OPTICAL MEASURING SYSTEMS
BASED ON CAMERA CLUSTER SYSTEMS

BY

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SYNOPSIS

One prerequisite to achieve higher product quality in high-speed production processes is use of new measurement and control technology. High availability and reproducible measurement results ensure the high process stability needed for continuous operation. The demands on optical measuring systems to optimise quality along the complete production process are discussed.

The following are presented:
- width measuring systems
- edge crack measuring systems
- large hole detectors
- pinhole detectors
- optical strip flatness measuring systems
- hot metal detectors.

IMS uses “camera cluster systems (CCS)” for all these measurement tasks. These systems comprise multiple high-speed intelligent cameras lined up one after the other in a cluster. By apposing multiple clusters, it is possible to measure foil, strip and plate of varying widths. Apart from the typical fields of application of CCD cameras, the cluster systems are also used in hot metal detectors. This article presents various cases of application as well as the results of existing installations.

Keywords: Measuring technology, width gauge, edge crack detector, hole detector, hot metal detector, flatness gauge, CCS

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1 Hundreds of mini-cameras in use in the production of slit strip

Production costs and dimensional accuracy are the most important criteria for attaining a lasting good market position particularly in the production of slit strip. They have a direct influence on the sales prices and thus on the competitiveness of the supplier. Service centres do not normally have a possibility to influence raw material prices, which means the market conditions on the buying side are mostly similar for competing slitting operators. Savings are only possible without impairing the quality of the products by shortening lead times and reducing scrap rates.

Slitting lines must work highly efficiently. Their operators are confronted daily with high setup times, caused by, among others, manual measurement of the individual strips and non-automated recording of the results. Critical problems lie in the often difficult access to the machinery and the high risk of injury, especially when measuring thick materials. Both measurement with calliper gauges and time-consuming measurement on measuring tables involve a relatively high magnitude of measurement error. Transmission errors in manual data setup and data processing are inevitable.

1.1 Customer benefits

The camera cluster systems, which are unique throughout the world, reduce the time needed for measurement and data processing to a few fractions of a second. The systems deliver measurement results of extremely high accuracy not only when the line is stationary, but also continuously along the complete length of the coil. Transgressions of width tolerance ranges are detected immediately during production and indicated. The end customers are given quality reports on every single strip delivered, thus ensuring 100% quality assurance.

Benefits:

✓ Online measurement of the individual strip widths
✓ Reduction in line setup and downtimes
✓ Reduction in wage costs
✓ Improvement in quality
✓ Continuous quality data evaluation, logging and long-term storage
✓ Compact, lightweight construction
✓ Quick amortization
2 The probably longest camera in the world detects edge cracks and holes and simultaneously measures strip width exactly

Broken strip and holes in rolling and strip lines are a frequent problem with which operators battle. High machine downtimes, damage to production lines and loss of production material cause considerable additional costs.

The most common cause of broken strip is damage at the material edges, called edge cracking. Holes in the strip, particularly in the area of the strip edges, also cause strip to break. The edge cracks/holes arise very early on in the manufacturing process. In slabs, for instance, cracks occur in the surfaces during cooling, which then migrate to the edges during the rolling process, thereby causing edge cracks or holes in the strip. High tensile stresses in the edge areas of the strips can also cause edge cracking and strip breakage during cold rolling.

Slight tensile stresses in the strip processing machinery then suffice to turn edge cracks into torn strip. Incorrect transport of coils not rarely leads to damage in the edge areas, which then develops into edge cracks in the subsequent processes.

Exact information and knowledge on defects help to avoid broken strips in mill stands and processing lines. Above all, however, data on the location and size of the cracks and holes found is interesting for subsequent processes. A quality data management system can decide automatically on the further processing steps for the coils. They are either reworked in the inspection lines if the edge crack and/or pin size and their number exceed the defined limit or they are passed on directly to the further processes. This direct evaluation prevents high-cost consequential damage right from the start.

The camera cluster technology enables full and continuous detection of edge cracks and holes as well as exact width measurement at the highest of strip speeds.

The detection of defects and width measurement are based on an optical measurement process involving the irradiation of strips with line-shaped LED sources of light. For this, a light source is mounted on the one side of the strip and a detector in the form of a camera on the other side of the strip. In the case of a strip perforation the radiation of the emitter hits the receiver/detector and signals the position of the light phenomenon to the inspection systems of the subsequent processing equipment. The distance between camera unit, light source and strip material can be varied from very big to very small and can be adapted to the mounting conditions. The system can therefore be integrated in production lines with confined spaces.
Logging of the exact time the defect was detected and the given strip speed make it possible to deduce from the data the location, shape and size of the hole in longitudinal and traverse strip direction. Photos of the defects can be saved for evaluation purposes. The defect data can be used to define quality grades or optimise transverse or longitudinal finishing.

