ISSN 1983-4764

INNOVATIVE MEASURING TECHNOLOGIES

INNOVATIVE MEASURING TECHNOLOGIES IN COLD ROLLING MILLS FOR BASIC AND FUTURE PRODUCTS[1]

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Summary

The essential pre-requisite for attaining the high quality of product required from high-speed continuous production processes is the use of new measurement and control technologies. High availability and reproducible measuring results ensure the high level of process stability necessary for fully continuous operation. The requirements for the optimisation of quality across the complete production process and for quality analysis systems will be discussed. This report will present examples of basic and new measurement technologies in Cold Rolling Mills. The following new developments will be discussed in detail: Strip thickness profile & edge drop gauging systems; Coating weight gauging & control systems for metallic coatings; IDD Internal Defect Detection using ultrasonic; Thickness measurements for thin oil layer and other organic coatings. The measuring systems in this presentation must be seen as high-tech solutions in the field of rolling mill technology. The measuring methods and technologies described are, together with optimised process models and precision control loops and actuators, the main pre-requisites for achieving the quality of product required from high-speed continuous production processes. Interconnected quality management systems enable optimisation across the complete production process.

Keywords: Measuring system; Cold mill; Innovative technologies.

1 *Technical contribution to the 48th Rolling Seminar – Processes, Rolled and Coated Products, October, 24th-27th, 2011, Santos, SP, Brazil.*

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ISSN 1983-4764

1 INTRODUCTION

IMS Messsysteme GmbH (IMS) was established in 1980. IMS is an international group of companies in the field of measuring technology for the steel and nonferrous metal industry. IMS develops and manufactures radiometric and optical measuring systems for flat and tubular products. IMS has two main divisions, the Hot Rolling Mill (HRM) division and the Cold Rolling Mill (CRM) division.
The essential pre-requisite for attaining the high quality of product required from high-speed continuous production processes is the use of new measurement and control technologies. High availability and reproducible measuring results ensure the high level of process stability necessary for fully continuous operation. The requirements for the optimisation of quality across the complete production process and for quality analysis systems will be discussed.
This report will present examples of basic and new measurement technologies in CRMs. The following new developments will be discussed in detail:

- Strip thickness profile & edge drop gauging systems
- Coating weight gauging & control systems for metallic coatings
- IDD Internal Defect Detection using ultrasonic
- Thickness measurements for thin oil layer and other organic coatings

This paper is about CRM measurement systems introduced or improved recently. Other long term established measurement systems aren't discussed here. IMS is the worldwide major supplier for HRM and CRM measurement systems. Simultaneous Multi Channel Thickness and Thickness Profile measurement systems for flat and tubular products, using x-ray or Isotope radiation, are state of the art and main products. Combinations of these radiometric systems with integrated laser triangulation systems increase the performance and functionality.

2 INNOVATIVE MEASURING TECHNOLOGY

1.1 General Mill Layout

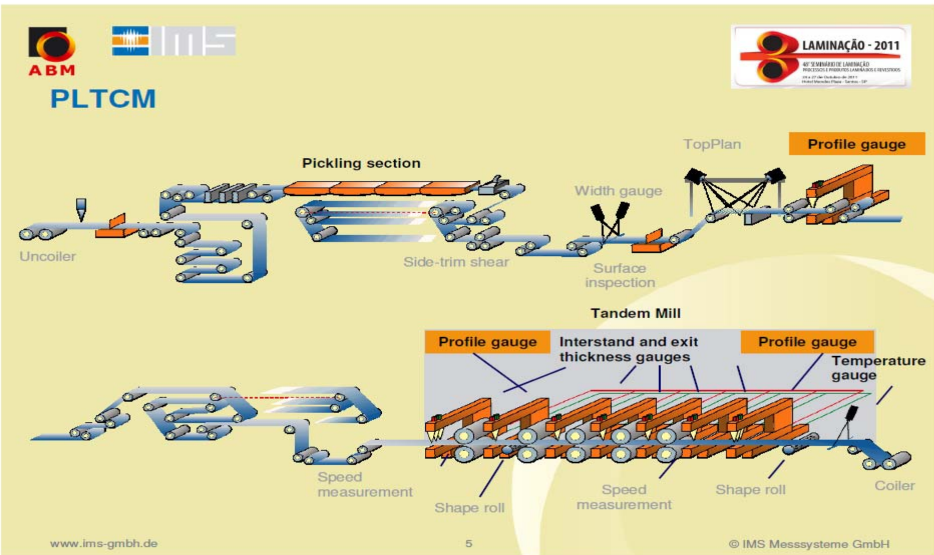

Figure 1. Basic picking line and cold mill layout.

