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INNOVATIVE MEASURING TECHNOLOGIES IN COLD ROLLING MILLS & PROCESSING LINES 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 full 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 and Processing Lines. The following gauging systems will be discussed in detail: Strip tension meter, roll force measurements, weighing systems and shapemeter rolls. The measuring and control systems in this presentation must be seen as high-tech solutions in the field of processing 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: Strip tension meter; Roll force measurements; Weighing systems; Shapemeter rolls.

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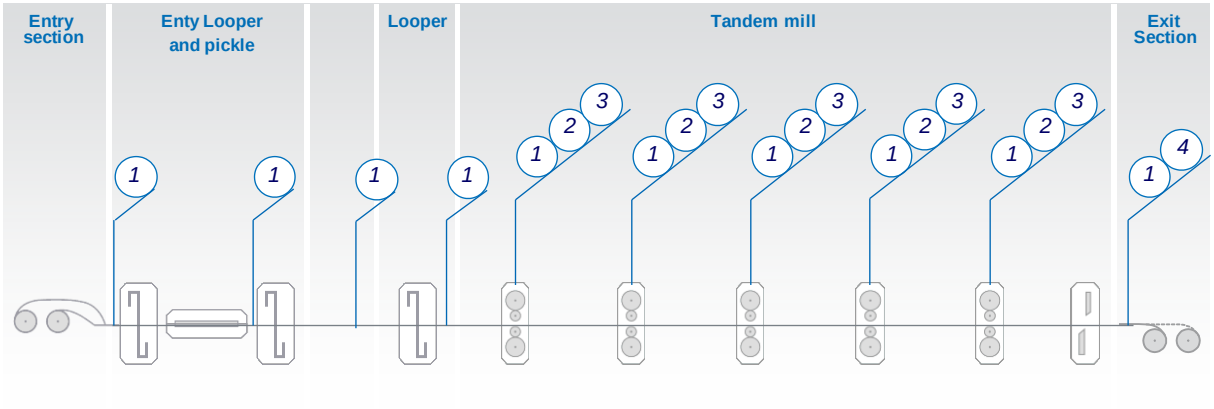
1 INTRODUCTION

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. It develops and manufactures radiometric, optical and other 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 full 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 measurements and control technologies in Cold Rolling Mills and Processing Lines. The following gauging systems in detail:

- Strip tension meter using strain gauge technology
- Roll force measurements using strain gauge technology
- Weighing systems using strain gauge technology
- Shapemeter rolls with piezo sensors (BFI principle)

This paper is (only) about force measurements and shapemeter rolls introduced or improved by IMS recently. Other long term established measuring systems aren't discussed here. IMS is the worldwide major supplier for HRM and CRM measuring systems. Simultaneous Multi Channel Thickness, Coating Weight- and Thickness Profile measurement systems for flat and tubular products, using x-ray, Isotope radiation or different optical methods, are state of the art and main products.

2 FORCE MEASUREMENTS BASED ON STRAIN GAUGE TECHNIQUE



1. Strip tension system
2. Rolling force systems
3. Pressure systems
4. Weighing systems

Figure 1: Overview Mill layout

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In the continuous production of steel, aluminum, paper or foil a large number of force sensors is required to meet the high quality demands of customers and to achieve a high degree of automation, according the figure 1.
Among several other measuring systems of the IMS Messsysteme GmbH, our force measuring systems provide important signals for automation can be used for different applications.
Well known force measuring systems are:

- Strip tension systems
- Rolling force systems
- Pressure systems
- Weighing systems

Several manufacturer offer these measuring systems, however, we distinguish only two types of measuring principle.

1. Pressductor systems from ABB and others.
2. Strain gauge technology, which is also applied by IMS Messsysteme GmbH.

The strain gauge technique is proven for more than 50 years and provides customized manufacturing of maintenance-free force transducers.

