

INNOVATIVE MEASURING TECHNOLOGIES¹

INNOVATIVE MEASURING TECHNOLOGIES IN HOT ROLLING MILLS FOR BASIC AND FUTURE PRODUCTS

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Abstract

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 Hot Rolling Mills. The following new developments will be discussed in detail: Slab dimension measurement system; Slab surface inspection system; High energy x-ray system for thickness and thickness profile measurement; Heavy plate dimension measurement system. 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.

Key words: Slab measurement system; Slab dimensions; Slab edge profile; Slab surface inspection.

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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 HRM. The following new developments will be discussed in detail:

- Slab dimension measurement system
- Slab surface inspection system
- High energy x-ray system for thickness and thickness profile measurement
- Heavy plate dimension measurement system

This paper is (only) about HRM measurement systems introduced 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 TECHNOLOGIES

2.1 General Mill Layout

The conventional Hot Strip Mill (HSM) (with slab reheating furnaces), the Continuous Casting and Rolling Mill, Plate Mill and Steckel Mill are the most common types of HRM. The common aspects and the differences between regarding process control will be discussed.

Please note: Temperature and/or temperature cross profile sensors as well as material speed sensors are nowadays integrated in measurements systems. In addition sensors are installed at other locations for process control.

2.1.1 Common design of a conventional Hot Strip Mill