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On the shown mill layout, according the Figure 1, I concentrate us only on the Triple Head Thickness Profile Gauge and the two Edge Drop Gauges.

Type of Gauge	**Location**
Triple Head Thickness Cross Profile Gauge	Exit pickling section
Edge Drop Gauge I	Behind stand 1
Edge Drop Gauge II	Behind stand 5

The measured thickness cross profiles of the triple head thickness profile gauge on the exit side of the pickling line are forwarded to the feed-forward edge drop controller of stand 1 where the preset is calculated. The edge profile information of the edge drop gauge behind stand 1 is used for closed loop edge drop control. While the results of the edge drop gauge are used for quality assurance.

2.1.1. Triple head thickness profile gauges

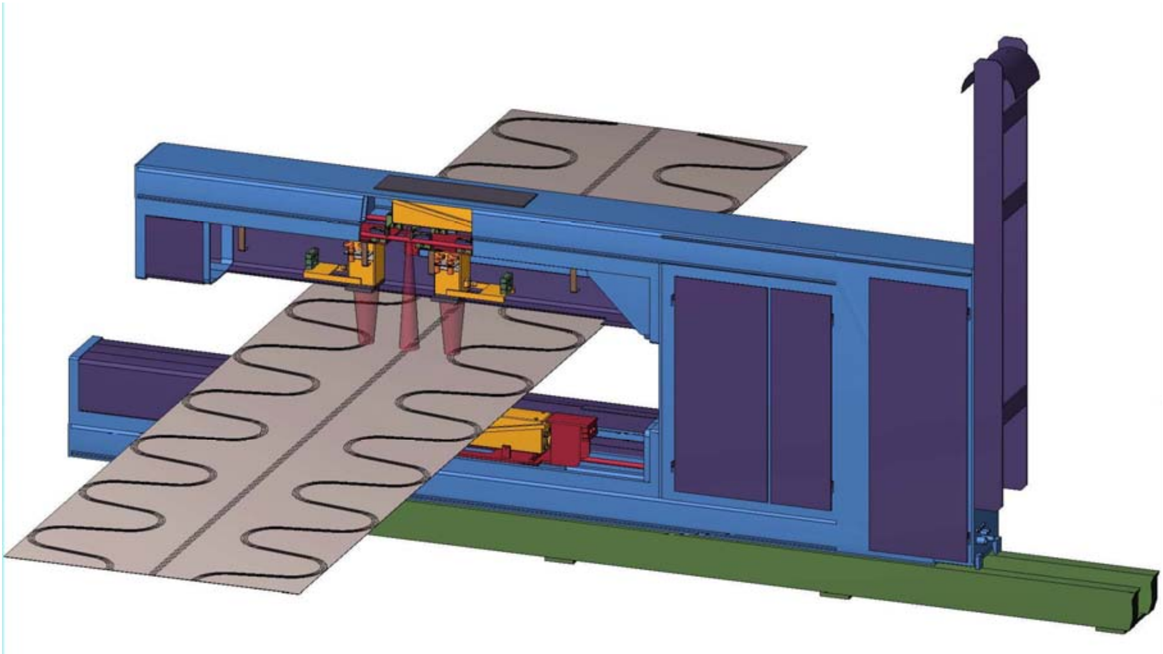

Figure 2. Triple head Gauge – Profile.

The Triple Head Thickness Profile Gauge, according the Figure 2, consists essentially of one C-frame containing three measuring heads, two edge measuring heads and one centreline measuring head. Each "head" consists exactly of one source head containing an x-ray tube and one detector head containing a 2-4 ionisation chambers. As detectors ionization chambers are exclusively used. The number of detectors depends on the customer requirements and also on the minimum and maximum strip width. Applications with more detectors are possible.
X-ray radiation is emitted from all three x-ray tubes. In front of each detector the radiation beam collimation is designed to avoid any cross-interference between adjacent measuring channels. The measuring geometry, including the measuring slit, can be seen in the attached drawings. The width of each edge measuring channel (at the pass line) depends on the application, and may typically be 4-7 mm.

