## New precise method for measuring sheet thickness using laser profile scanners

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Increasingly complex processing, optimisation of raw material costs or new standards mean there is a continually growing demand for sensor technology.

Optical measuring techniques are becoming more and more important here.

An important quality characteristic of semi-finished aluminium products is their thickness profile.

Deviations occur mainly at the start of the processing chain in hot or cold rolling processes. In order to ensure that the nominal thickness is maintained, it is necessary to determine the instantaneous value of the control variable dynamically and precisely.

This requires modern sensors.

With conventional mechanical devices, thickness is determined by contact using a pincer-like arrangement at individual measuring points, whereby it is only possible with this approach to get a rough estimate of the thickness profile. Such devices are too slow for recording transverse or longitudinal thickness profiles during the production process and thus unsuitable.

Furthermore, such techniques are often prone to wear and therefore interrupt production.

Radiometric processes require radiation from a source of isotopes or X-rays that are absorbed by the sheet or plate being measured. The difference between the radiation transmitted and received is then converted into an average thickness. The process is strongly dependent, though, on the alloy and the condition of the material.

The cost of radiation protection and ongoing safety inspections means high variable costs are associated with this method.

If one wants a non-contact system that operates with a stand-off distance that is both production- and user-friendly and allows measurements to be carried out independently of the alloy, it is necessary to employ a precise geometric method of measurement based on the strip surface as the point of reference. This means using optical distance sensors coupled with laser triangulation.

By employing laser line scanner systems, Micro-Epsilon Messtechnik has introduced an evolutionary new step in the technology of thickness measurement. Following a brief introduction to optical thickness measurement, the benefits of line sensors over point sensors will be discussed in this article and a technical solution is presented that has already proven itself in service at a customer’s plant.

## The advantages of an optical thickness-measuring technique

When measuring the thickness of metal strip optically, a distance sensor is arranged on each side of the strip. The thickness is then the difference between the individual distances measured. However, the distance between the two sensors needs to be known and kept very constant.

This means having a stable mechanical construction, either as a C- or O-shaped frame, and places particular demands on the positioning and calibration of the sensors and on compensation for deflection of the frame. At a measuring point, triangulation sensors determine the stand-off distance of the object being measured very precisely by registering the positional shift of the spot from a detector positioned at an angle. Focal diameters of less than 100 µm are not uncommon.

The stand-off distance can only be taken to be the average value over the whole spot. Consequently, it is desirable for the spot size to be small. Working against this is the effect of surface roughness, which can only be reduced by increasing the spot size.

It therefore does not make sense to design the spot size to be arbitrarily small. If the strip is wavy or not plane positioned, point-wise measurement always results in a measuring error. One can only eliminate such so-called angle errors if one knows the position of the strip. Micro-Epsilon is concentrating here on a new innovation. The use of profile sensors rather than point sensors increases the information density and thus permits a significantly better optical measurement over the widest possible range of strip materials. Compared with point lasers, the measuring accuracy is also significantly better.

## Thickness measurement on slit strip in slitters

There are often large vertical movements when processing cold-rolled strip, for example in slitters. However, when it comes to resolution and linearity, point sensors capable of covering a large measuring range are usually not capable of achieving the desired precision needed to monitor tolerances in accordance with EN 485-4.

The reason for this is that point sensors only measure the value at a single point. With line sensors, though, lots of points are measured and furthermore these are recorded considerably more frequently. With the line sensor approach, a line of best fit can be drawn through the measured height profile.

If one then measures the thickness, a much higher resolution can be achieved because this now results from the minimum change of two lines of best fit. If there is a stand-off distance of 190 mm and a measurement range of 40 mm, suitable algorithms enable systems that use line scanners to measure linearities of ± 5 µm. By comparison, if point sensors were to be used in this case, only linearities of ±25 µm could be achieved.

With the slitters previously mentioned, an additional challenge is the changes to the position of the strip (tilting) that take place during the slitting operation (Fig. 1).

