

Further Developments in Strip Thickness Measurement Laser-based Strip Thickness Measurement

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Abstract: VTLG is a new type of laser-based strip thickness gauges for cold rolling mills and offers the solution for strip thickness measurement that the industry has long been searching for: Irrespective of the alloy, contact-free, highly precise and reliable. This article describes the developments which had to be done so that now with the VTLG a solution is possible that has not been possible to date.

Standard to Date

Strip thickness measurement in the mill is one of the central themes during rolling, because ultimately the right thickness of the strip material is one of the key quality parameters in the rolling process.

The only technologies available for strip thickness measurement in cold rolling mills to date which work were contact gauges, X-ray gauges, isotope gauges and (but only for non-ferrous metals) eddy-current gauges.

The disadvantages of the state of the art technologies are:

Contact gauges need regularly service and spare parts and a good alignment to the pass line.

X-ray and isotope gauges are not measuring the thickness absolutely but the density of the material. Additionally the operations have to be protected against the radiation

Eddy-current gauges can only work on nearly Fe-free material (max 2 %).

These technologies have been employed for many years, in some cases for decades, represent the worldwide standard and function. But because of the specific disadvantages inherent in each of the technologies, the market has been looking for alternatives for a long time.

This alternative can be found in laser technology which, however, did not really appear suitable for use in cold rolling mills and was therefore not used due to its sensitivity to environmental conditions and ambient influences.

The Possibility of Laser-based Strip Thickness Measurement with the Help of VTLG

After several years of development time, the breakthrough of laser technology for thickness measurement in the cold rolling industry has now been achieved.

The measuring device consists i.a. of a C-frame that positions a sensor above and a sensor below the strip. These sensors operate on the triangulation principle, in this case laser triangulation (see Figure 1).

Each sensor focuses a laser beam onto the strip surface and observes it using a camera. The angle at which the light spot is detected changes as the distance between the strip surface and the camera changes. The system then calculates the distance between the strip surface and the camera using trigonometric functions.

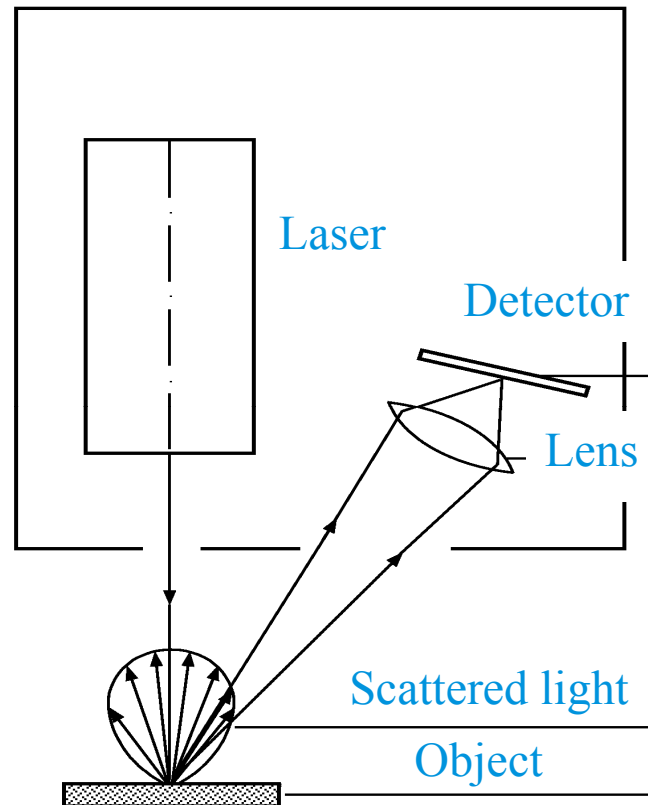


Figure 1: Laser triangulation

Laser triangulation is nothing new – it has been around for many years. The simple theory: Two sensors positioned directly opposite one another on each side of the strip and the strip thickness is determined.

That would be so simple if it didn't have to take place in a cold rolling mill. With strip temperature variations from 10 to 180 °C, with oil or emulsion on the strip, steam and mists, vibrations and strip collisions and widely differing strip surfaces from high gloss to dark and matt. Nevertheless the measuring device has to reliably measure the strip thickness of e.g. 1 mm thick material to within $\pm 1 \mu\text{m}$ as otherwise it would not be suitable for automatic gauge control.