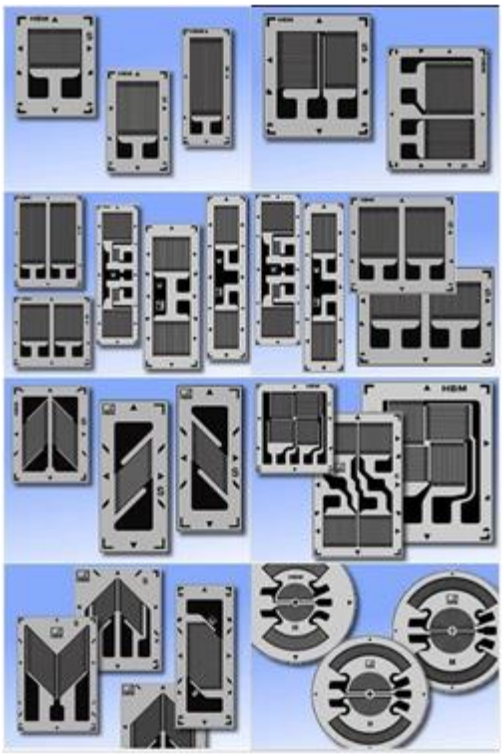

Figure 2 : Strain gauges

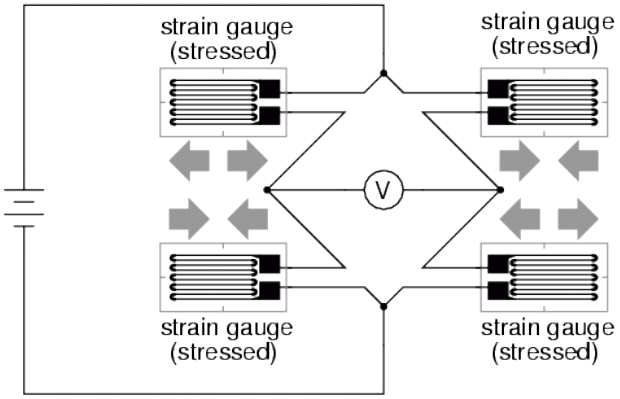

Figure 3 : Wheatstone-measuring bridge

Strain gauges are basically variable resistors which are applied to the measuring zone of the force transducer. Hereby special glue establishes a permanent connection to the body of the force transducer. Strain gauges can be realized in a broad variety of shapes, sizes and materials and allow flexible design of the measuring zones and thus of the force transducers themselves, according the figures 2 to 7.

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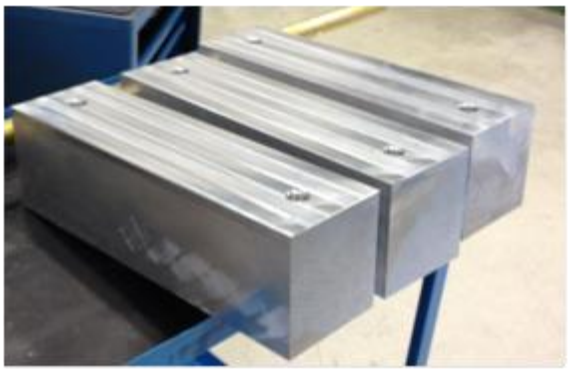

Figure 4: Raw material

Figure 5: Production on a 5-axis CNC machine

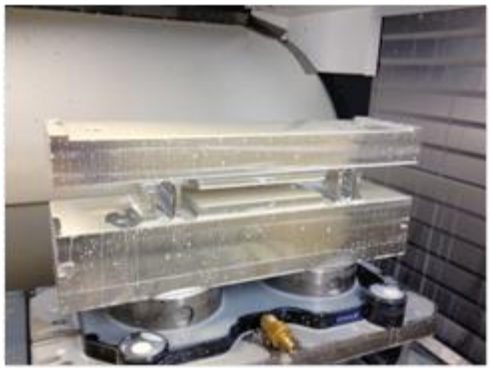

Figure 6: After completion of production

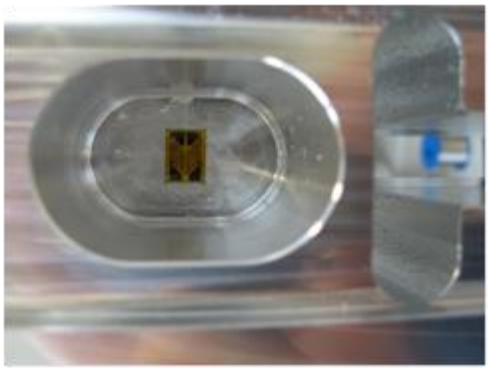

Figure 7: Applied strain gauges

To measure the change of the resistance, and thereby the deforming of the measuring zone, the strain gauges are connected to a Wheatstone-measuring bridge. This kind of connection transforms a change in resistance into a change in voltage. Even smallest deformations of the measuring zone can be measured.