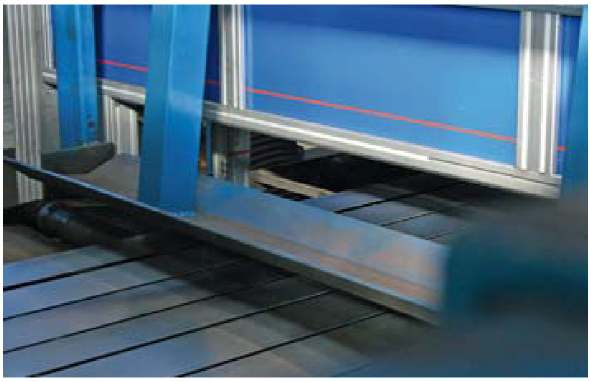

**Fig. 1:** Tilted strips in a slitter

In a slitter, it is above all the measurement of the individual webs after the cutter spindle that is of interest because the measured variable can be determined here for each individual web. With a point sensor, there is always an angle error as shown in Fig. 2 even if described the sensor is fitted perfectly. In systems with line sensors, the tilting of the material can be determined as

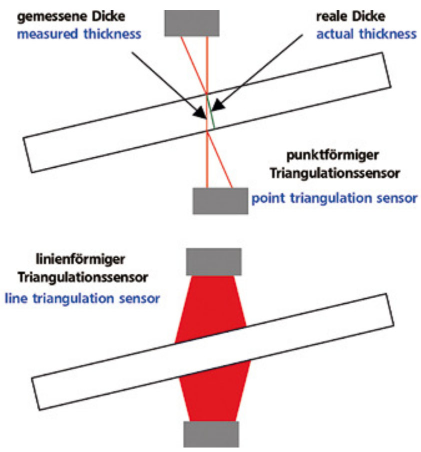


**Fig. 2:** Measuring error resulting from angle errors with point sensors

above using lines of best fit and compensated accordingly. It is therefore alsopossible to obtain a precise measurement of the thickness even under such difficult conditions.

## Stability requirements

With sensors arranged on both sides as described above, maintaining a constant standoff distance takes on a particular significance.

Two different design principles are available, which because of their shape are referred to as either C- or O-shaped frames. With C-shaped frames (Fig. 3), the sensors are positioned at the outermost ends of the arms and connected tightly to the frame, which is open on one side in order to be able to feed it round the strip. C-shaped frames are preferably used for applications involving narrow strip (e.g. up to 800 mm wide) because with increasing depth of the 'jaws' the upper arm becomes increasingly susceptible to oscillation.

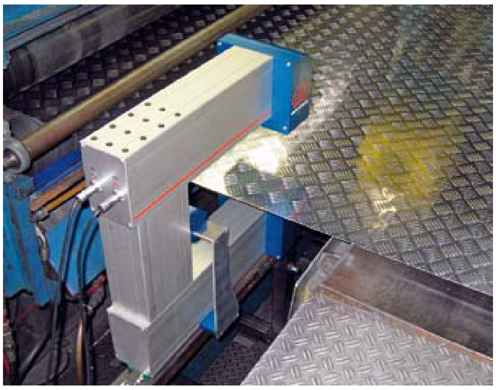

**Fig. 3:** C-shaped frame system at AMAG Ranshofen

In the case of measurement in the middle of the strip, the necessary jaw depth is given by half the strip width plus provision for the sideways movement of the strip edges. If the C-shaped frame is designed as a traversing unit, there needs to be sufficient space next to the line to move the line into the zero position.

There are time-dependent thermal changes acting on the frame so it is important to find suitable ways to keep the width of the jaws constant.

Systems supplied by Micro-Epsilon rely on the principle of iterative calibration.

This offers significant benefits compared with the markedly higher costs of a temperature-invariant frame. Particularly in hot environments, temperature affects not only the mechanics but also the electronics.