Intensive development work with the result of innovative new solutions especially for the use of laser triangulation in the cold rolling mill has led to the VTLG, a measuring device that can be reliably used for strip thickness control in the cold rolling mill.

The new measuring device (see Figure 2) operates contact-free and irrespective of the alloy. At the same time it is inexpensive and requires little maintenance.

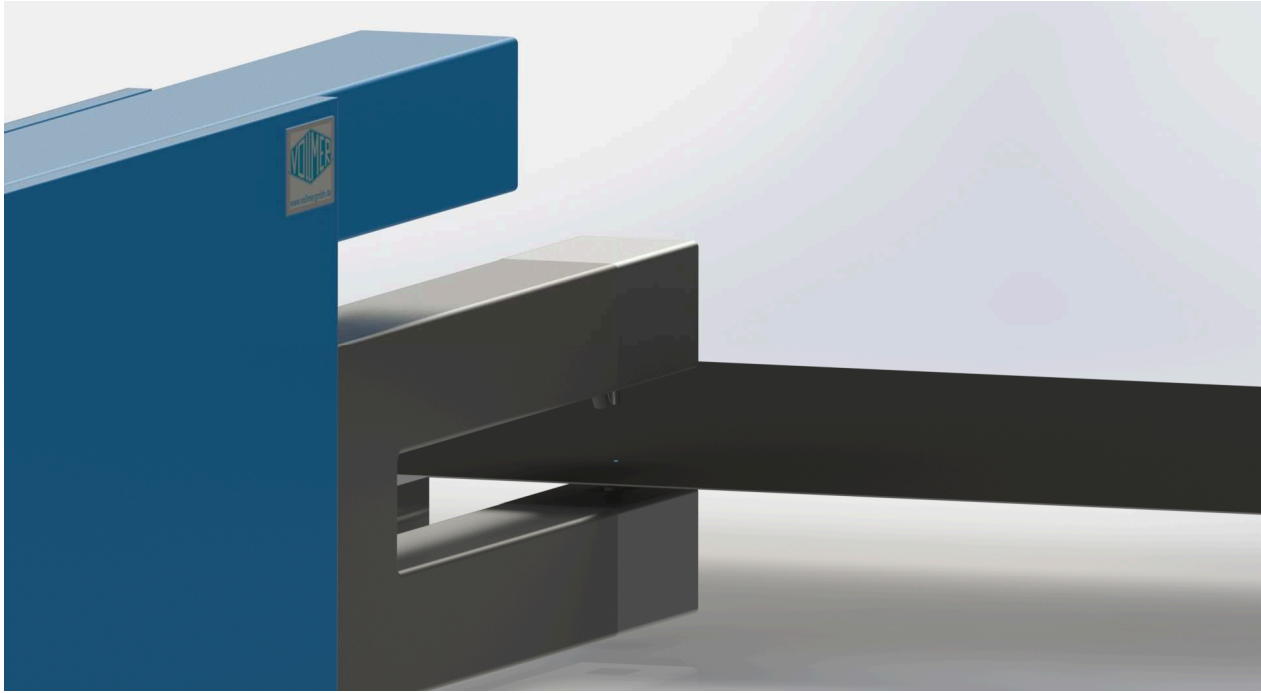


Figure 2: VTLG, laser-based strip thickness gauge for cold rolling mills

Key Development Results

Measuring Frequency and Laser Control. High measuring frequencies are not unusual with laser measurement. But even in this context, the 50 kHz of the VTLG is an impressively high frequency.

The crucial aspect, however, is to synchronise the 50 kHz measuring frequency of the upper laser sensor with the 50 kHz measuring frequency of the lower laser sensor to the microsecond, because if the measurement lasers were not "fired" simultaneously and precisely to the microsecond, every micro movement of the strip would result in an incorrect thickness measurement. This high-precision synchronisation is so important because the strip is moving constantly.

The laser control system developed in-house makes this possible.



Figure 3: VTLG laser control

Furthermore, the Vollmer laser control performs a fully automatic adaptation of the laser intensity so that even widely differing surfaces (from black plate to high gloss) are measured with the same precision without intervention from the outside, simply through the control of the laser measuring heads.

Temperature Management. The two laser sensors measure the distance from the strip surface from above and below using laser triangulation. The strip thickness is calculated directly from these two distances.