3 STRIP TENSION MEASUREMENTS

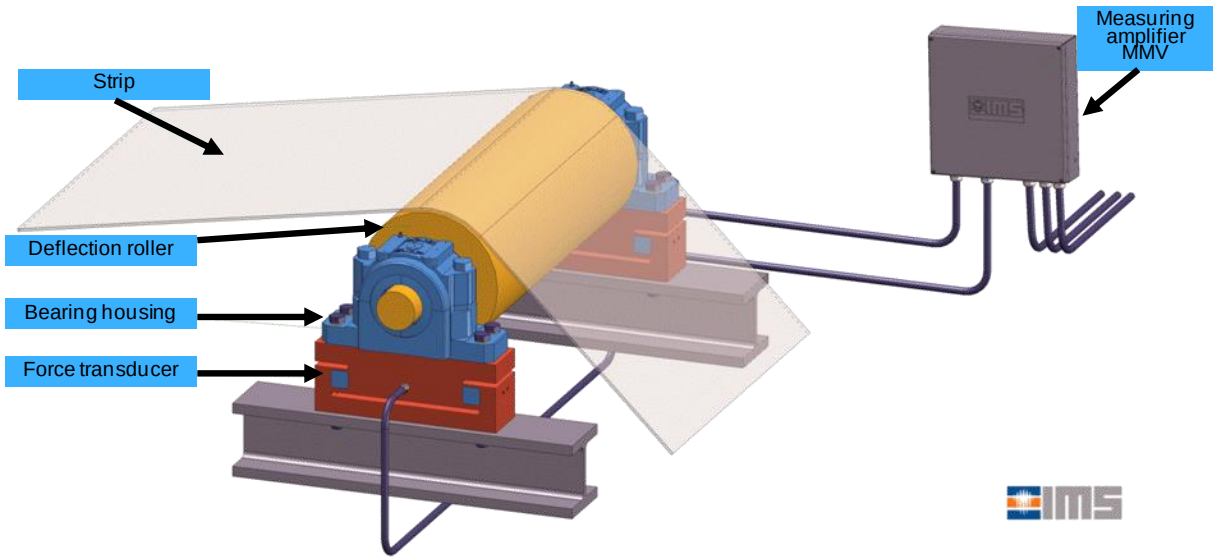

Figure 8: Principle of a strip tension measuring system

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Continuous production of steel, aluminum or paper requires to measure the tension within the strip at different locations in a production line in order to be able to control the individual drives.
As you cannot measure the strip tension directly at the strip itself, the common method is to have a deflection roll. The strip passes the deflection roll and we measure the occurring reaction force at the bearing. The knowledge of the strip flow allows the calculation of the strip tension from the measured values and thereby the control the drives, according the figure 8.
To measure these forces a special force transducer is placed between the bearing housing of the deflection roll and the machine frame or socket.
There are two basic types of force transducer to measure the strip tension. The decision which type to apply is dictated by the circumstances such as the installation position, the strip flow and the direction of the pre-load of the deflection roll. Also the accessibility and the installation platform play an important role for the force transducer assembly. Those are only some of the factors to figure out the right force transducer type for your application.

