Measuring Systems
in Coating Lines

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Measuring Technology in the Steel Industry

Surface treatment plays an important role in various fields of manufacturing such as the automotive, household appliance, building and packaging industries.

Using continuous coating techniques such as, for example, galvanic coating or hot-dip, foil and paint coating of aluminium and steel strip, it is possible to produce surfaces that improve the usability and corrosion resistance of the sheet material decisively. The different types of coatings are also growing thinner and more effective with ever more complex layer structures.

Users expect not only excellent processing properties and usage characteristics, but also high lifetime, long-term value and high quality from modern materials.

With increasing demands on coating quality, the responsibility of the manufacturing industries has grown immensely. Rising expectations regarding quality and savings in raw materials necessitate a maximum in the precision and operational reliability of measuring equipment.

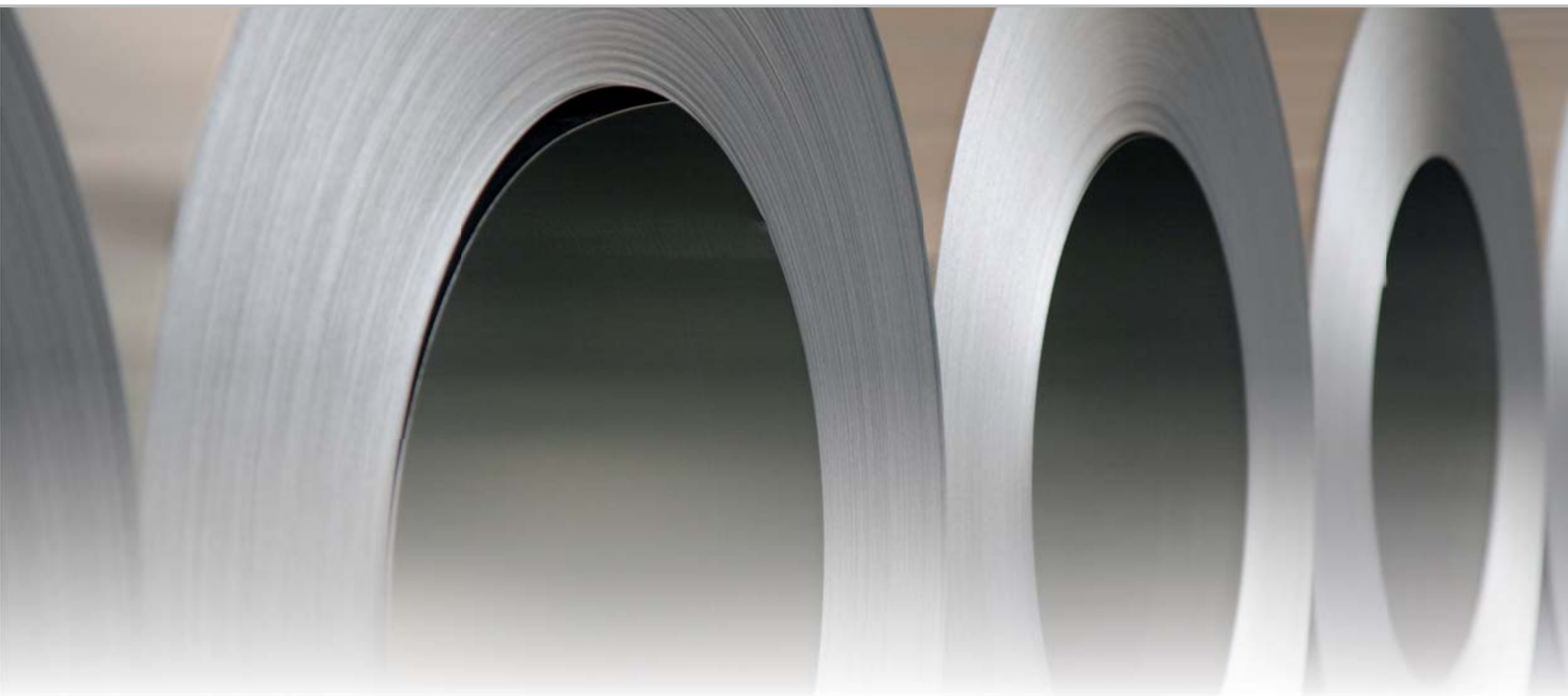
To meet the high demands, the steel industry needs innovative and accurate online measuring technology with intelligent quality management and evaluation systems.

The measuring processes and technologies described in this brochure are, together with optimised process models, precision control loops and appropriate regulating elements, the prime pre-requisites for achieving the high level of product quality required from high-speed continuous production processes.

Maximum availability and reproducible measuring results ensure the high process stability required for continuous operation.

Development of new Measuring Systems

Continuity at IMS



IMS works permanently on improving its existing measuring systems and developing new ones.

The measuring equipment is optimised continuously regarding accuracy, resolution and time response and adapted to the latest safety standards.

Output and profitability at the individual plants involved in the production of coated materials depend on, among other factors, compliance with prescribed tolerances for

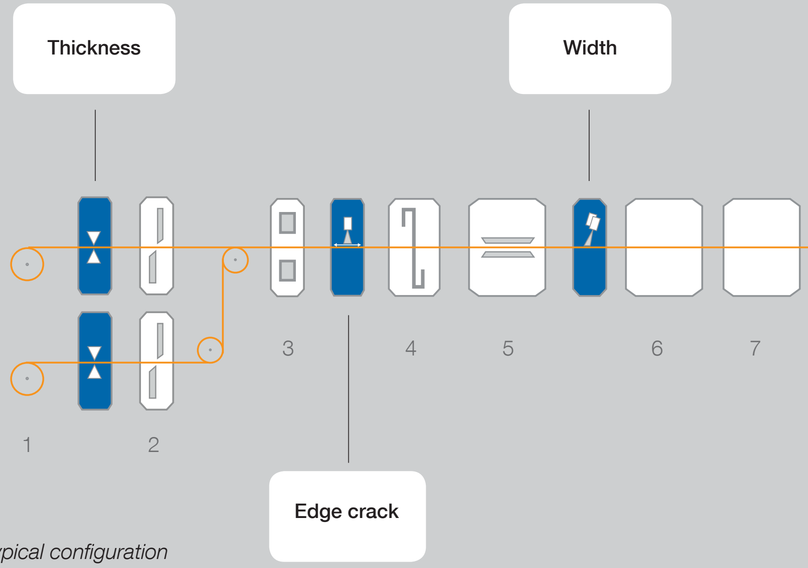
- thickness
- thickness profile
- coating thickness/ coating mass per unit area
- coating profile
- width
- flatness
- holes
- edge defects
- strip tensions

The ideal is a product with constant properties within the specified tolerance ranges over the complete width and length of the strip.