A change in distance of the respective sensor could be caused by a change in thickness of the strip, but also by a change in the C-frame to which the laser sensors are attached.

That is really a problem. After all, the required measuring precision for the strip thickness is $\pm 1 \mu\text{m}$. In other words, $\pm 0.5 \mu\text{m}$ for each of the sensors. The arms of the C-frame are 400 mm, 800 mm or 1200 mm long, and the strip passing between them becomes hotter from pass to pass. Without careful selection of the material and temperature compensation, the influence of the heat radiated by the strip onto the mechanics of the C-frame is enormous.

Because it is not reachable to get an affordable, low-maintenance, compact C-frame that does not react to the heat radiated by the strip we have to live with the fact that the C-frame reacts to changes in temperature, but we then have to ensure that this reaction does not influence the thickness measurement.

The VLTG achieves this through the combination of several measures.

On the one hand, the mechanical design of a C-frame is such that the temperature-related movements of the mechanical parts occur only in defined direction.

On the other hand, the design of the mechanical parts allows only an attenuated, delayed reaction to thermal changes.

Furthermore, temperature measuring systems are installed at defined points in the C-frame which signal the momentary thermal situation in the C-frame to the control system.

A temperature model is stored in the control system that selects the appropriate compensation function in relation to the different thermal situations at the C-frame and corrects the measured values accordingly.

Lenses / Sensors. The extreme conditions in the cold rolling mill make great demands on the sensors.

The emulsion or oil on the strip, in particular, causes problems for conventional lenses. You never know whether the sensor has detected the surface of the oil or really the surface of the strip.

VTLG sensors offer more. First, an exceptionally sharp imaging of the laser beam on the strip surface. Not the usual slightly fuzzy area but a sharply focussed spot. This is made possible by the 405 nm wavelength with 15 mW laser power (Laser class 3B according to DIN EN 60825-1).

An important role for the good imaging is also played by the multi-lens focussing optics of each sensor.



Figure 4: VTLG laser sensor

With this performance the lasers detect the multiple reflections and not the blurred, fuzzy image of the laser beam somewhere on the surface of the strip or the oil. By this sensitivity the control system is enabled to make the right evaluation. This is the reason why VTLG measuring devices can measure the strip thickness extremely precisely and reliably even in the cold rolling mill with oil or emulsion on the strip.

And because such special sensors were not available on the market until now, they were developed specially for the VTLG and are produced by Vollmer.

Air Cleaning. High strip temperatures, oil or emulsion on the strip, high pressures and speeds result in fumes, splashes and dripping.

These are naturally not good operating conditions for an optical measuring device.

The function of the air cleaning is to keep the laser sensors clean, and also to keep the beam path from the laser sensor to the respective strip surface free so that the view of the imaging point is sufficiently clear.

The development of the air cleaning nozzles was a great challenge. But the result is a surprisingly small and simple-looking solution that with the combination of self-cleaning by air purging of the lenses with active blowing free of the beam path fulfils the required function outstandingly.

Self-calibration. Parallel to the C-frame, but outside the strip area, is the adjustment station (see Figure 5) that during normal measuring operation is unobtrusively in the background and does not play a role.

But every time the C-frame moves from its parking position onto the strip, the adjustment station opens and swivels a gauge block holder into the beam path. Contained in this holder are 4 certified gauge blocks which represent the strip thickness range of the respective cold rolling mill. The VTLG measures the gauge blocks as it moves onto the strip, then the gauge block holder swings back into the adjusting station and the station closes again.