The online inspection system guarantees the operator process stability, reduces the risk of machine failures (downtime costs) and prevents the loss of production material. Full and complete material inspection ensures constant material quality.
3 CCS camera with "microscopic eye" detects pinholes

The detection of pinholes is particularly important in the production of aluminium and tin plate for the packaging industry. Tin plate is considered a reliable material for food and animal food cans, spray cans for aerosols, beverage cans, bottle caps, buckets and canisters. Packaging made from aluminium is also indispensable for our everyday lives if one only thinks about the preservative effect for beverages, milk products, chocolate, ice-cream, coffee and tea, soups, dry food or ready-made meals. And not to be forgotten are medicines (tablets, ointments, sprays), glues and ink cartridges.

It can fundamentally be said that the thinner the plate or foil is, the higher the likelihood that pinholes and edge cracks will form. Pinholes occur mostly as a result of external and internal contamination during smelting, casting, rolling and annealing. The size and shape of the pinholes depend on various factors. The type and size of the contamination and the physical and mechanical properties of the rolled material in particular play a decisive role. Damage and contamination on work rolls are also a common cause of pinholes. They can range in size from a few micrometres to several millimetres.

To achieve high quality standards, it is particularly important to detect all pinholes or cracks, no matter how small, in the material already during the manufacturing process of aluminium and tin plate. Pinholes are not only a quality feature, they are also the reason for broken strips, particularly in the case of foils. The detectability of a hole depends on many parameters (MTF and light intensity of the lens, sensitivity and resolution of the image sensor, intensity of the light source, strip speed, hole position, etc.).

The pinhole detector developed for the metal industry has very many image sensors lined up next to each other in a camera housing. These sensors communicate with each other via a digital highway and exchange neighbourhood information. There are 50 image sensors in a beam-shaped camera housing per metre measurement range. The "mini-cameras" are lined up next to each other with a gap of 20 mm in between. The field of vision of the cameras used for evaluation of the data lies near the optical axis, which means the defects can be detected optimally. Measurement is based on detection of finest quantities of light by CMOS photosensors.
Thanks to intelligent strip edge tracking and control of the power LED light source, it is possible to achieve very small edge blankout. The strip is inspected to almost 100%. The pinhole detector measures directly online in a non-contact process during production at the highest of production speeds. The system allows detection of perforations of a few micrometres in size including determination of their positions in a millimetre range.

![Figure 4 Pinhole in aluminium foil, approximately Ø8µm](image4)

![Figure 5 Pinhole in aluminium foil, approximately Ø8µm](image5)
4  Mini-cameras and multiple laser pairs measure the flatness and levelness of flat products

Strip shape is a key property for the quality of flat products in the metal industry. Flatness has a big influence on the strip shape. A flatness or levelness measuring system and its control are critical factors for success that lead to improvement of the quality of the products manufactured. They reduce equipment failures, equipment damage and scrap rates.

A common ground for complaints regarding strips and plates is transgression of the tolerance limits for flatness and levelness. The typical defects are centre buckles and wavy edges, transverse crown, coil set and turn-up/turn-down. The defects are mostly caused by the rolling process or in the subsequent cutting process.

To achieve optimum strip flatness in various production steps, both contact and non-contact flatness and levelness measuring systems are used. They are used for online and offline operation.

The optical CCS flatness/evenness measuring system is based on the measuring principle of laser triangulation and is mainly used in plants such as galvanising lines, tinning lines, pickling lines and annealing lines, cut-to-length lines, slitting lines and stretcher-levellers in cold rolling mills and service centres, i.e. wherever the material is subject to low to little strip tension. The system consists of two components: a laser and a camera unit. Multiple pairs of laser lines are projected on to the surface of the strip across its complete width and then detected by cameras. Fifty matrix cameras are used per 1,000 mm inspection length to film the surface of the material and evaluate the laser lines. These intelligent camera clusters offer superior image data processing with high sampling rates for matt and shiny surfaces. The arrangement of the laser lines ensures that flatness defects with very short wavelengths can also be detected. The topographical and flatness data can be used for control systems and / or shown at an operator station for monitoring and control purposes. Thanks to the compact construction and pre-calibration, installation and commissioning of the system are very easy, even in confined spaces.