IMS has worked in close cooperation with end customers for decades to develop measuring systems and automatic controls that meet these demands.

Application

Electrolytic Tinning Line



Example of a typical configuration of an electrolytic tinning line

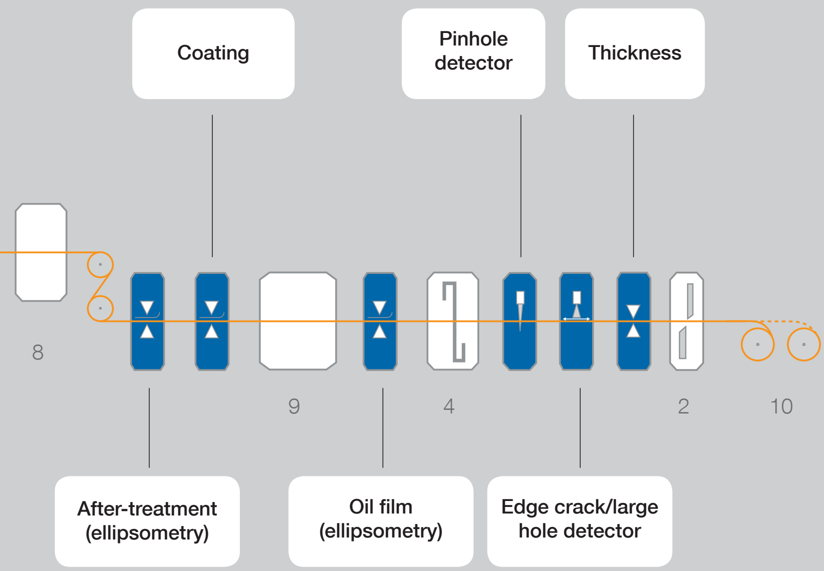
In finishing lines the input coils are first welded together to form a continuous strip. The loop tower ensures a continuous supply of strip material so that continuous strip pass through the tinning section is guaranteed even during downtimes.

After thorough cleaning by electrolytic alkaline treatment and pickling with subsequent rinsing, the strip is passed to the stannous electrolytes. There it runs as cathode between two rows of tin anodes. With the help of an electrical current, the tin is attracted away from the anodes and deposited on the strip. In electroplating tin can be deposited in any thickness, and if necessary, with different thicknesses on the two sides of the strip (differential tinning).

Standard tin layers lie between 1 g/m² and 16 g/m².

To obtain the brilliant shine of electroplated tin plate, the strip is then heated above the melting point of tin and quenched in water. Tin plate is black plate (thickness < 0.5 mm) that is coated with a thin layer of tin to protect it against corrosion.

The high adhesive strength of the tin coat acquired by melting improves corrosion protection, which is optimised by chemical after-treatment (passivation). Covering the strip with



1 Decoiler
2 Shear
3 Welding machine
4 Loop tower
5 Trimming shear
6 Process section
7 Melting
8 After-treatment
9 Lubrication machine
10 Coiler

a thin film of oil of a few mg/m² leads to better sliding properties during further processing at the customer's. The strip is inspected optically for surface defects at the inspection stand.

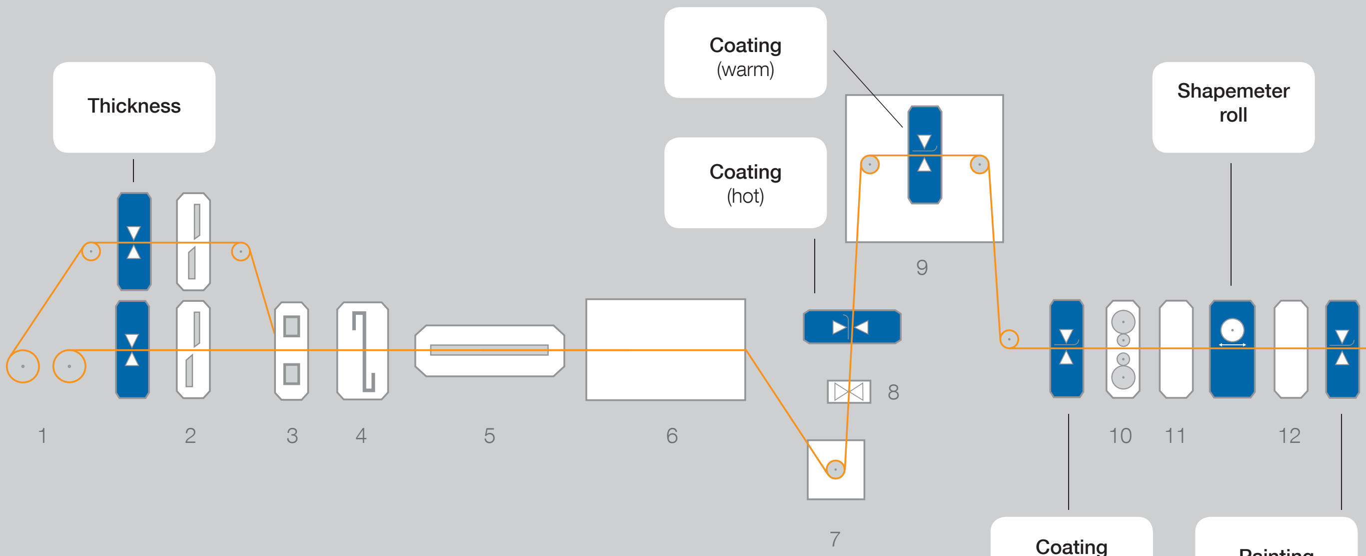
IMS offers measuring systems for electrolytic finishing lines that guarantee highest product quality:

- strip thickness gauge (strip centreline measurement or with cross profile function) in the coiler and decoiler sections of the finishing line
- strip width gauge, behind the trimming shear
- tin coating gauge at the top and bottom sides of the strip, behind the treatment section of the finishing line
- edge crack and large hole detector at the coiler and decoiler sections of the finishing line
- coating gauge to measure the passivation layer, behind the applicator in the after-treatment section
- oil film gauge, behind the lubrication machine
- pinhole detector

In a process similar to tinning, special chromium-plated black plate called Electrolytic Chromium Coated Steel (ECCS) or Tin Free Steel (TFS) internationally is manufactured. The coating thickness in electrolytic chromium coating lies between 50 mg/m² and 200 mg/m².