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The width and position of the strip are determined from the measuring signals from the channels in the strip edge area. For the edge detection the detectors in the edge measuring heads are arranged so that if the head moves to the edge, the outer measuring channel sees ‘no strip’. The next channel – looking towards the centre of the mill – is used as a strip edge position detector, the head drives until this chamber is fully covered with strip.
The proposed 3-head profile gauge is designed to measure following parameters:

- Strip centerline thickness
- Edge thickness profile
- Cross profile of strip thickness
- Edge drop
- Crown
- Wedge
- Strip width
- Position of the strip edges

2.1.2. Edge drop gauges

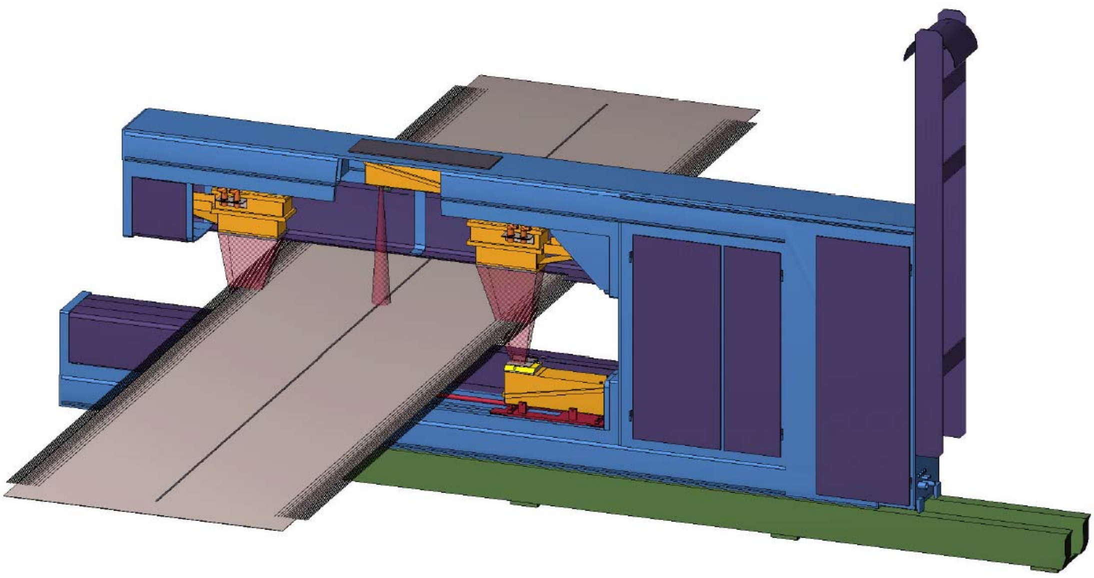

Figure 3. Triple head Gauge - Edge.

The edge drop gauge, according the Figure 3, consists essentially of one C-frame containing three measuring heads, two edge measuring heads and one centerline measuring head. Each of the two edge measuring heads contains 15/22 detectors, the centre head contains 2-4 detectors. As detectors ionization chambers are exclusively used. The number of detectors depends on the customer requirements and also on the minimum and maximum strip width. Applications with more detectors are possible.
X-ray radiation is emitted from the x-ray tubes of the three source heads. The radiation beam collimation in front of each detector is designed to avoid any cross interference between adjacent measuring channels. The measuring geometry, including the measuring slit, can be seen in the attached drawings. The width of each edge measuring channel (at the pass line) depends on the application, and may typically be between 4-5mm.