**Typical specification for the complete measurement of slit strip**
Thickness : 1-5 mm
Stand-off distance: 300 mm
Linearity: ±5 µm
Output: thickness profile
Width : linearity: ±100 µm
Output: max. 25 strips
Speed : unit: max. 580 m/min
Signal transmission for synchronisation of the cutter spindle
Length : coil length, strip length
Linearity: ±0.05%

In order to achieve permanent stability, the electronics would then have to be heated or cooled to make it reliable and accurate regardless of the temperature in the production environment.

If one calibrates the jaw opening at suitable intervals to ensure it is exact, one can work with a much simpler design. If the calibration is automated, one has the advantage that with the aid of a calibration piece (calibration standard) one can verify the capability of the unit's measuring system at any time or document that it is in proper working order.

In addition to C-shaped frame systems, Micro-Epsilon also offers solutions based on O-shaped frames (Fig. 4). These are mainly used with wide strip and can also measure the complete thickness profile over the whole width.

**Fig. 4:** O-shaped frame systemfor measuring sheet thickness

Amongst others, larger widths also lead to a more complex construction because of the thermal requirements mentioned above. The measuring heads are each attached to a horizontal shaft and move in a direction transverse to the direction of processing or transport of the web. Practical tests have shown that even with a frame that is 2 m wide the stand-off distance (jaw width) will deviate by 400 µm if there are temperature fluctuations of ±20°C.

To compensate for this, Micro-Epsilon is now employing a system with a temperature-invariant mechanical compensation frame for which a patent has been applied. Novel is that the compensation sensors assigned to the measuring sensors measure the position of the measuring sensor relative to the horizontal beam of the compensation frame. If the position of the sensor moves vertically as a result of thermal effects, the compensation sensor measures the displacement and the analytical software adds or subtracts this change to or from the measured stand-off distance. From a virtual point of view, the transitory jaw width thus remains constant (Fig. 5).

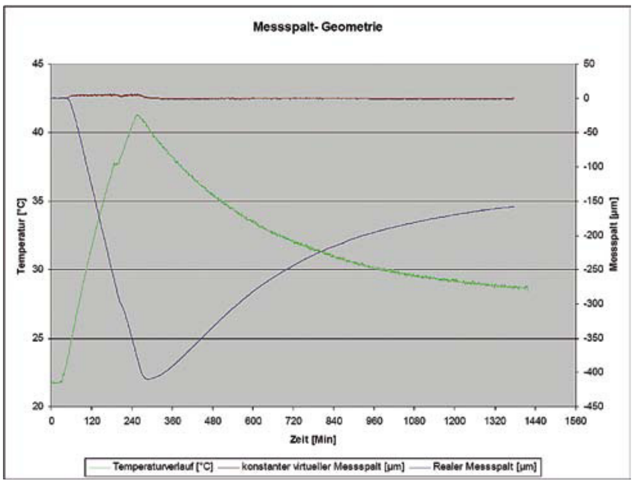


**Fig. 5:** Changes in stand-off distance as a result of thermal effects
**Axes:** – Stand off geometry, Temperatur – Temperature (° C),
– Change in stand off (µm), – Time (min);
**Curves:** green – Change in temperature (°C), red
– Change in virtual stand off (µm), blue – Change in real stand off (µm)

In addition to this very efficient procedure, mechanical or thermal changes in the mountings of the sensor housing are compensated for by means of iterative calibration.

## Quality inspection of strip

Besides simple thickness measurement, many strip plants now demand quality inspection of the strip thickness. High-tech light barriers provide support of the profile sensors here.

They take over the job of width measurement and possibly detecting the edges of the individual strips after slitting. All measurements made can be used to document the metal strip. Thickness and profile are assigned to an exact position on the strip online. The position of the strip is also determined without contact. Tried and tested ASCOspeed technology is employed; this enjoys a good reputation at many rolling mills and strip plants in the cold-rolled strip area where machine manufactur ers have often installed this technology.
ASCOspeed measures the speed of the strip significantly more reliably than the transmitter on the rolls or separate measuring wheels. By means of non-contact working principle, slippage and operational wear are avoided (Fig. 6).