ECCS/TFS is used wherever the material does not need to be welded.

Hot-Dip Galvanising Line



Example of a typical configuration of a hot-dip galvanising line

The strip runs from two decoilers in the decoiling section of the line to a welding machine, which joins the front and end of the strips to form a continuous strip.

The loop tower fills up during decoiling of a coil and ensures continuous strip run in the process section of the line during welding.

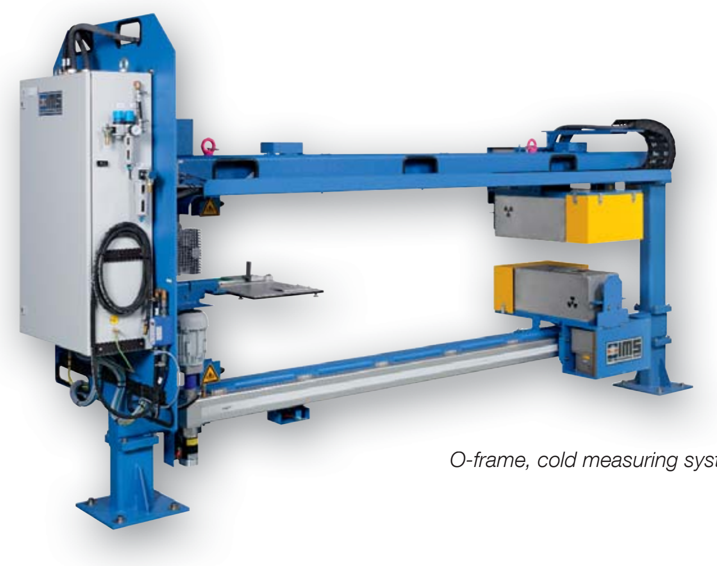
In the cleaning section the strip is freed of oil residues and iron particles. It is first cleaned by spraying and by electrolytic cleaning with an alkaline solution, followed by brush cleaning. A hot-water rinse removes the solution from the strip before it is dried with hot air.

The cold strip running into the hot-dip galvanising line is hardened to the limits of its formability. Therefore it is heated in an annealing furnace in an inert gas atmosphere at temperatures between 750 and 850 °C. After annealing the strip is cooled down in several steps to about 460 to 480 °C and passed through the zinc bath. The coating thickness is controlled by air knives arranged above the strip.

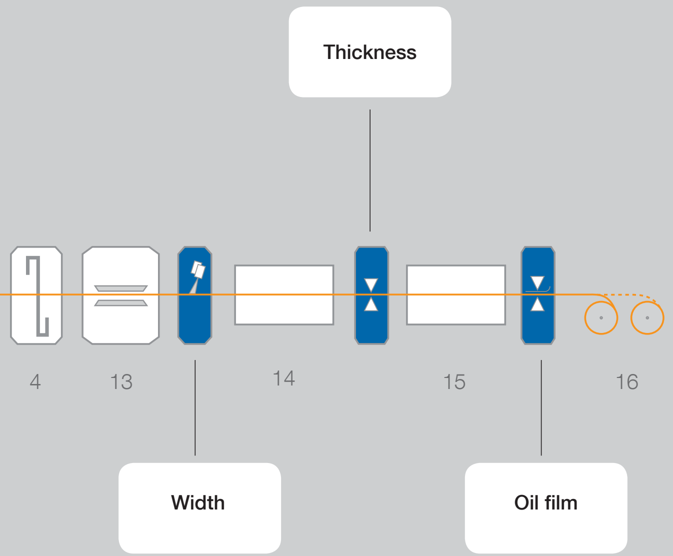
To manufacture high-grade galvannealed steel strip (GA), the strip covered with liquid zinc is heated in an induction furnace to about 550 °C.

The strip acquires the desired surface structure and material hardness in the skin pass rolling mill.

The subsequent stretch-levelling machine eliminates irregularities such as ripple, sabre or longitudinal and transverse bending.
In modern hot-dip galvanising lines coatings (paint, anti-fingerprint coatings, chromium-free passivation) can be applied in downstream roll coaters. The strip is then dried with hot air and cooled.



O-frame, cold measuring system



1 Decoiler
2 Shear
3 Welding machine
4 Loop tower
5 Cleaning section
6 Furnace
7 Zinc pot
8 Air knife
9 Cooling and galvanising furnace
10 Skin pass rolling mill
11 Stretch-levelling machine
12 Roll coater
13 Trimming shear
14 Inspection stand/Final control
15 Lubrication machine
16 Coiler