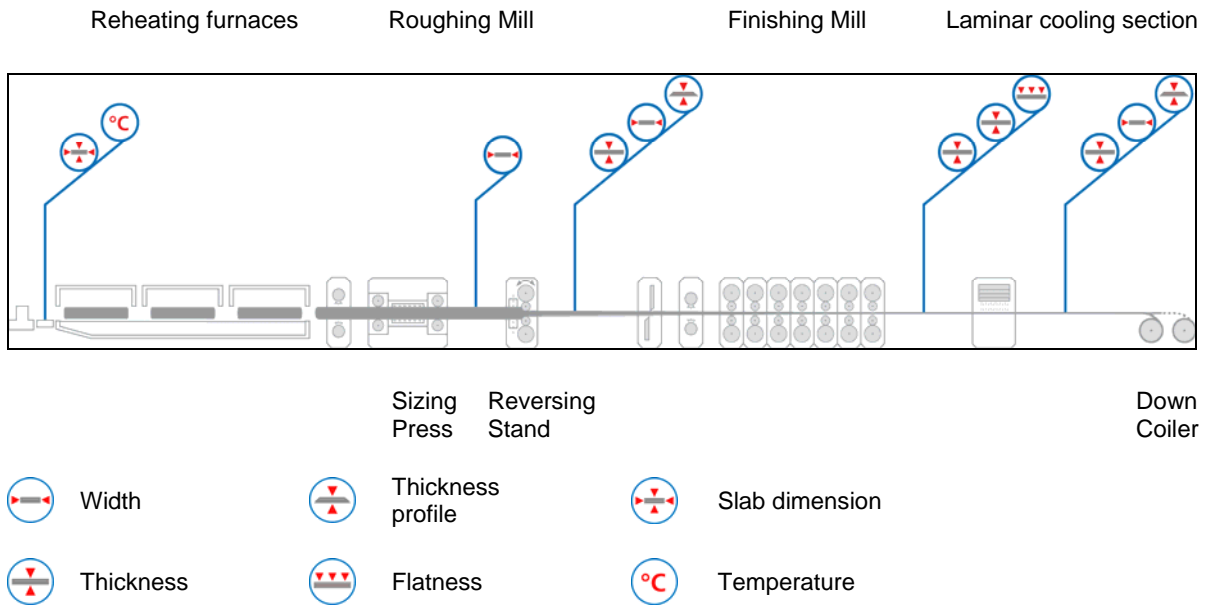
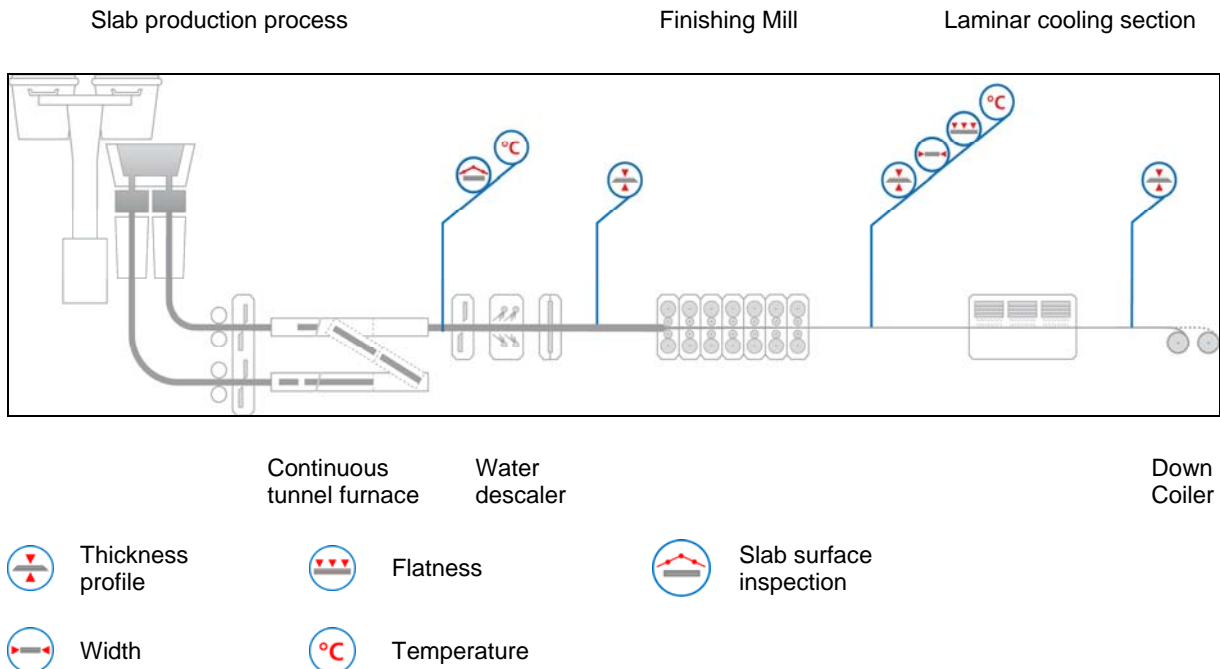


Figure 1. Layout Conventional HSM.

Enumerate in rolling direction, following measuring systems are usually located in a Conventional Hot Strip Mill:

- Entry Reheating furnaces: Slab Identification, Slab Dimension
- Entry Roughing Mill (RM) Reversing Stand: Width
- Entry Finishing Mill (FM): Thickness and Thickness Profile, Width, Crop Length
- Exit FM: Thickness and Thickness Profile, Width, Flatness
- Entry Coiler Section: Width, Flatness

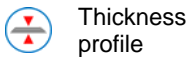
2.1.2 Common design of a continuous Casting and Rolling Mill



Continuous tunnel furnace

Water descaler

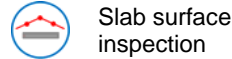
Down Coiler



Thickness profile



Flatness



Slab surface inspection



Width



Temperature

Figure 2. Layout Continuous Casting and Rolling Mill

Enumerate in rolling direction, following measuring systems are usually located in a Continuous Casting and Rolling Mill:

- Exit tunnel furnace: Slab Surface 3D Inspection (under development)
- Entry FM: Thickness and Thickness Profile
- Exit FM: Thickness and Thickness Profile, Width, Flatness
- Entry Coiler Section: Width, Flatness

2.2 Slab Dimension Measurement System

Slab identity verification system in front of the reheating furnaces of a HRM is in common use. The dimensions are measured roughly and verified to assure the expected slab will be loaded into the furnace and the slab will fit into the furnace with its dimensions. IMS introduced so far two systems which allow a precisely measurement of slab dimensions. The standard system consists of two edge profile measurements, length and temperature measurement.