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The width and strip position are determined from the measuring signals from the channels in the strip edge area. For this purpose each measuring head moves individually. The complete C-frame is fixed with a release latch in the measuring position (mill centerline), so that always a reproducible position is guaranteed.
The edge measuring heads automatically take up their respective positions depending on the width of the strip; at changes of the set width the heads take a preposition.
The detectors in the edge measuring heads are arranged so that the outer measuring channel always sees 'no strip'. The next channel in - looking towards the centre of the mill - is used as a strip edge position detector. If the strip should shift sideways the parameter"*Automatic edge detection"* is switched on, and the measuring head drives automatically to track the strip edge. The measuring head drives until third ionization chamber is fully covered by strip.
Our proposed edge drop gauge is designed to measure the following parameters:

- Strip centerline thickness
- Edge thickness profile
- Edge drop
- Wedge
- Crown
- Strip width
- Position of strip edge

2.1.3. Multi channel thickness profile gauges

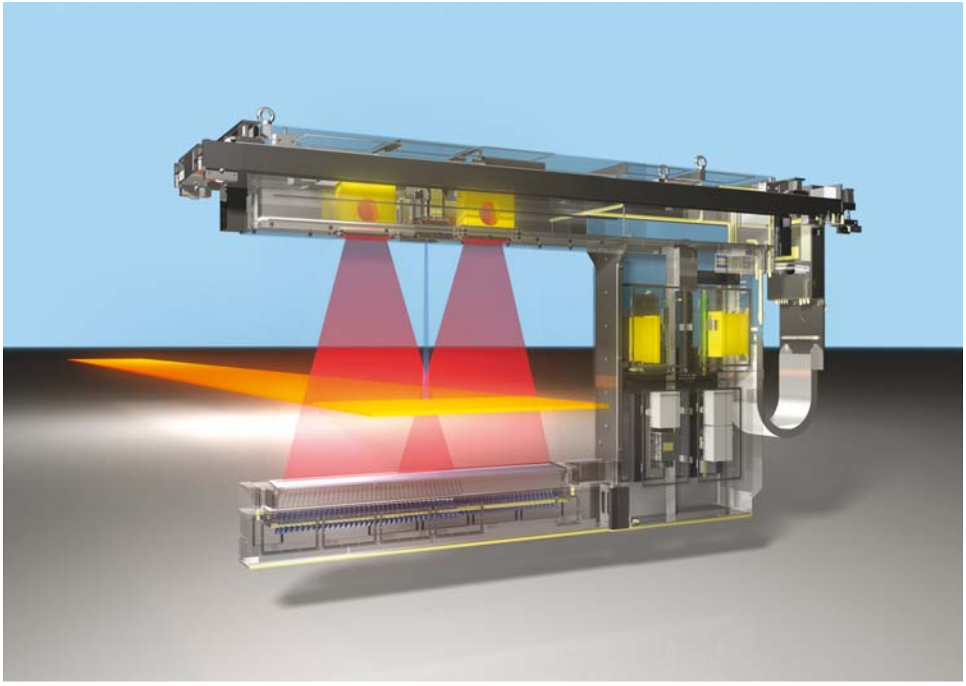

Figure 4. Multi Channel Gauge – Profile.

An oscillating C-frame, according the Figure 4, contains a number of radiation source-detector segments. One segment consists of a radiation source located in the top arm of the C-frame and a number of detectors in the bottom arm. The number of segments and the total number of detectors are determined by the range of strip widths to be measured. The detectors are spaced at definite intervals across the strip

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width. Each detector and its radiation source form a completely independent thickness measuring channel.
By allowing the C-frame to oscillate backwards and forwards in the cross strip direction it is guaranteed that the whole of the strip width is irradiated. By knowing the exact width of the strip and the strip position in relation to the mill center line, the gauge is able to measure the cross profile of the strip accurately, irrespective of the strip shape and strip position.
The strip position with respect to the mill center line (side walk) is measured either radio metrically by the profile gauge itself, or by a separate width gauge located adjacent to the profile gauge (this can be supplied by IMS if required). Any horizontal shift in the strip position (side walk) is thus measured and compensated for within the gauge computer.