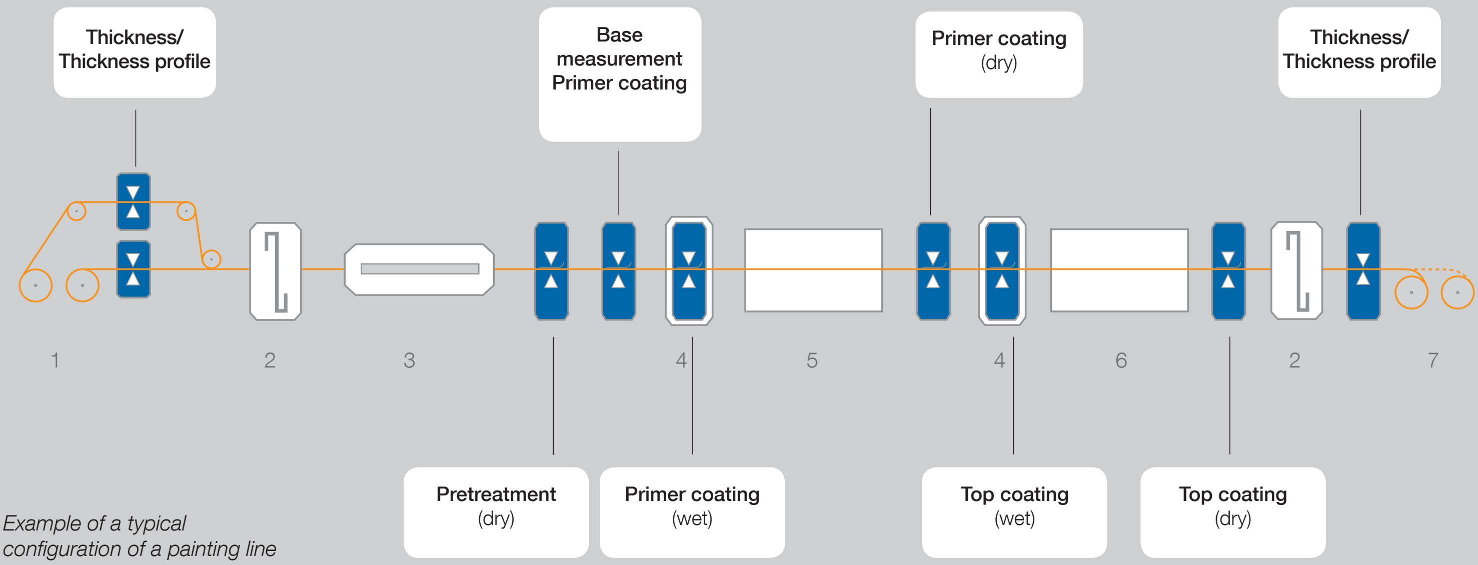
The trimming shear cuts the strip to the required width. At the inspection stand the strip is checked optically for surface defects.
In the lubrication machine a conservative protective coat (oil or wax) is applied to the strip surfaces.
Apart from the zinc and galvannealed coatings already mentioned, strips can also be aluminised or plated with zinc-magnesium coatings.

IMS offers the following measuring systems for galvanic finishing lines that guarantee highest product quality:

- strip thickness gauge (strip centreline measurement or with cross profile function) in the coiler and decoiler sections of the finishing line
- x-ray coating gauge on the top and bottom side of the strip as hot, warm or cold measuring system, behind the air knife in or behind the cooling tower
- shapemeter roll, behind the stretch-levelling machine
- UV-VIS coating gauge *IMSpect* or beta backscatter gauge at the top and bottom sides of the strip, behind the roll coater to measure organic coatings
- strip width gauge, behind the trimming shear
- oil film gauge, behind the lubrication machine
- automatic coat control for the top and bottom side of the strip (pressure and/or distance control of the wiping nozzle)
- strip tension gauge

Application

Painting Line



Example of a typical configuration of a painting line

Coil coating is the continuous organic coating of cold-rolled, usually galvanised steel or aluminium. The process produces a painted metal strip under constant and reproducible conditions that is used in industry as material with already coated surface. Coated coils are used wherever a decorative appearance, corrosion protection and weather resistance are of decisive importance.

Due to the many different uses, various substrates are used in coil coating, chiefly hot-dip galvanised steel and various aluminium alloys.

Galvanisation produces a cathodic protection coat and increases corrosion protection in steel.

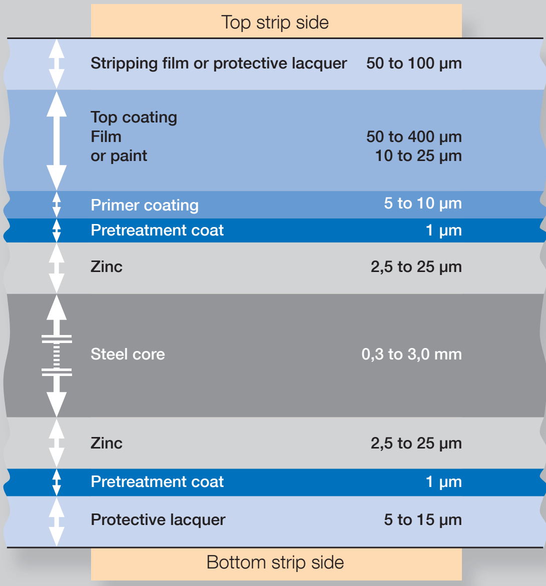
At the decoiler of the coil coating line the coil in the painting line is joined to the end of the strip already running in the line. After the loop tower the strip is cleaned, rinsed and pretreated in the first process section. These steps are necessary to free the steel or aluminium of soiling and oxide films and to apply a very thin conversion film as preparation for painting. The next process steps serve application and drying of the paint.

A primer is applied as first organic coat. From the scoop roller the primer is applied evenly to the actual applicator roll and then transferred to the strip.

The strip now coated on both sides with liquid paint runs into the first paint dryer for baking of the paint coatings. The fast heating of the strip in the paint dryer is, considering the high strip speed, necessary to limit the length of the drying oven furnace. After drying of the primer the metal strip is cooled again and then runs on to the top coating painting section. The top coating is applied in the same way already described for the primer, but the coatings are thicker. The top coatings give the strip the required colour and lustre and lend it protection against external influences (elasticity, weather resistance, corrosion resistance).

The back sides of steel and aluminium strip are often only coated with

1 Decoiler
2 Loop tower
3 Pretreatment
4 Coater
5 Drying oven – Primer
6 Drying oven – Top coating
7 Coiler



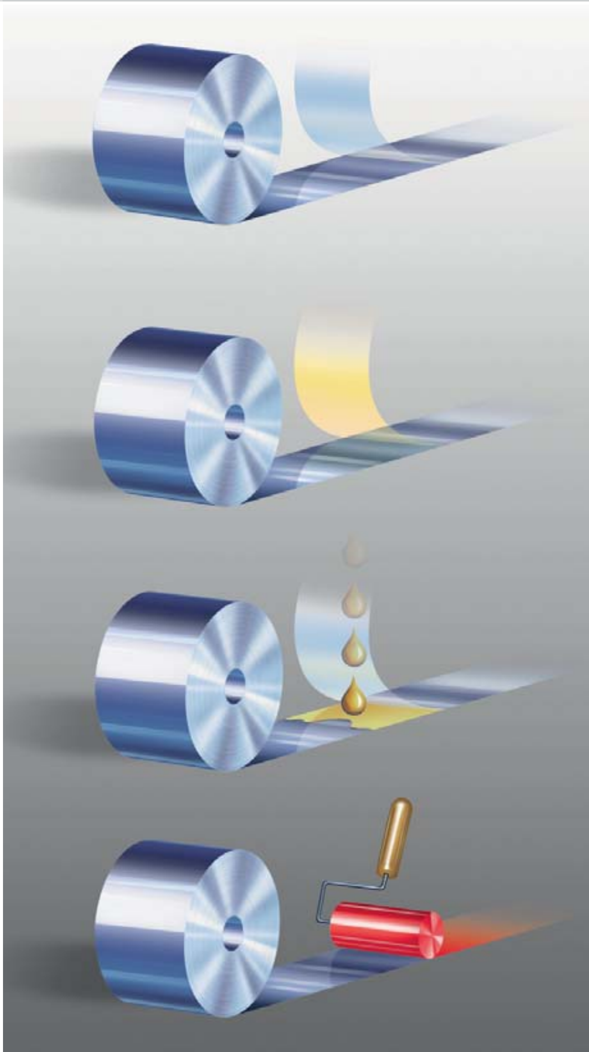
Right:
Schematic diagram of a coating sequence for a galvanized steel strip