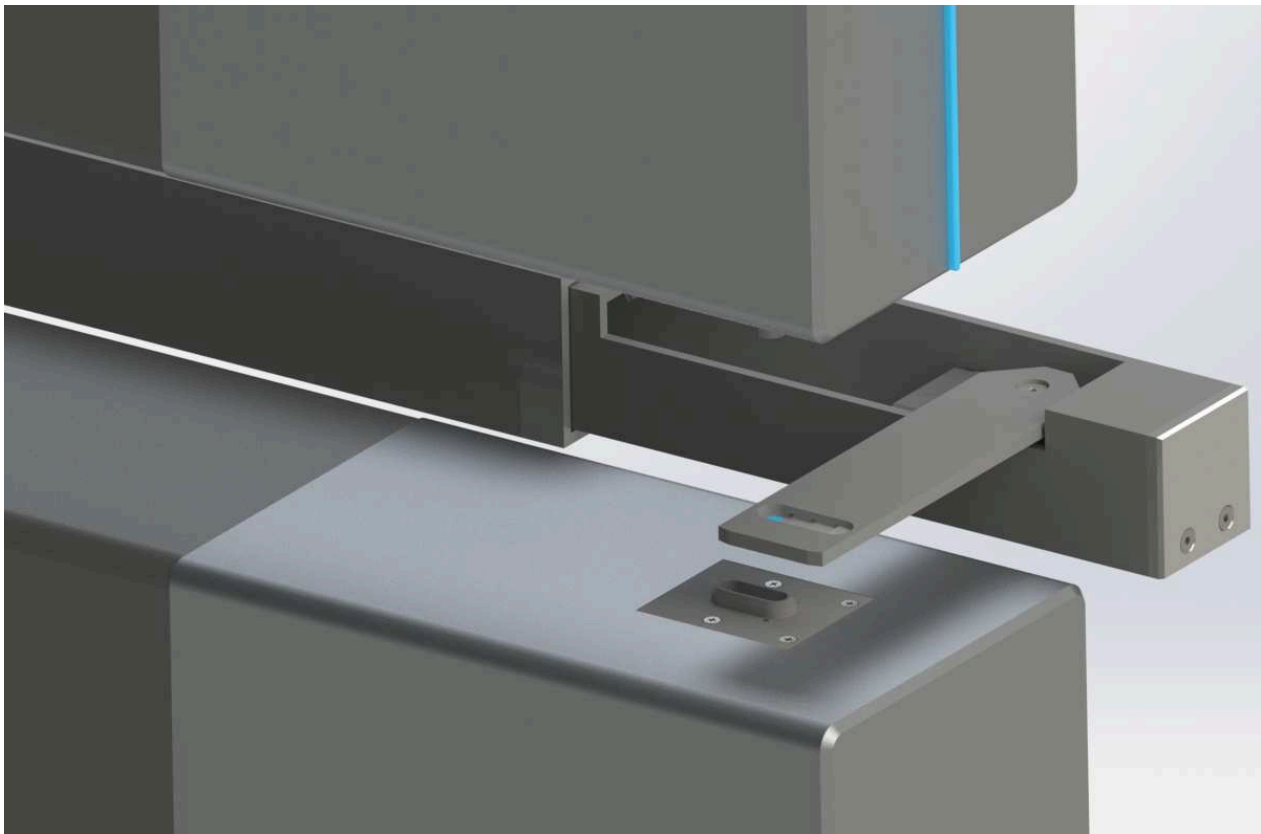


Figure 5: Adjustment station

The effect is that it is ensured that the VTLG is correctly aligned, whether the sensor windows are clean enough, the lenses are free, all the control functions necessary for measurement are running correctly and if not, the system would give an information for maintenance.

This calibration is absolute, functions without operator intervention, fully automatic and is documented. The calibration values are stored and can be examined at any time on the operating unit of the VTLG. That not only makes measurement with the VTLG extremely reliable and plausible, but also creates great confidence for the operator and satisfaction for the auditor.

The set of gauge blocks can naturally be removed and is replaceable so that re-certification in the calibration laboratory can be easily organised.

Design of the VTLG

C-frame with Housing. The C-frame with the temperature sensors has already been described. A motorised carriage guide including integrated position measurement ensures mm-precise positioning at the strip, but also for cross-profile measurement.

The motorised height adjustment of the VTLG allows it to be adapted to different pass line situations.

