the strip, parts that would otherwise have been graded as out-of-spec will leave the press line as OK products. For example, a poorly oiled strip that would normally have failed in the forming process can be turned into a "good" strip by re-oiling and produce parts of perfect quality. This avoids scrap and significantly increases the rate of OK parts – two effects from which press operators benefit in terms of massive cost savings and higher profits.

## 7. Offline process optimization

The inline measurement provides valuable information for the downstream production process. In addition to this, Amepa supplies the Roughness Oilfilm Measurement (ROM) table also for offline use. Here, the system performs high-resolution oil film and roughness measurements of individual plates of up to 2,000 × 4,000 mm size (Fig. 8).

These data can be used for detailed analyzes in incoming goods and quality control, for example. The system measures and visualizes the entire spraying profile of the blank's oiled surface. This provides a highly useful tool for root cause analyzes and optimizing the forming process (Fig. 9).

## 8. The Benefits

The press operators benefit from the inline measurements in multiple ways. Alone the fact that they provide

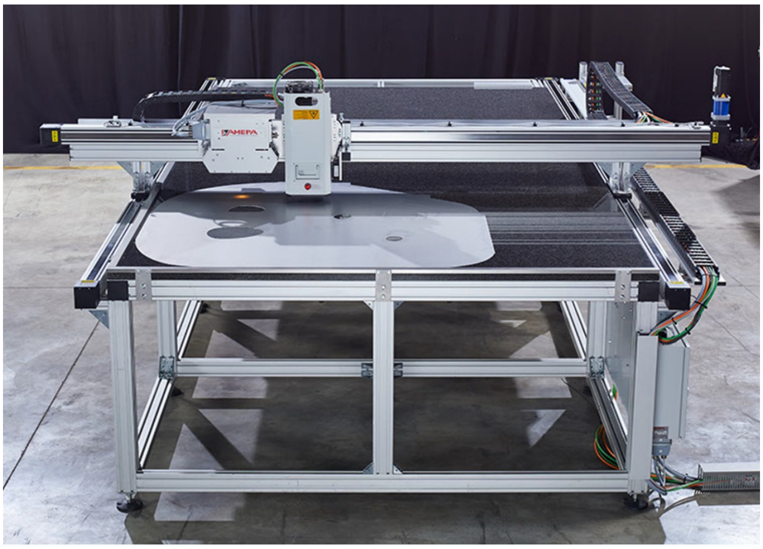

**Fig. 8. With the Roughness Oilfilm Measurement (ROM) table, the oil film and roughness of individual plates of up to 2,000 × 4,000 mm size can be measured with high resolution**

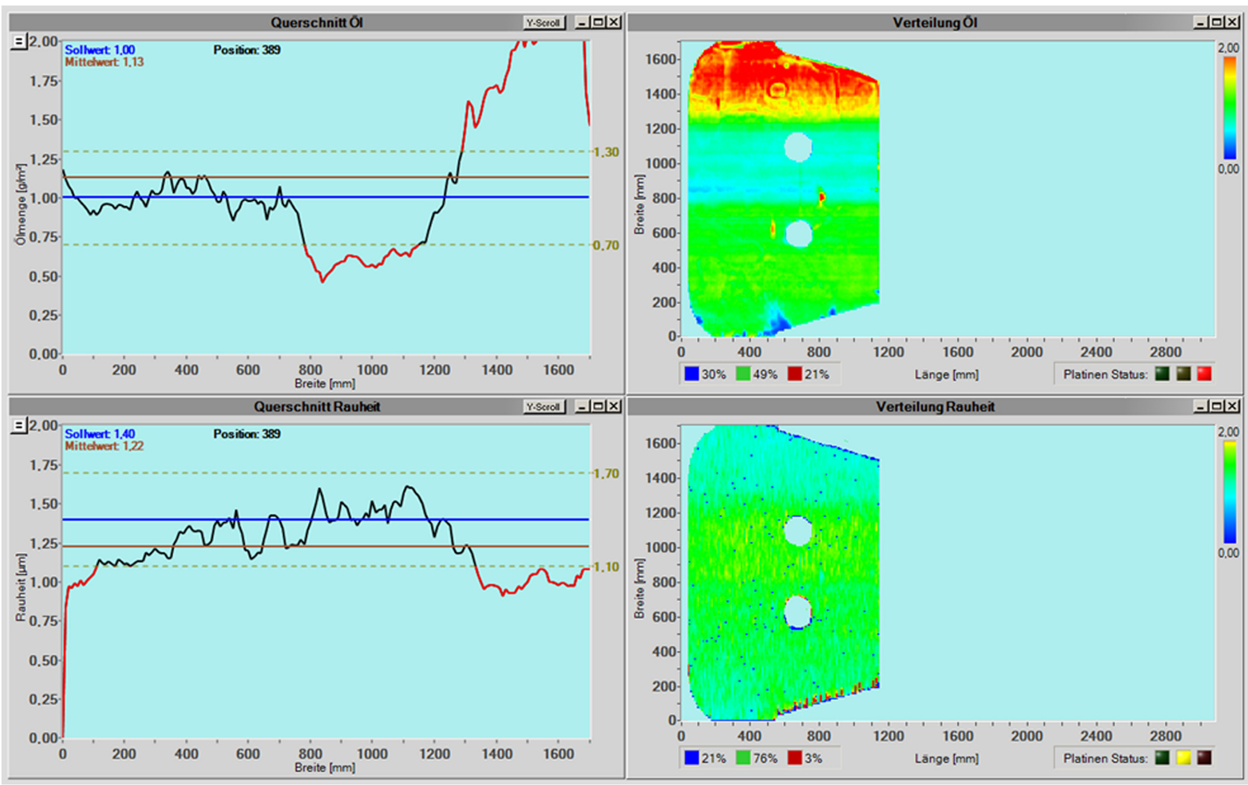


**Fig. 9. Results of ROM table measurements: Oil film (displayed at the top) and roughness (displayed at the bottom)**

objective measurements of the entire surface instead of subjective evaluations and measurements of single, randomly chosen areas of the surface is a great advancement. The new system helps press shop operators to become less dependent on the skill and experience of individual employees and mitigate the effects of the shortage of labour, which is a growing problem for an increasing number of producers.

The capability of interlinking the measured strip values with each individual blank also supports overall process


**Fig. 10. The display at the inspection station shows the oil film and roughness values of each individual car body component**

optimization. If, for example, it turns out that certain combinations of surface roughness, oil film condition and other parameters are unable to achieve the desired quality, processes can be adjusted and fine-tuned with the support of the combined measuring and track & trace systems (Fig. 10).

It may even be the case that certain combinations of material parameters lead to better results than expected from experience. In this case, it may be an option to try out operating within a larger process window because, due to the enhanced process understanding, it may well be possible to weaken the coil specifications for certain products.

Thanks to the data available from the inline measurements, we also gain unprecedented understanding of where exactly defects and poor product quality originate. This provides us entirely new possibilities to intervene. When a finished component, such as a bodyshell part, showed defects after welding or painting, it has so far never really been possible to relate that product to the original coil because there was no way to interlink the product with the measurements taken of the coil before processing.

With the track & trace system, all process and material parameters relative to a specific product are readily available and can even be transferred to external downstream processing facilities.