a single layer of paint to protect the metal against corrosion.

The hot coated steel or aluminium strip is cooled and checked at a visual inspection station for visual defects. It is then coiled up.

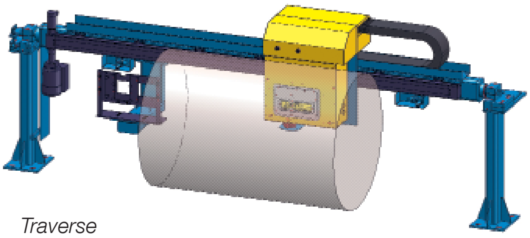
IMS offers the following measuring systems for coil coating lines that guarantee the highest product quality:

- strip thickness gauge (as strip centreline measurement or with cross profile function) in the coiler and decoiler sections of the line
- coating gauge to measure the pretreatment coat on the top and bottom sides of the strip with the optical UV-VIS measuring system *IMSpect* as dry measurement behind the pretreatment drying furnace
- coating gauge to measure the primer and top coatings on the top and bottom side of the strip with beta backscatter measuring heads as wet gauge directly behind the respective coater or as dry measurement behind the drying ovens
- colour difference measurement with the optical measuring system *IMSpect*
- automatic coat control for the top and bottom side of the strip (coater roll control) with the help of the dry and/or wet measurement
- strip tension gauge

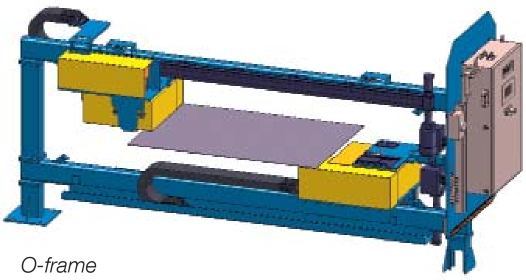


System Description

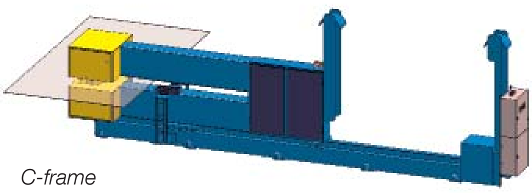
X-Ray Coating Measuring System, Cold Gauge



Traverse



O-frame



C-frame

IMS deploys x-ray systems only to measure the mass per unit area or thickness of metallic coatings (e.g. zinc, zinc/iron, zinc/aluminium, zinc/magnesium, tin, aluminium, chromium, lead).

Three different versions of gauge are used:

- traverse
- O-frame
- C-frame

Depending on the measuring tasks in question, two or four ionisation chambers are used per measuring head.

Traverse

To measure coatings on the top and bottom sides of strip, two traverses placed at deflection rolls or at a S-roll stand are needed. The strip is guided on the rolls optimally such that passline variations do not occur (except when the thickness of the strip changes). Unflatness in the strip in longitudinal or transverse direction has no influence on the measuring result.

O-Frame

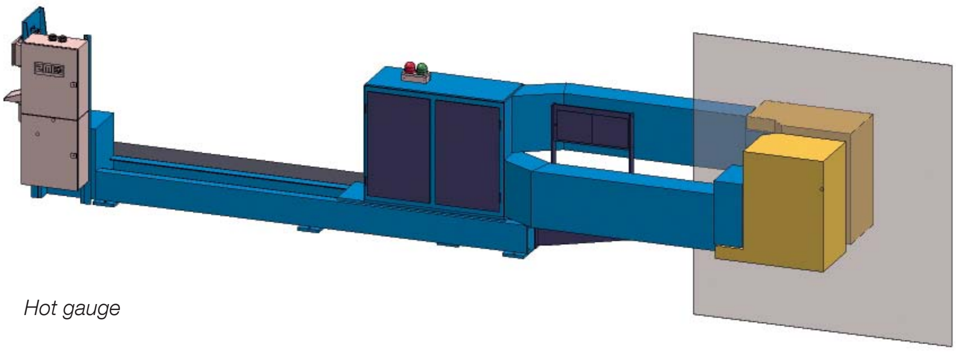
Apart from small space requirement, the O-frame version of gauge offers the advantage of easy installation. To stabilise the passline of the strip, it may be necessary to install support rolls before and after the gauge.
Like in the traverse version, the travel movements of the individual measuring heads can be carried out independently of each other.
The software offers various movement programs. Individual parameterisation is easy.

C-Frame

The C-frame for a coating measuring system is similar in assembly to that of a thickness gauge. The measuring heads for the top and bottom sides of the strip always measure the coating thickness at the same point in strip cross direction at every point in time.
Here, too, it may be necessary to install support rolls before and after the gauge to stabilise the passline of the strip.

System Description

X-Ray Coating Measuring System, Hot Gauge



Hot gauge

The hot gauge in a hot-dip galvanising line is installed directly above the air knife. Measurement is performed in the centre of the strip.

Due to the high ambient temperatures in the production line, the measuring frame and measuring heads need to be cooled.

To measure the top and bottom side of the strip, a measuring head with an x-ray tube and two detectors (ionisation chambers) is used. The measuring point is about 20 x 60 mm in size. Through use of various shutters in front of the ionisation chambers, a different signal behaviour is achieved in the case of distance changes. Correlation of the two measuring signals guarantees high accuracy in the case of position changes.