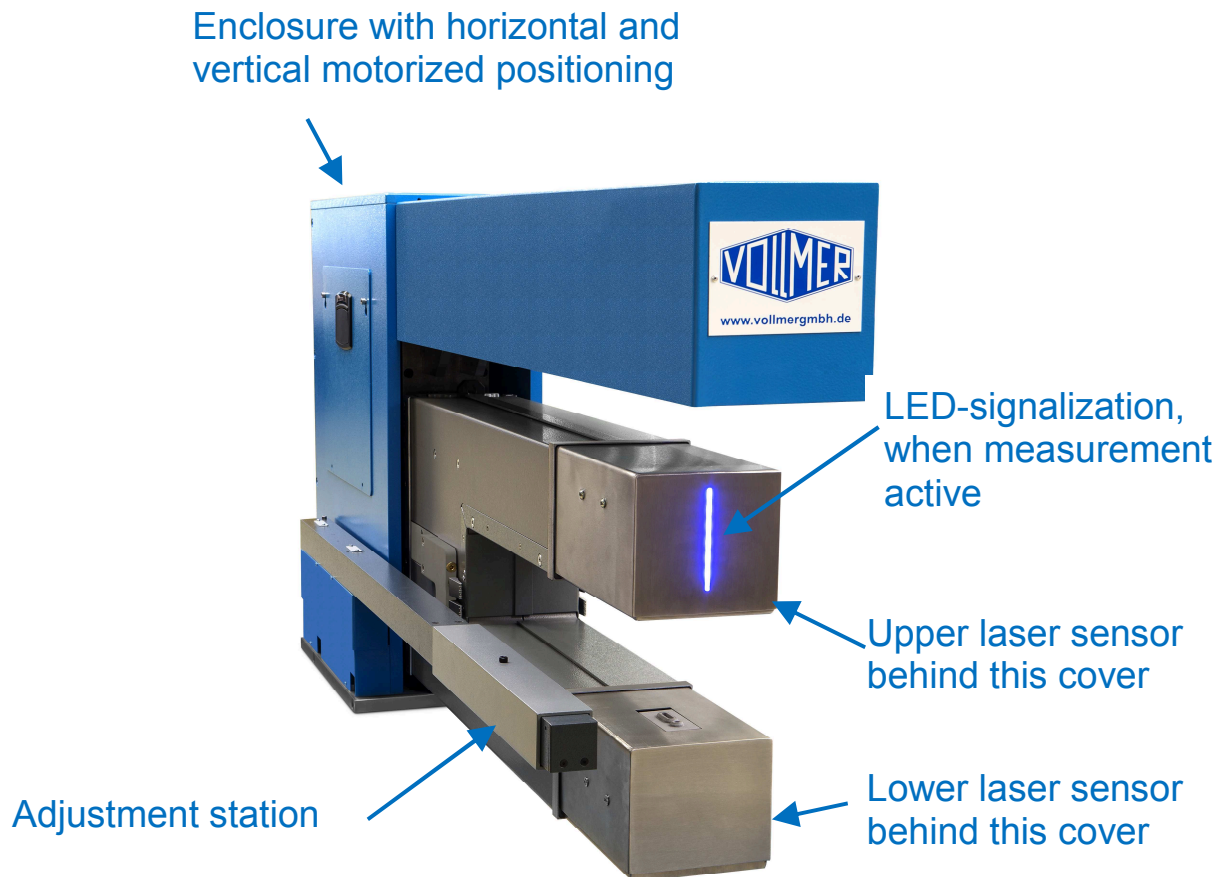


Figure 6: Design of the VTLG

Operating Panel. Operation is via a simple and self-explanatory touch panel that not only allows control of the measuring cycles, but also stores the calibration values and provides status information.

Control Unit. The VTLG was deliberately designed without a control cabinet. The small control box containing all the control units for the VTLG has to be installed in the vicinity of the system. The cable length between gauge and Control Unit is 10 m. Where 2 VTLGs are used (e.g. in a reversing mill), each VTLG has its own control box.

Series Production. Series production is trumps, otherwise this high-quality measuring technology would not be possible at an attractive investment cost.

Simple design. No special solution, just good, compact, reliable, tested and proven measurement technology. This was the guiding principle for the development of the VTLG and can be seen time and again when the details of the measuring device are considered.

VTLGs are available with two different air gaps and 3 alternative measurement depths. The device has a lean and compact design, and fits wherever other strip thickness measuring systems have been installed before.

Outlook

A large number of VTLGs have already been delivered and are proving their value in the cold rolling mills in many countries around the world. We are continuing to expand the series production in order to be able to manufacture to the values that were originally planned.

At the same time we are also considering expanding the range of potential applications for the VTLG, e.g. for strips below 0.015 mm thickness, or for strip temperatures above 180 °C, or for measurement depths of more than 1200 mm, etc.

We will be keeping the market informed of further developments.

Summary

It is to be seen that laser thickness measurement during cold rolling is possible in the needed accuracy of $\pm 1,0 \mu\text{m}$.

But to reach this result reliable, long term and stable several new developments had to be made.