3.1 The Basic Types of the Force Transducers

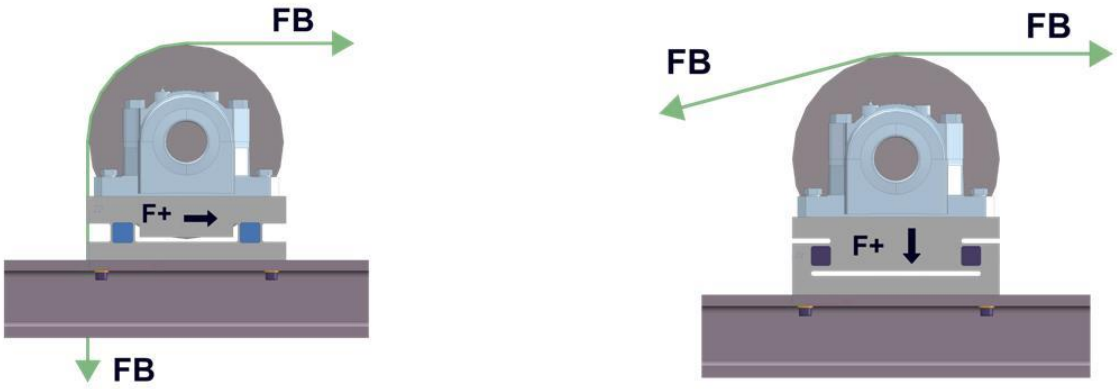

Figure 9: Overview basic types of the force transducers

- Basic Type HMK (Horizontal measuring force), according the figures 9 – left example and 10.
- The basic type of HMK is sensitive to forces parallel to the force transducer mounting plane.
- Basic Type VMK (Vertical measuring force), according the figures 9 – right example and 11.
- The basic type of VMK is sensitive to forces vertical to the force transducer mounting plane.

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Figure 10: Measuring point with forcetransducer HMK

Figure 11: Measuring point with force transducer VMK

4 MEASURING AMPLIFIER

Figure 12: Measuring amplifier - Front view

Figure 13: Measuring amplifier - Inside

Figure 14: Measuring amplifier – Control unit

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Force transducers using strain gauges are passive systems, which mean that they do not emit signals by themselves. An electronic measuring amplifier of the type MMV (Modular Measuring Amplifier) is needed for evaluation of the force signals and calculation of the strip tension, according the figures 12 and 13. The modular measuring amplifier type MMV may be connected to any IMS force transducer (based on strain gauges technique) and is shipped in a stainless steel closure. The standard measuring amplifier has two input channels for IMS force transducer, according the figure 14.

The signal emitted by the force transducers passes by a fixed preamplifier and is directed to the A/D-converter. The adjustment of the signal takes place in the software and is therefore a digital process. Therefore the amplifier type MMV is particularly comfortable to operate. It also grants a maximum of flexibility. The modular design allows the installation of two additional input channels, without drawbacks in terms of process speed. The analogue outputs are for current or voltage signals. Galvanic isolation must be implemented by the customer. Optionally the measuring amplifier type MMV can be equipped with a field bus module. It supports all common field bus systems, including EtherCat, Profibus-DP and EtherNet-IP.

The field bus system enables the measuring amplifier type MMV not only to provide the measurements, but also to receive additional information, for example the coil diameter.

Furthermore the measuring amplifier type MMV may be controlled via the field bus system. The four digital in- and outputs offer the integration of the measuring amplifier type MMV at site, even if there is no field bus system available. That makes the measuring amplifier also interesting for the replacement of old electronics without changing the force transducers.

5 INNOVATIVE MEASURING TECHNOLOGIES

5.1 General Mill Layout (example Reversing Cold Mill)

On the shown mill layout, according the figure 1 we concentrate only on the strip tension meters and the shapemeter rolls.

According the figure 15, there is one example in the Reversing Cold Mill application for shapemeter roll with strip tension meter + X-ray thickness gauge with strip velocity meter.

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Figure 15: General Mill Layout (example Reversing Cold Mill)

5.2 Shapemeter Rolls

Usually, during the cold rolling process, the strip is rolled under high tension. This high strip tension compensates for differences in length or shape defects so that the strip appears to be flat during the rolling operation. As soon as the strip is uncoiled latent shape defects will become visible.
The result is a decrease in quality or a reduction in production capacity for subsequent processes.
Cold Mill operation is also adversely affected. The strip tension resulting from a compensation of varying lengths creates a non-uniform tensile stress distribution over the strip width. These uncontrolled tensile stresses my lead to processing disturbances such as strip breakage, strip accumulation and strip mistracking. This is the main reason why even advanced mills operate at a considerably reduced speed for safety reasons.
Shape defects are due to differences in length over the strip width. So the type of length distribution over the width and the size of the length differences characterize the shape effects.
Typical shape defects are:

- Camber
- Long Strip Center
- Short Strip Edges
- Long Strip Edges
- Edge Waves
- Quarter Buckle

Of course, during the rolling process usually several shape defects occur at the same time.
Therefore it is obligatory to measure and to control the flatness. Our shapemeter roll systems (IMS-BFI) offer the measuring function and system visualize shape defects which can't be seen with the eyes.