This system already provides following measurement values:

- Edge profiles on both sides
- Edge thickness on both sides
- Width and centre line shift
- Length
- Calculated weight (based on dimensions and temperature)

Laser light barriers or Hot Metal Detectors are in use to increase the accuracy of length measurement.

The more sophisticated system measures in addition:

- Thickness cross profile by top and bottom laser triangulation
- Wedge and Crown
- Camber

- Deflection

For camber measurement two additional laser triangulation edge tracking sensors are mounted in front of measuring system.

Company Salzgitter Flachstahl GmbH (SZFG) installed such a system in June 2008 in parallel to a new walking beam furnace. Slabs have a width range of 600mm to 2.150mm and a length range from 4.800mm to 12.400mm.

Identification of slabs is a main task of the system. By measuring the exact dimensions of the slabs, allocation of slabs in the different reheating furnaces is optimized as well as the calculated heat-up duration.

The thickness cross profile is monitored to detect unusual amount of scale on the surfaces which would result in inhomogeneous heating (cold spots) of the slab in the furnace. In such case now the scale will be removed. In addition the function of the slab scale brushes are monitored and worn out brushes are identified and replaced short term.

For the future SZFG has the intention to use wedge, camber and deflection measurement to improve the casting process.

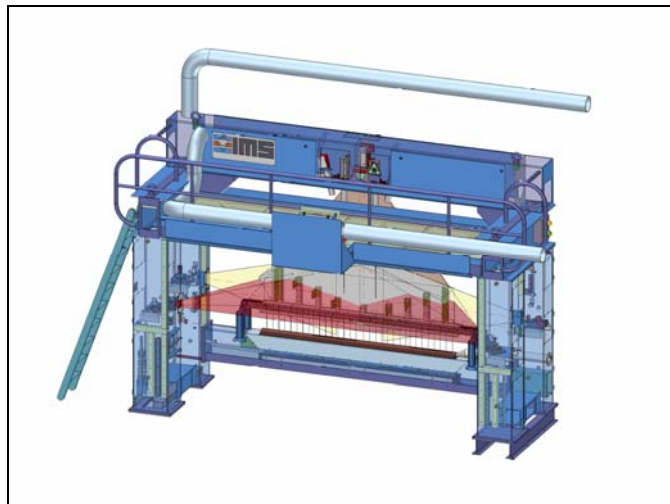


Figure 3. Sophisticated slab dimension measuring system.