The gauges are also able to measure the coating thickness exactly in the case of strip jitter. The gauges are further protected mechanically against contact as a result of uncontrolled strip movements. If the distance between a measuring head and the strip drops below an adjustable value, the measuring head automatically gives way (optimum distance: 80 mm). The measuring heads can each move independently of each other and driven apart by up to a distance of 200 mm. If there is a risk of collision with the strip, the distance between the measuring heads and strip is increased automatically.

The measuring signal is influenced by density changes in the air due to temperature changes in the air gap between strip and measuring head.

Sensors on the top and bottom sides of the strip measure the temperature of the air sucked in from the beam path. This is used to correct the effect of the change in air temperature on the measured coating thickness.

Radiation calibration of the measuring heads is carried out outside the production area. Optimum radiation calibration is enabled by reference plates made of various materials.

System Description

Beta Backscatter Measuring System

Wet measurement

IMS coating measuring systems measure the thickness of individual coating layers applied in coil coating.

The coating weight is determined in plastic or hardened state on the top and bottom sides of the strip (separate measurements).

Depending on the requirements, wet or dry gauges are used. The wet gauges are installed directly behind the coater and deliver measured values for quick coating control. Dry gauges are installed behind the respective drying oven.

All measuring heads in the system are synchronised. The strip length-related assignment of "base" measured values (if available) and "coating" is effected by the strip tracking system integrated in the measuring system.

Measuring Principle

When beta rays hit a material, a certain quantity is reflected. The number of reflected beta particles depends essentially on the atomic number of the material.

If the atomic numbers of the base material and coating are different, the intensity of the backscatter lies between the following two limit values:

- the backscatter rate of the base material

and

- the backscatter rate of the coating material.

The signal develops according to an exponential transfer function.

The absorption process uses the energy range characteristic for the base material. Thin layers generate high intensities and thick layers low intensities.

The wet and dry indices of the paints depend on the composition of the paints and can only be determined with the help of a laboratory measurement or with a measuring device built into the production line.

Due to the small clearance between measuring head and material, the measuring head is automatically moved away from the strip when the weld seam/tack seam passes (approximately 150 mm). No measurement is possible in this time.

The measuring system is delivered with basic calibration based on a film set with known mass per unit area. This calibration cannot be changed by the customer.

All that is needed to determine the coating mass per unit area of the respective coating is the infinity index of the respective paint and base material. These infinity indices are determined with the help of a laboratory measuring device (see scope of supply) and stored in an internal IMS paint database.

In addition to the infinity index, the density of the paint is also needed to show the coating thickness (in the case of the dry gauge the dry density of the paint).

The customer's own painted sheets can later be used for reproducibility measurements. These sheets can be placed in the measuring system to check measurement results.

System Description
Force Measurement Systems, Shapemeter Roll

Force Measurement Systems

Modern production equipment is designed for high productivity and quality. To achieve these aims, it is of critical importance that all production parameters are complied with exactly.

IMS force measurement systems are used for a multitude of purposes, e.g. to measure strip and web tension. They are characterised by high precision, reliability and durability. Thanks to modern fabrication techniques, it is possible to manufacture special solutions for application-specific force transducers.
It is also possible to replace older systems step by step. In this case the measuring electronics are replaced in the first phase and later then also the force transducers. This procedure reduces the current cost of investment and delivers reliability in the event of a failure.

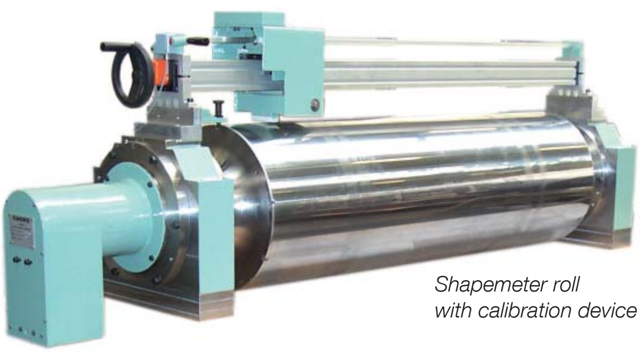
Precise – Dynamic – High-Speed Response

Our force transducers boast high dynamics, precision and fast reaction to force changes. They are also very easy to put into service. Integrated calibration signals make a reference measurement on site unnecessary. The high overload capacity – standard up to eight times the nominal load and optionally up to 20 times the nominal load – enables use in many fields of application.

Shapemeter Roll

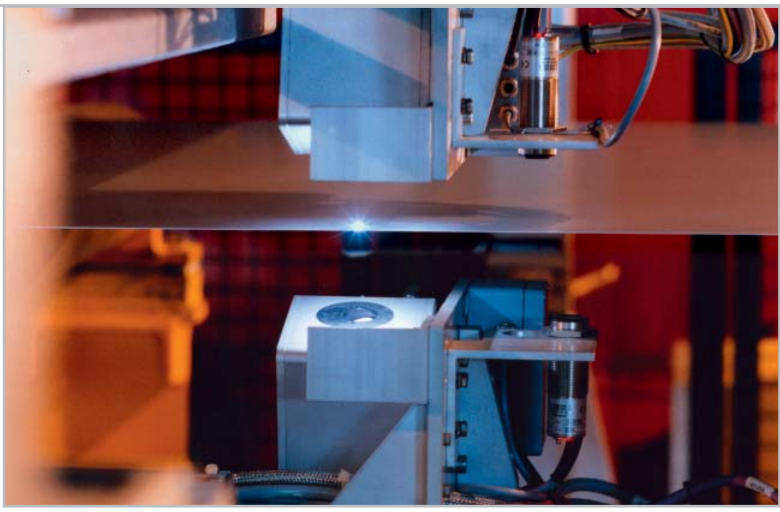
Measuring rolls to measure strip flatness are usually employed in rolling mills behind the first and last stand (in finishing lines behind the skin pass rolling mill) for optimal flatness regulation and to ensure process stability.
The distribution of the tensile forces – in other words the differences in strip length tensions resulting from differently directed strip fibres – is measured across the strip width and sent to the strip flatness control system. The force is measured by robust and high-strength quartz force sensors integrated in the roller bodies. In order for the flatness control system to respond quickly, the measured values must be accurate and sent to the control system immediately after the strip has passed the roll. The shapemeter rolls fulfil these requirements.
Depending on the application in question, the shapemeter roll can be constructed with suitable measurement zones, measurement zone width and roll surface.