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A measure for lengths deviations of cold rolled strip is the distribution of length tensile stresses over the strip width during the rolling operation. It is this distribution of length tensile stresses which is evaluated by the automatic flatness control system.
For example, the shapemeter roll can take the place of the deflector roll between the mill stand and the coiler, according the figure 15.
The shapemeter roll consists essentially of, according the figure 16:

- A solid body roll with axial bores
- Force sensors
- Charge amplifiers
- Contactless data transmitter unit

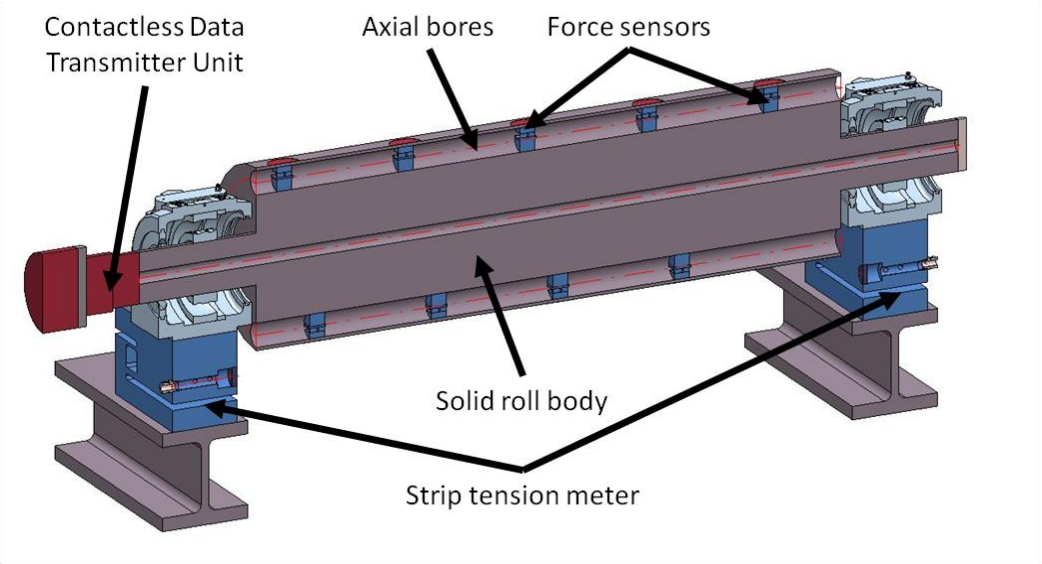

Figure 16: Cross section of a shapemeter roll with solid body

5.2.1 Technology

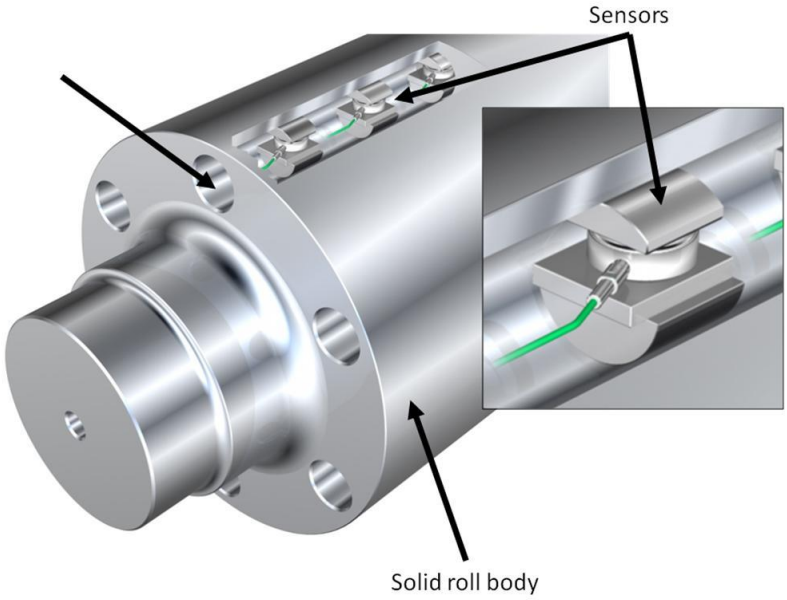

Figure 17: Mounting of sensors

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The piezo sensors will be mounted through the axial bores one after the other. Thereby the final measuring position in cross direction will be accurate. All sensors are pre-stressed, according the figures 17 and 18.