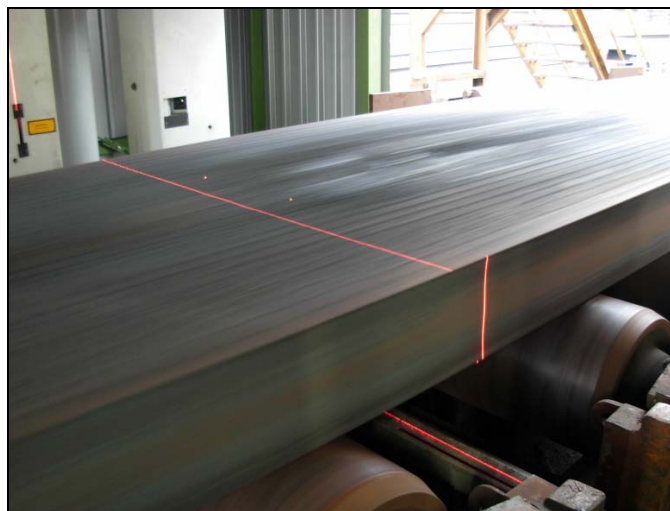


Figure 4. Projected laser lines visible on top and edge

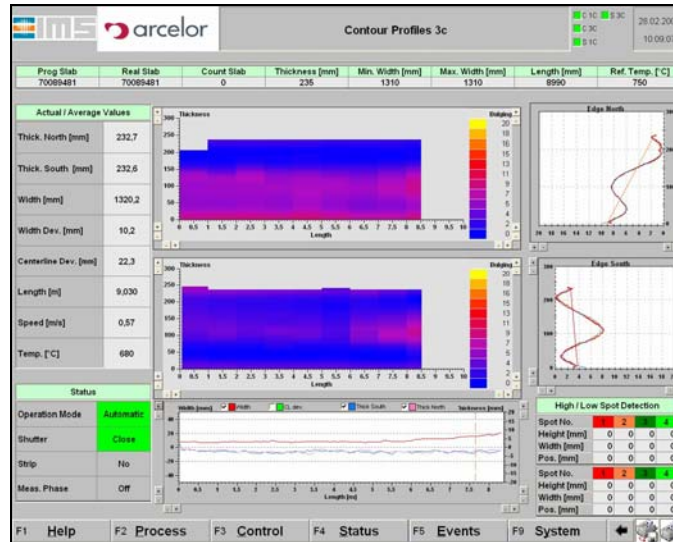


Figure 5. Slab edge profile, width and thickness display

2.3 Slab Surface Inspection System

Companies SMS and IMS launched company SURCON GmbH 1st January 2009.

The company's name SURCON was derived from "surface control".

The new company pools the know-how of the two partners in the fields of casting and rolling technology and measuring technology for flat rolling mills.

SMS Demag (now SMS Siemag) belongs to the SMS group, the holding for a group of companies internationally active in plant construction and mechanical engineering for the steel and nonferrous metal industry. The SMS group consists of the divisions SMS Siemag and SMS Meer.

surcon GmbH will offer slab inspection systems based on 3D measuring processes as well as hot-strip and cold-strip inspection systems using 2D measuring processes. The new company will develop, produce and market these measuring systems itself.

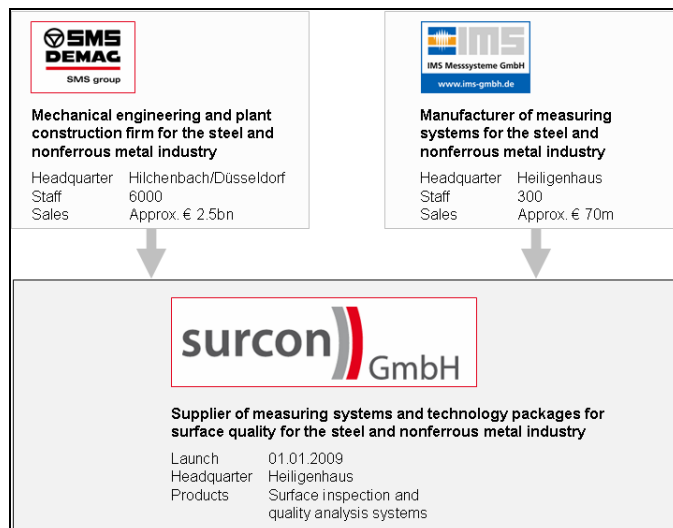


Figure 6. Launch of company surcon GmbH

2.3.1 Product spectrum

Two systems are used for surface inspection:

3D slab measurement (X-3Dvision – product name)

In addition to the extent of a defect, the depth of the defect is also determined. 2D hot strip inspection measurement (X-2Dvision – product name)
The usual techniques for surface inspection systems are used, after defect detection a defect assignment and classification is carried out.