2.2. Coating Weight Gauges

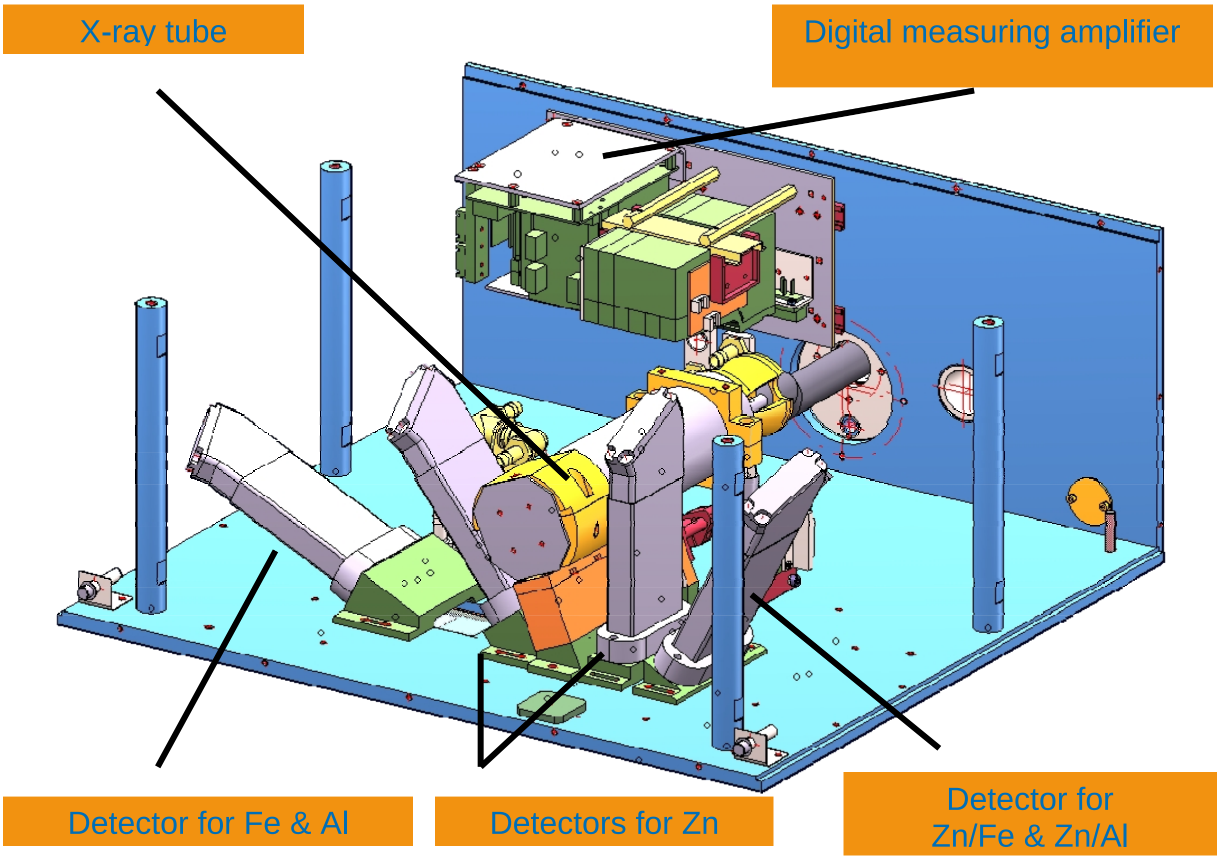

Figure 5. Coating Gauge.

The shown detector head, according the Figure 5, allows measurements of Zinc, Galvanneal & Galvalume. All materials can be measured immediately without mechanical or electrical modifications. Only different calibration curves have to be loaded.

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2.2.1 Air knife control system