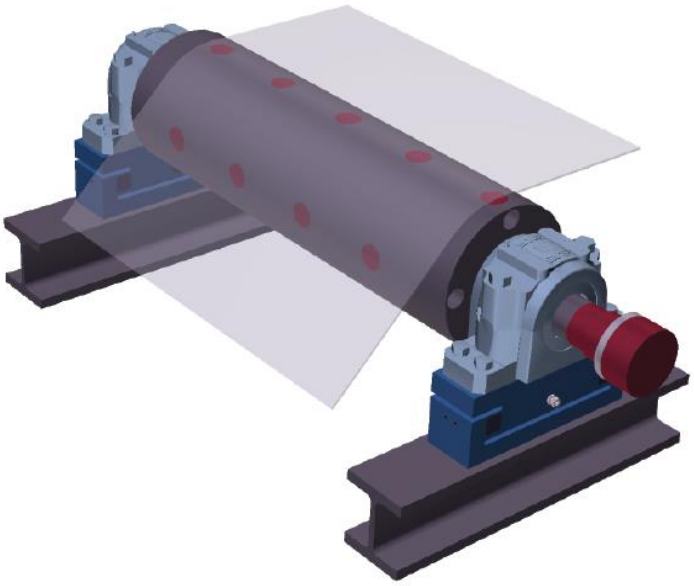

Figure 18: Abstract example of the sensor alignment

5.2.2 Advantages of IMS-BFI shapemeter rolls, according the figure 19

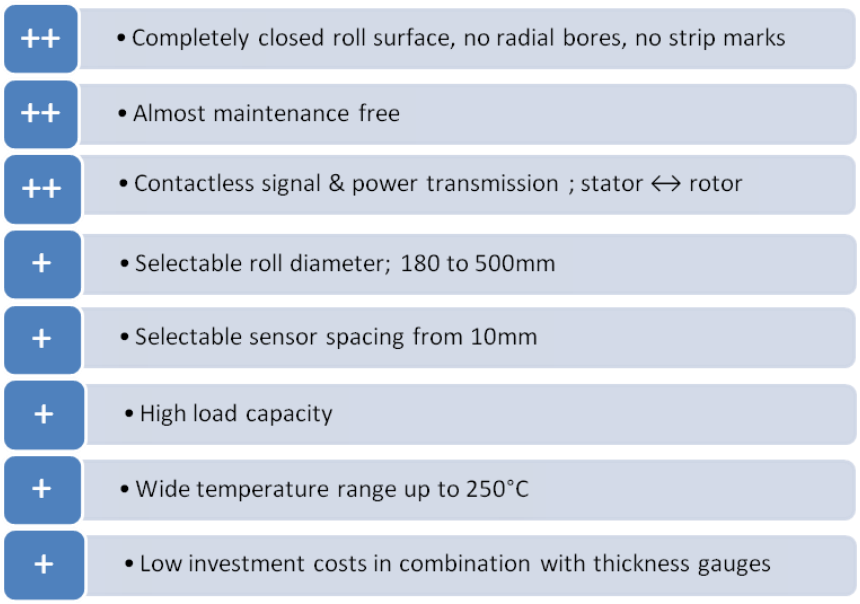

Figure 19: Advantages of IMS-BFI shapemeter rolls

- Due to the completely closed surface four (4) surface designs can be provided and customized to the application. For the rubber coating the grinding range is 20mm in diameter, for the others it is 6mm.

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- The only maintenance required is the cleaning of the roll and a check of the gaskets.
- Since the signal and power transmission between the rotating and static part is contactless the signal quality is highest. It is a big difference to other roll supplier who use brushes for the transmission.
- The roll diameter can be selected between 180mm and 500mm. It depends on the strip angle, strip tension and the application.
- The sensor spacing is selectable from 10mm. Standard is 26mm in strip edge zone and 52mm in the strip center.
- And the high load capacity results in a long lifetime of the rolls.
- An extremely wide temperature range allows the application in rolling mills with high strip temperatures, e.g. for electrical steels.
- The shapemeter rolls fit in perfectly in the family of IMS gauging systems, like thickness gauges, width gauges, tension meter etc.. All gauges can be operated separately but connect to one (1) system electronics. A common visualisation on the process screens is standard.

5.2.2.1 Roll surfaces

	Hardness	Coating Thickness	Grinding Range
Hardened & Ground	56+3 HRC ≈ 700HV	8mm	6mm in ø
Special Rubber or Polyurethane	95 Shore	15mm	20mm in ø
Chromium	≈ 950HV	5-30µm	6mm in ø
Tungsten Carbide	≈ 1,350HV	100-200µm	6mm in ø

Figure 20: Roll surface data

Here we list the properties of our four (4) surface designs, according the figure 20.
.Hardened and ground steel surface

- Special rubber or polyurethane surface
- Chromium plated surface
- Tungsten carbide surface

The type of surface depends on the application.