2.3.2 Current projects

- Arcelor Mittal Sestao (ACB) CSP plant (pilot system)
- (3D slab inspection system)
- TKN Bochum casting plant (Test plant)
- (3D slab inspection systems and dimensional measurement)
- Severstal Columbus USA (2D hot strip inspection systems for top and bottom inspection)

2.3.3 3D-System

X-3Dvision is a three-dimensional measuring system using the projected fringe technique. The measured data are captured online in a non-contact process with the help of CCD matrix cameras. Powerful image processing methods evaluate the projected lines mathematically and determine the surface contour in high resolution. The resolution is approximately 1 mm in transverse and longitudinal direction and 0.1 mm in depth direction.

2.3.4 Classification

Example of an on-line measured slab height matrix of size approx. 450mm x 550mm. A lot of slab surface defects are known and divided in one, two or three dimensional defects.

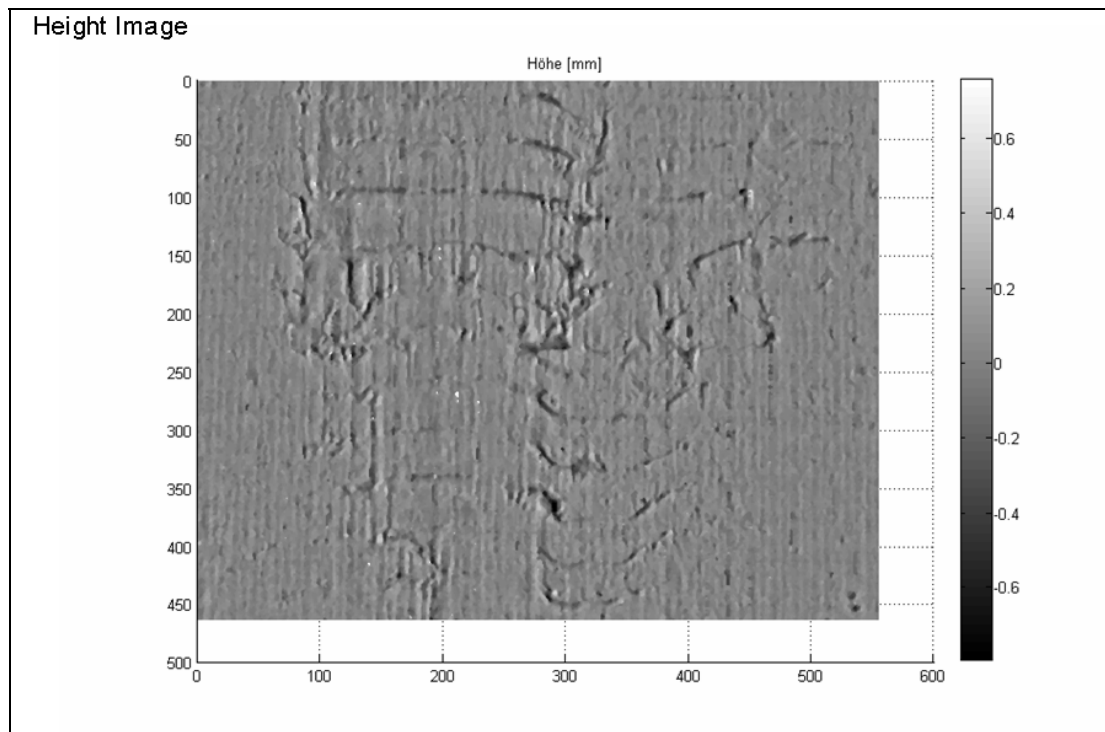


Figure 7. Partial slab surface 3D-height matrix.