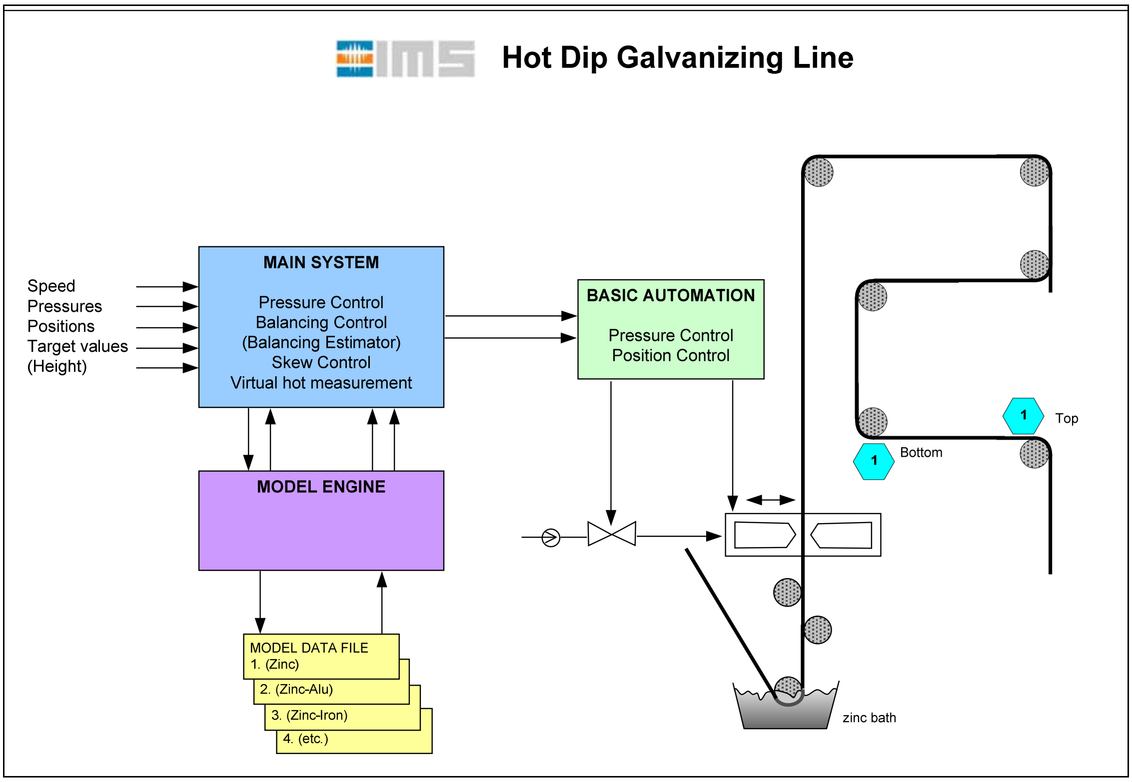

Figure 6. Model Control System.

The presetting, according the Figure 6, feed forward and feedback control strategy is based on the “Model Control System” as developed by IMS Messsysteme GmbH and Nixie Oy for use in hot dip zinc coating lines.
The feedback control and model adaptation are utilizing only the coating profile information of traversing cold measuring heads. The edge areas of profiles can be parameterized away from the profile data to avoid the effects of non-ideal jet stripping process in the strip edges. The control system tolerates different dead lengths for top and bottom measuring heads.
The model contains the needed often strongly non linear relations of process parameters as:

- Coating layer
- Nozzle pressure
- Strip speed
- Air knife to strip distance
- Coating material
- Strip thickness
- Geometrical nozzle arrangement
- Strip alignment to the air knives based on cold measuring profiles

The model can also adapt the transition area from laminar to turbulent jet stream. Slow effects as geometrical and coating material influences are handled with automatic model data sets. One of the model high lights is the very fast and flexible self adaptation to the ever changing process conditions.

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2.3 Edge Crack Detection Systems

The optical and non-contact measuring systems are designed to detect possible edge-cracks of the strip continuously. The measured data is used for the control of the production process as well as for the quality assurance system.
In order to solve the measuring task, an edge-crack measurement system with two or more cameras and a back light will be provided. These systems also provide the function of width measurement and large hole detector, according the Figure 7.
A classification of large hole defects will be provided as standard function of the system, the sensitivity of the size (1 – xx mm) and the correlation in failure classes is adjustable. In case the system detects a hole or edge-crack, an alarm will be generated and the related data will be logged.
Some customers use the systems to measure edge cracks before the Tandem Mill in order to prevent strip breaks. In combination with IMS quality data management systems MEVInet-Q the logged data can be forwarded to the next processing lines to prevent strip breaks in e.g. Continues Annealing Lines or Continues Tinning / Galvanizing Lines.
Other customers count the number of holes and edge cracks and set limits for changing the work rolls. Some use the information for side trimming.