Fig. 6: Complete measurement with record of length using ASCOspeed

The instantaneous length of the strip is measured precisely and forms the basis for the coil production log. The accuracy of length is 0.05% and ensures that it is easy later to find off-size sections of strip, for example as a result of eccentricity of the rolls. By incorporating measurement of the profile in a slitter, the width and profile of all strips can be measured.
Each strip has its own measurement record. This provides improved support for the quality assurance of subsequent process steps. The unit is used in service centres to inspect incoming hot-rolled strip, prior to cold rolling and after slitting the coils. The unit is in the upper performance class for systems that measure the geometry of metal strip. It is an effective substitute for the well-known processes used until now. The economic benefit of investing in laser scanners to carry out measurements is the fact that one has detailed knowledge of the actual strip tolerances through to documentation of each individual strip for the end user.

## Experience in use at a production plant

The Micro-Epsilon group has had good experience working with aluminium manufacturers going back many years. There have been many joint projects in the past, especially with AMAG Ranshofen.AMAG has over 70 years' experience in the production of aluminium strip, sheet and plate. AMAG's quality assurance systems meet the high demands of the aerospace and automotive industries. The company regards itself as a supplier of special products with a high level of customer benefits. Of course, these demands also require suitable monitoring and quality assurance with respect to material thicknesses and/ or strip profiles.

Nearly all the usual types of thickness-measuring system have been used at the company's Ranshofen plant in the past, from isotope radiators, via mechanical thickness measurement through to optical systems. The company is currently markedly expanding its capacity in the finishing area (slitting lines).

As part of these investments the company was also looking for a modern thickness measuring system for its slitters and cut-to-length lines. The mechanical systems previously used were disadvantageous with respect to surface damage, vulnerability and limited area of measurement (only the areas near the edge) and no longer met the company's requirements.

Test constructions using the laser measuring system from Micro-Epsilon were so promising that a decision could be reached very quickly. Amongst other things, measurements were also carried out during the manufacture of tread plate. Although it was originally intended to meet demand from the automotive industry and not from this product group, it nevertheless demonstrated the capability, flexibility and the broad field of application of Micro-Epsilon technology.

Currently, a C-shaped frame is undergoing testing in an existing cut-to-length line (Fig. 3). Based on the experience gained there, it is planned to supply and commission an O-shaped frame for a new slitter due to be installed in the first quarter of 2012. It was particularly important for AMAG to cover as varied a range of different surfaces and reflectivities as possible with a single system. The experience gained thus far has confirmed the test results and shows that Micro-Epsilon has the right solution for Ranshofen.

## Summary

Systems that use laser line scanners in C-shaped and O-shaped frames supplied by Micro-Epsilon Messtechnik of Ortenburg, Germany, mark a new step in the evolution of optical thickness-measuring technology. The use of profile sensors instead of point sensors increases the information density and thus allows a significantly better optical measurement to be made on the most varied range of strip materials. Compared with point lasers, line lasers also improve the measuring accuracy significantly and with a stand-off distance of 190 mm and a measuring range of 40 mm achieve a linearity of better

than ±5 µm. One can compensate for tilting of the material when line sensors are employed.
By determining the exact width of the jaws, one can use a markedly simpler construction. Automatic calibration gives the operator the opportunity to verify the capability of the unit's measurement system at any time or document that it is in proper working order with the aid of a calibration piece (calibration standard).
If profile measurement is incorporated in a slitting line, the width and profile of all strips can be measured. The technology is used in service centres to inspect incoming hot-rolled strip prior to cold rolling and for complete testing of the slit strip.
Customer satisfaction with the units already in use documents the capability of the method of measuring thickness described.
There will also be further business opportunities for Micro-Epsilon at the Ranshofen plant, where the operator will have to meet increasing quality demands in future for shears as well as existing plant.

Literature

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