2.3.4.1 'One' dimensional defects

Cracks:

- Longitudinal cracks
- Transversal cracks
 - over full width
 - partial in centre or edge region
 - edge

Pores:

- unfilled (voids - blowhole)
- filled pores (non-metallic inclusions on the surface)

2.3.4.2 'Two' dimensional defects

Non-metallic coverings:

- Adherent scale (after slab descaling)
- Adherent casting powder films

Adhesive:

- Detection of casting marks in width direction

2.3.4.3 'Three' dimensional defects

Depressions:

- Impressions (ratio length to width < 3, recurrent)
- Longitudinal depressions (partly combined with longitudinal cracks)
- Mechanical scratches

Bleeders:

- Repaired damage to the casting shell

Scabs:

- Bleeders with embedded casting powder

Roll marks:

- Marks from the furnace rollers

Apart from the newly developed measuring processes, inter-system measures to avoid surface defects will be derived from the measurement results using technological processes, thus enabling considerable cost savings.

2.4 High Energy x-Ray System for Thickness and Thickness Profile Measurement

State of the art, up to end of 2009, were x-ray measurement systems in HRM with max. 225kV, measuring up to approx. 50mm thickness of low alloyed steel. For Plate Mills and for RM section in HRM higher max. measurable thickness is requested. Other reasons lead in direction of development of higher radiation energy as enforced government rules for Isotope handling and operating, safety concerns regarding Isotope source handling, increasing Isotope source disposal costs and more important better performance of x-ray compared to Isotope systems.

Company COMET in Switzerland designed a x-ray tube, named MXR451, based on IMS requirements for up to 450kV operating voltage exclusively for IMS. Useful for thickness and for thickness profile measurement systems up to ≥ 80 mm thickness of low alloyed steel.

The first thickness measurement system of its art will be installed and commissioned in July 2010 at SSAB Steckel Mill in Alabama USA. Location of the gauge is between Reversing Stand Exit and Steckel Box. A second gauge will be located between

Steckel Box and Reversing Stand Entry in 2011. Both thickness measurement systems will be used for AGC

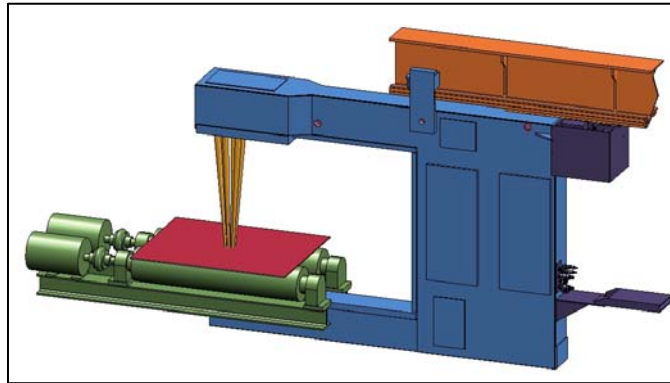


Figure 8. Multi-channel thickness gauge with material slope compensation.

2.4.1 Hardware schematic layout 450kV application

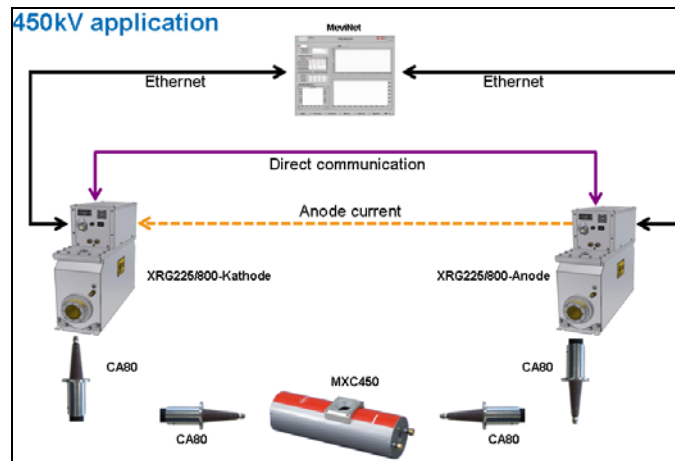


Figure 9. 450kV x-ray application components.

To achieve 450kV two x-ray high voltage generators each of 225kV are connected in serial. Anode and filament current is controlled by one of the two controllers.