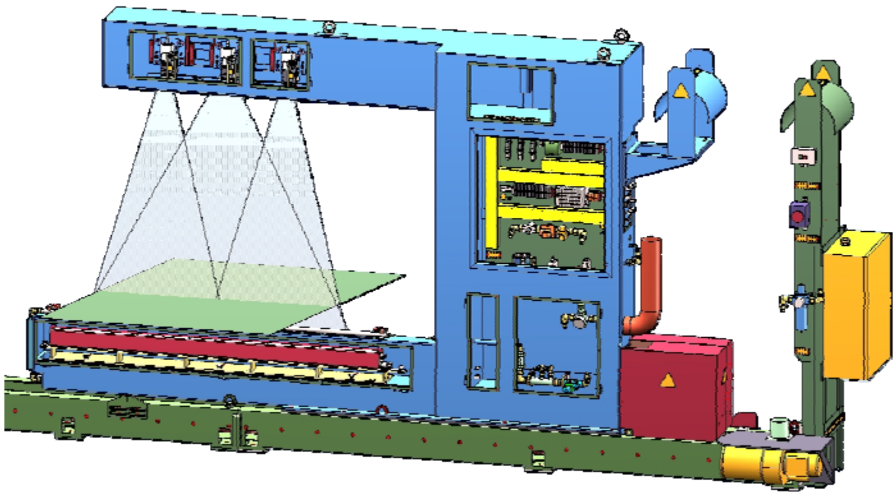

Figure 7. Edge crack detection gauge.

2.4 Internal Defect Detection IDD

IMS is developing a new ultrasonic measuring system to measure internal material defects and surface flaws in a non-contact and non-destructive inspection process.
The system is developed in cooperation with the German steel industry's research institute BFI. The measuring system is suitable for the detection of flaws in normal and stainless steels and in aluminum.
The detection of surface flaws and material defects inside steel or aluminum strip is very important for subsequent processing steps. Flaws that are not detected in time can lead to expensive consequential defects.

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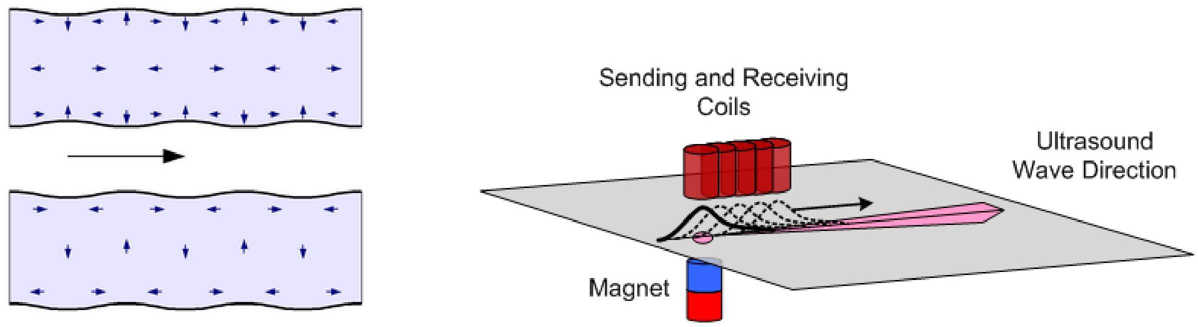
The technique of continuous ultrasonic flaw detection has for the first time achieved a decisive improvement in material quality over the complete length and width of a strip by means of efficient monitoring of the process with short reaction times. With knowledge of the flaws as detected by the measuring system, it is possible to optimize upstream processes, especially in the steelworks.
The ultrasonic detection system can be used in the following production plants.
Fields of use:

- Pickling lines
- Shearing and slitting lines
- Coil optimization lines
- Galvanizing lines
- Tinning lines
- Processing plants

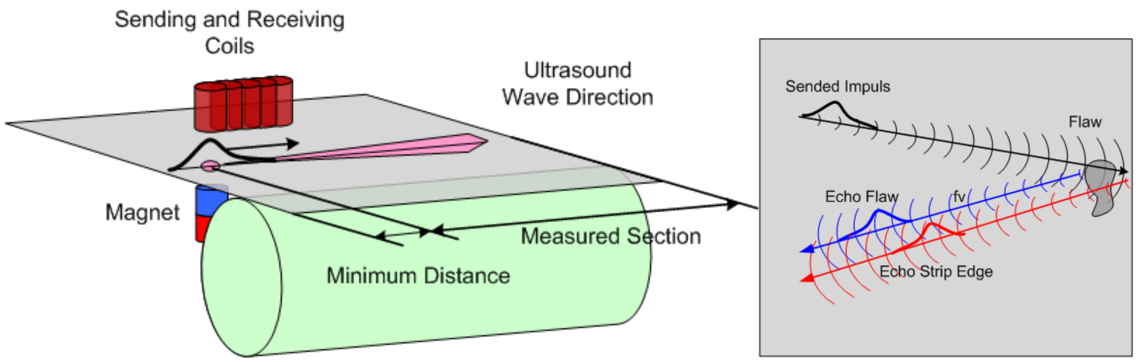
2.4.1 Measuring principle of the EMAT ultrasonic flaw detection system