Due to the optical rotary transmitter, the roll electronics are completely maintenance-free.



Shapemeter roll
with calibration device

Optical Coating Measuring System IMSpect


UV-VIS measurement with IMSpect

The optical coating measuring systems from IMS determine the thickness of organic coatings on steel and aluminium strip with the help of UV-VIS spectroscopy. The *IMSpect* measuring system measures the coating thickness of chromates, titanium/zirconium compounds and chromium-free pretreatments, paint coating thicknesses and anti-fingerprint coatings.

Transparent lacquers and thin coatings of paint can be measured very easily. Lacquers consist of bonding agents and pigments. Bonding agents are colourless and absorb light, primarily in the UV range. Pigments, by contrast, absorb radiation in the VIS spectral range.

Paint coating thicknesses are measured with light in a spectral range from UV to VIS. For this, at least a part of the light from one spectral range must pass through the paint coating and be reflected back to the surface of the material by the base material. Coatings of pigmented paint (covering paint) can often only be measured when very thin, especially in the case of dark pigments or dyes with high absorption rates.

The spectra are measured with *IMSpect* by a measuring head positioned above the strip. This measuring head transmits the measured data to a spectrometer unit via an optical light beam. The coating thickness is then determined by analysis of the light spectrum.

System Architecture

The complete measuring system consists of the following components:

- traverse with optical measuring head
- illumination and spectrometer unit
- central signal processing system
- visualisation and operating system
- quality management system (*MEVInet-Q*) for documentation and archiving of strip and system data over a longer period of time

Components

Light Source

The xenon high-pressure lamp is mounted in an aluminium housing together with a suitable power supply unit. The hinged cover grants easy access to the components. The temperature inside the housing is monitored and the components are cooled with a fan to prevent excessive heating.

Spectrometer Housing

The spectrometer converts the light spectrum into voltage signals.

Optical Fibre

The optical fibre connects the measuring head, illumination unit and spectrometer.
The optical fibres can be manufactured in lengths up to max. 12 metres. Depending on the application, one or two measuring heads are connected to an illumination unit.

Measuring Head

The measuring head consists of an aluminium housing with integrated mirror system. The housing contains connections for the optical fibre cable and for the compressed air (air wipe for the glass).

The mirror system is arranged geometrically such that the light emitted by the illumination unit is projected on to the material being measured.

System Description

Coating Measuring System Ellipsometric/Infrared

Ellipsometry

Ellipsometry is an optical measuring method for inspection of surfaces and near-surface coatings. It works by the basic principle that material reflects polarised light and that conclusions regarding optical and structural properties of the material can be drawn from the resultant change in the state of polarisation of the light.

This method of measurement is particularly suitable for measurement of very thin coatings (maximum thickness about 100 nm) such as oil films on black plate, detection of residual oil/residual contamination in skin pass rolling mills or after-treatment layers in finishing lines.

Infrared Spectroscopy

Infrared spectroscopy uses the interaction between infrared radiation and molecules. It observes the absorption/emission of radiation in dependence on the wavelength.

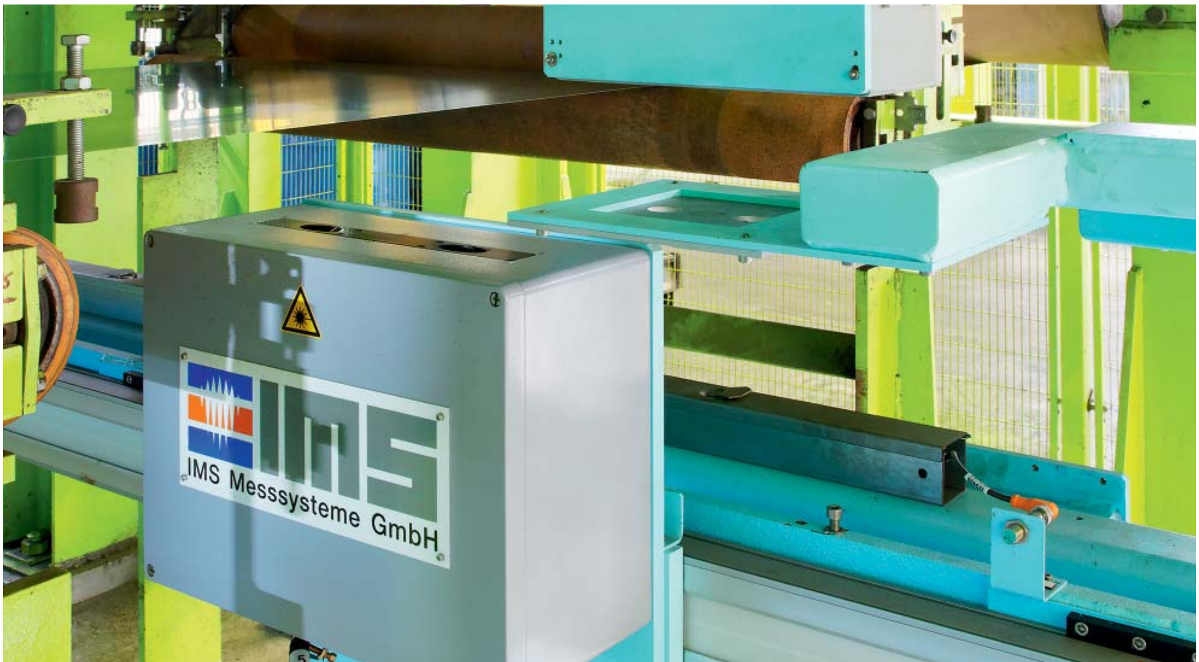
Infrared spectroscopy for oil film measurement works in a wavelength range of between 2.5 and 4.5 µm. The measuring method is used to measure oil films on fine plate with a mass per area unit of 0.2 – 3.5 g/m².

With a single calibration it is possible to measure pre-lube and dry lube oils on various base materials (coated and uncoated).

Measuring Method

The middle infrared wavelength range (MIR) of the light is defined as measuring range. Here a silicon carbide pin (Globar) serves as long-life thermal light source. The light emitted passes through an interferometer as focussed beam and is directed to the oily steel strip by deflection mirrors. The interferometer modulates the light and breaks it up into its individual wavelengths. The resultant beam passes through the oil film and is absorbed by the molecules of the oil on a wavelength basis. The attenuated radiation is reflected at the metal surface and passes back through the oil film and is focussed in direct reflection on a detector. An A/D converter digitalises the information of the detector and outputs an interferogram as measured quantity. A Fourier transformation converts the interferogram into a spectrum, which is then used to determine the oil film. The system is also able to perform and document quality controls of the oil at any system.