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5.2.3 Signal flow in detail

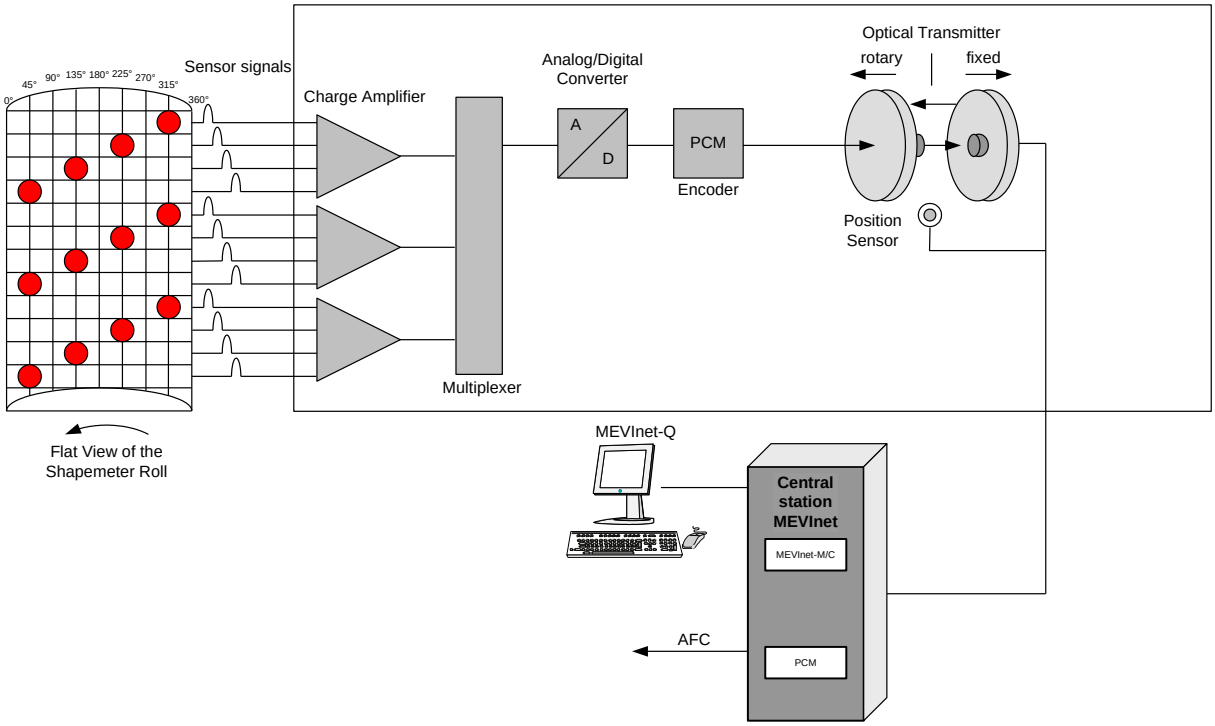

Figure 21: Signal flow

For one (1) measuring zone one (1) sensor is used. In the standard application the roll has four (4) axial bores. And the neighbour sensors have an offset of 90°
The piezo sensors are connected to multi-channel charge amplifiers which give their results to a multiplexer. On the output of the multiplexer we have an Analogue-Digital Converter which is connected to an encoder. This encoder performs a pulse coded modulation (PCM) which guarantees highest transmission speed and highest protection against any electro-magnetic inferences. Those signals will be passed optically (means contactless) from the rotating part to the static part. All the measuring cycles are synchronized with a position sensor. From the signal receiver in the static part the signals are transferred to the main cubicle where a processor unit which is called 'SIKO' (Signal Converter). This unit mainly consists of a decoder for the PCM signals and processor for the calculation of the forces per sensor. Through Ethernet interface the force values are transferred to our real-time computer for data processing, according the figure 21.
After calculation the measuring results will be given to the Automatic Flatness Control System.

6 SUMMARY

The measuring systems in this presentation must be seen as high-tech solutions in the field of processing line and 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

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quality management systems enable optimisation across the complete production process.

IMS Messsysteme GmbH supplies the necessary measuring 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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