Lamb waves (S_0 top, A_0 bottom)

Ultrasonic generation and propagation (pink: sound beam)

Figure 8. Ultrasonic measuring system principle.



Measuring set-up

Echogram with flaw

Figure 9. Ultrasonic measuring system principle.

2.5 Thickness Measurements of Thin Oil Layer & other Organic Coatings

Ellipsometry is a highly sensitive optical measuring method which uses reflection-induced changes in the polarization state of light. See the illustration in the Figure 10.

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In the application described here, the method provides layer thickness measurements in the nanometre range, that means film weight measurements in the milligram range (1 - 100 mg/m²) on steel strip, running at speeds of up to 2000 m/min.

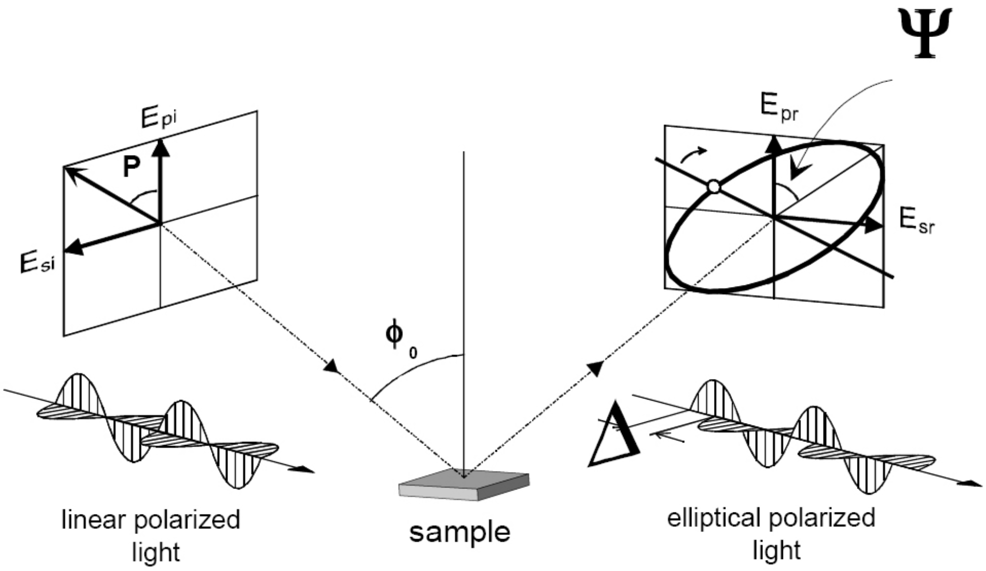

Figure 10. Ellipsometry measuring system principle.

3 SUMMARY

The measuring systems in this presentation must be seen as high-tech solutions in the field of rolling mill technology. The measuring methods and technologies described are, together with optimised process models and precision control loops and actuators, the main pre-requisites for achieving the quality of product required from high-speed continuous production processes. Interconnected quality management systems enable optimisation across the complete production process.
IMS Messsysteme GmbH supplies the necessary measurement systems and technology and above those systems the required data acquisition and evaluating system (MEVInet-Q) to allow correlation between process parameters and product quality from slab to final cold rolled sheet. The main target is to identify defects in the material being processed in the production chain. And further on to avoid any defects with bad effect on final product quality in connection with process automation systems.
Outlook: Future development projects for IMS will be e.g. grain structure analysis and chemical analysis based on x-ray technology to measure and to verify product properties on-line.

Acknowledgements

Rainer Fackert, CEO, IMS Messsysteme GmbH (IMS)
Guido Stallknecht, General Manager Sales Cold Mill Division, IMS.

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