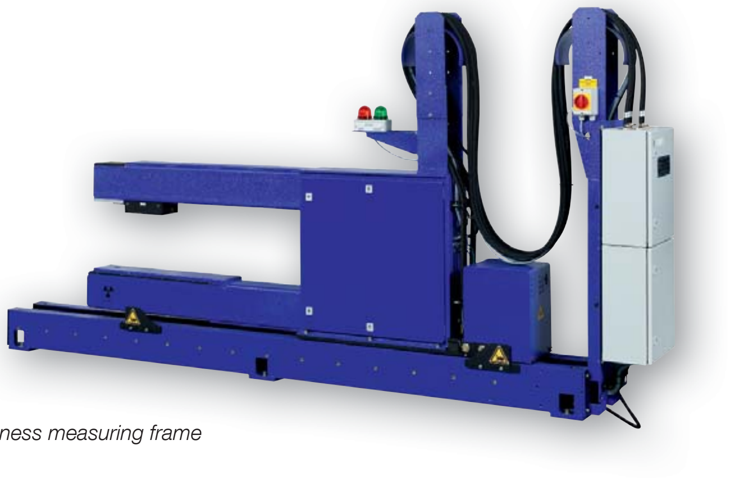
The measurement takes place in a cycle of one second and is to a large extent independent of external parameters such as substrate, angle, height adjustments, etc. The measuring head is mounted 100 mm from the oily strip and is able to traverse.



Ellipsometry measuring head

System Description

Thickness Measuring System



Thickness measuring frame

Modern production and inspection lines are run at high speeds and within tight tolerances.
Quality and profitability depend decisively on compliance with specified thickness tolerance ranges. IMS thickness measuring systems measure the thickness of material precisely on the centreline – online und without making contact with the material.

Apart from the fixed position on the centreline, the thickness gauge can also be equipped for thickness profile measurements. In this case the measuring frame traverses continuously between the two opposite ends of the material.

Advantages of our measuring systems:

- Non-contact, continuous and fast measurement of parameters in real time with the highest possible accuracy.
- The measuring devices are adapted individually to the particular place of installation and are universal in use.
- Thickness measuring devices can be equipped additionally with length and speed measuring devices

The measured values are needed to control thickness in order to obtain a specific and constant thickness over the length of the material. The thickness measuring systems are used in coating lines for final control of the product before delivery.

Measuring Principle

IMS thickness measuring systems work by the principle of material irradiation. Ionising radiation emitted by a radiation source passes through the object and, weakened by the thickness of the material, arrives at a detector (ionisation chamber) specially developed by IMS. Measuring transducers in the measuring frame process the measured values for further use.

Measuring systems in cold strip rolling lines are equipped today with advanced x-ray technology. The advantage of this radiation energy compared to conventional isotope radiation is a much bigger signal-to-noise ratio.

The x-ray systems work with a constant energy level optimised to the respective application over the complete measuring range. This results in the following advantages:

- one linearisation curve over the complete measuring range
- continuous measurements without additional switching functions and range calibrations
- no delays from thermal transient responses of the x-ray tubes because there is no change in the high voltage
- under constant conditions of use, x-ray tubes offer high lifetimes
- alloy compensations do not need to be adapted to changing energy ranges

Compensation of disturbances:

- Alloy changes by mathematical processes in dependence on chemical analysis and quality.
- Contamination in the beam path by mathematical processes during radiation calibration.

System Description

One to four detectors are used. Every detector output signal of a measuring head is treated individually as independent thickness measuring channel. A plausibility check is carried out continuously both during measurement and during the radiation calibration process. This means every channel that is not measuring correctly is detected and automatically shut out without interrupting the function of the measuring system.

System Description

Width and Edge Crack Measuring Systems, Hole and Pinhole Detectors

Optical measuring systems from IMS are used in various production lines – for example in tandem lines, pickling, coating, inspection and recoiling lines as well as in slitting and cut-to-length lines.
In production lines IMS systems measure the width, centreline deviation, strip contour, cross crown as well as the position of strips, and in slitting lines, for example, every single strip. They detect and classify edge cracks and holes.

The optical measuring system basically consists of a "camera beam" above the strip and a "backlight beam" underneath the strip. The camera beam detects the infrared radiation emitted from the backlight beam. Using an innovative camera cluster technology, 50 cameras are used per 1000 mm inspection length to perform the measuring tasks, thus ensuring extremely high resolution.
The backlight is based on LED technology and guarantees very long life. Influences from extraneous light are suppressed by use of special spectral ranges of the LEDs.
The measuring system works without electro-mechanical moving parts and is thus maintenance-free.
The distance between camera housing and strip material can be varied from very big to very small. The system can be integrated in a production line, where it requires a minimum of space, or in an existing IMS measuring system. Thanks to its modular design, the system can be extended to any strip width required.

Strip Width Measuring System

Compared to conventional traversing camera systems, the system achieves higher accuracy. The strip edges are detected stereoscopically. Vertical movements in the strip therefore have no influence on measuring accuracy. The system can optionally be extended by: hole detector and edge crack and contour measuring systems. All measurement tasks are performed in one measuring beam and communicated via interfaces.

Edge Crack Measuring System

Edge crack information is needed for optimum trimming and for quality control. The measuring beam detects the depth, length and position of cracks in the strip. Photos of the defects are also generated. The system can optionally be extended by: hole detector and strip width and contour measuring systems.

Hole Detector

The hole detector detects holes with a diameter of a few hundred micrometres and more at high strip speeds. The system enables exact localisation of the defects over the strip width and strip length and also provides information on the size and position of the holes. In contrast to the pinhole detector, images of the flaws are also produced. The system can optionally be extended by: edge crack, strip width and contour measuring systems. All measured values are determined in the measuring beam and can be visualised on a PC if wanted.

Pinhole Detector

Pinholes with a diameter of a few micrometres are a critical quality feature particularly in the production of aluminium and tin plate packaging material. The maintenance-free pinhole detector detects the size of the hole together with its exact position in transverse and longitudinal direction. The system can optionally be extended by: edge crack and strip width measuring systems.

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