2.4.2 Comparison x-ray versus Isotope

In addition to the better performance of x-ray system, x-ray systems are less sensitive to environmental conditions as air gap temperature (air density) change and coolant in measuring gap or on strip surface. Due to arrangement of radiation detectors for x-ray thickness measurement systems strip angle is automatically detected (in any direction) and thickness error due to strip angle is compensated. This is very important for Steckel Mills with more or less permanent strip angle present, but also for other HRM whilst strip isn't under coiler tension.

Table 1. x-ray versus Isotope radiation

	X-Ray ~ 200kV	Cs137 Isotope 662keV
Thickness drift per 8hours	<=+/-0,05%	<=+/-0,05%
Thickness linearity	<=+/-0,05%	<=+/-0,05%
Thickness repeatability	<=+/-0,05% / >=+/-2µm	<=+/-0,05% / >=+/-5µm
Thickness accuracy	<=+/-0,1% / >=+/-2µm	<=+/-0,1% / >=+/-5µm
Statistical Noise 2-Sigma up to 8 HVTs at time constant below	<=+/-0,1% / >=+/-2µm	<=+/-0,2% / >=+/-5µm
Time Constant typically	5...50ms	30...300ms
Measuring Range	0...50mm (80mm >=320kV)	0...150mm
Safety concerns, radiation can be	switched off	not switched off
Life time of source	> 5 years (up to 10 years experienced)	> 15 years
Loss of activity/dose rate	None	30 year half-life period
Statistical Noise increases of life time	No	Yes
Maintenance required	<= 6 month (High Voltage connector greasing)	No
Investment 225kV	approx. same price	approx. same price
Investment 450kV	more expensive	Less expensive
Costs for source disposal	Inexpensive	expensive
Water on strip per 1mm water film results in thickness error	+50µm	+125µm
Alloy compensation	density & alloy element related	Only density related
Air gap temp. change of +/-10K results approx. in thickness error	+/-4µm	+/-10µm
Strip angle compensation	standard	Impossible due to high statistical noise and slow response time
Source cooling	by water required (by oil for >= 320kV)	Not required

Remark: HVT = HalfValueThickness, 12mm steel for Cs137 Isotope, 2.56.5mm for x-ray systems based on x-ray high voltage kV-level (defining radiation energy level).

2.5 Heavy Plate Dimension Measurement System

The described measuring system was developed in 2009 by IMS for latest generation of 5000mm wide Plate Mills located in Russia and China. The measuring system is a combination of a topographic evenness system and stereoscopic width measurement system. Further plate properties are measured in addition. Plates coming from the Cooling Bed down stream in direction of Cross and Length Shearing Lines are measured.

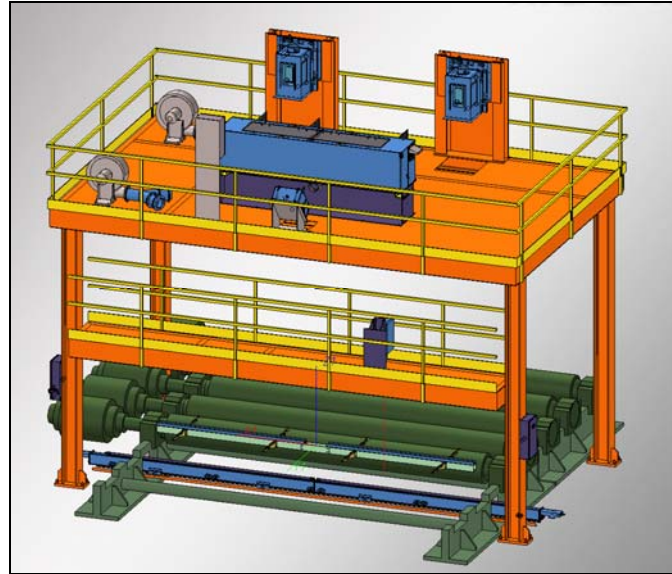


Figure 10. Heavy plate dimension measuring system

This measuring system provides following information to the operator and process computer:

- Evenness distribution
- head and tail ski height,
- width, head and tail crop length,
- outline shape
- camber
- length

The measuring values together with values measured at the Exit of FM Reversing stand (thickness and temperature recordings) are used to cut the plate into individual finished rectangular plates with homogenous steel properties and requested dimensions. The process computer decides on given parameters (e.g. safety edge margins) and nominal dimensions values and especially based on the outline shape (crop, camber) and length of the plate where to cut finally.

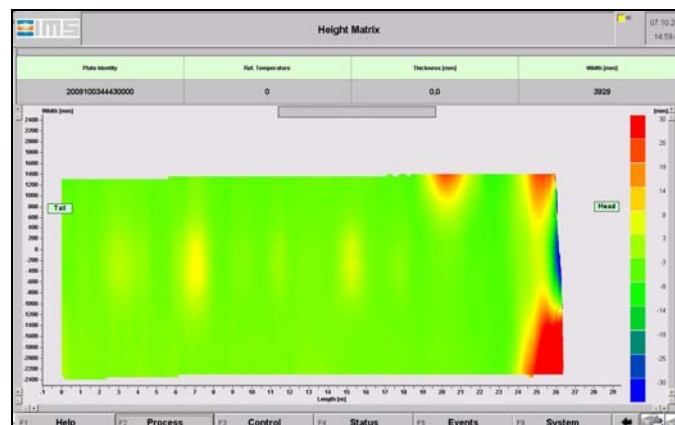


Figure 11. Evenness (height) matrix over plate length and width.

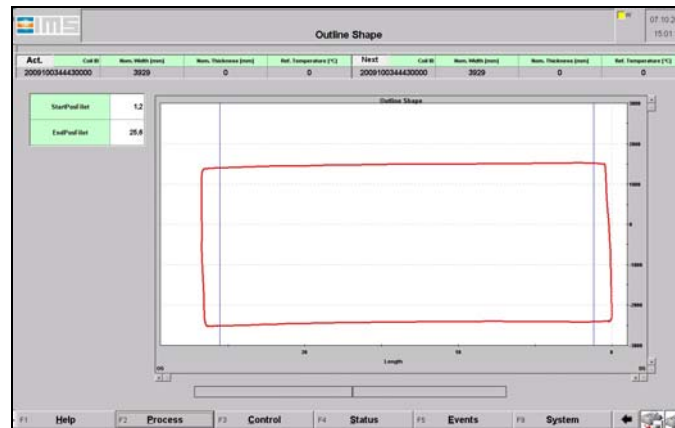


Figure 12. Plate outline shape.

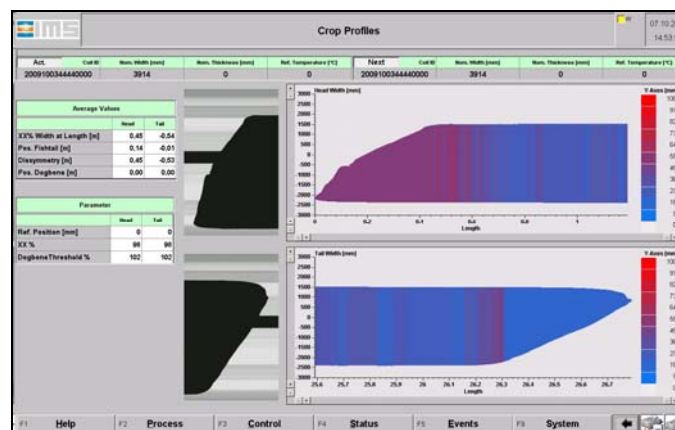


Figure 13. Crop length determination.

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.

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C. Antoine, General Manager Process and Measuring Technology, Salzgitter
Flachstahl GmbH

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