Optical Measurement Systems for Quality Improvement in Hot Strip Mill and Plate Mill Technology

Helmut Hlobil\textsuperscript{a}, Johann Reisinger\textsuperscript{a}, Gerhard Trinkl\textsuperscript{a}, August Wurm\textsuperscript{a} Michael Traugott\textsuperscript{a}

\textsuperscript{a}vatron – voestalpine mechatronics GmbH, voestalpine Str.3, 4031 Linz, Austria

INTRODUCTION

The use of optical measurement technique in steel production lines both for hot and cold strip increases steadily \cite{1}. Supervision, inspection and measurement tasks - each important fields for quality assurance - are already state of the art for systems based on image processing technology. This contribution shows the possibility of application of optical measuring technique in hot strip mills and plate mills.

One of the most important parameter to be known during the rolling process is the size (shape) of rolled material directly after the rolling process. The measuring devices shapescanner and geomecs fit these requirements. Both systems are designed to measure the shape of the plates fully automatically and determine a set of data necessary for the rolling process to be controlled and optimised.

A very similar measuring principle is applied for two other measuring devices - cambermecs and centerliner:

cambermecs measures the camber of the strip. It can be installed close to the stand to optimise the rolling process itself as well as behind the finishing mill to optimise the coiling the strip.

The centerliner is designed to measure the position of the strip in the finishing mill. The strip position is essentially important for the geometric strip quality (profile, flatness, …).

Optical measuring systems are non-contact systems which turned out to be a big advantage in the rough environment of hot rolling processes. The basic assembly of these systems is quite simple (the sensor, e.g. a CCD-line- or aera-scan-camera; the illumination unit, a backlight or a laser; an IPC for data acquisition and data evaluation). In combination with increasing algorithm quality and increasing CPU-speed, optical systems have become more and more an alternative to devices based on conventional measuring technology.

MEASURING PRINCIPLES

Self-Radiation

Steel with a temperature above about 650 °C emits radiation not only in the near infrared but also in the visible red spectrum. Sensors of CCD-cameras with a spectral sensitivity in this region (600 nm up to 750 nm wavelength) are designed to get a signal (picture) from these objects which can be subsequently processed by image processing algorithms. Figure 1 shows a shot (by a CCD area scan camera) of a hot block (about 1200 °C).

![Figure 1: measuring principle: self radiation](image)

The choice of the exposure time of the camera on the one hand and of the aperture of the objective lens on the other hand determines the light intensity, the sensor is exposed. The sensor has a dynamic range of typically 256 gray-levels. It is to be considered, that the exposure of the bright zones (the hot material to be measured) does not exceed the gray-level of 256. Otherwise over-exposure appears which leads to a so-called blooming effect. The object to be measured will appear distorted in this case.

The emissivity of the body in the spectrum of the sensor increases with higher temperature. To get optimum measurement results over a wide temperature range it is necessary to avoid the blooming-effect by using a proper exposure time or a aperture-controlled system. Figure 2 shows the...
same block with proper exposure-time (right) and with too high exposure time (left).

Figure 2: example for wrong (too high)/correct exposure time

Back Light Illumination

If temperature can not be guaranteed to be higher than about 650 °C it can be necessary to use backlight instead of light caused by self-radiation. An illumination unit with a high light intensity has to be used. It is not possible to illuminate a large area (to use a principle similar to the self-radiation method) behind the object between the rollers or below the roller table to get the same measurement ranges as with the principle described before. So it turned out to be useful to use backlight in a line-form (e.g. a fluorescent tube) in combination with a line-scan camera. Figure 3 shows the measurement principle. The left picture shows two fluorescent tubes between two rollers of the roller table. The right picture shows the same field of view with an object (steel plate) passing this region. The line scan camera detects the transition from the back light below the object and allows the calculation of the width of the plate.

Figure 3: measuring principle: back light

The advantage is to get an optimum signal quality because there is no need of controlling the exposure time because the backlight is of constant intensity. This principle demands a position signal to be available to synchronize the measured spots of each width measurement with the actual position of the object to be measured. By using light sources of cool white light temperature in combination with filters which block the red and infra-red spectrum it is possible to measure objects with temperatures of room temperature up to 850 °C.

MEASURING DEVICES

Shape Measuring Devices

The shape of rolled slabs is one of the most important parameter needed to optimize the rolling process. Two systems designed by vatron meet this demand: geomecs and shapescanner.

Geomecs is based on the back-light measuring method. It is typically installed above the roller table a couple of meters behind the stand (e.g. 200 m, next to the hot levelling machine). During the pass of the slab or plate width, position and temperature is collected every 10 mm without influencing the production process (Figure 4).

Figure 4: principle geomecs

A line-scan camera synchronized with a laser velocimeter measures the width signal every 10 mm in the crop area (which is of greater interest) and every 100 mm in the middle zones of the object. The typical accuracy for geomecs is +/-4 mm for width and 0.05% for length measurement. In connection with a pyrometer for temperature-correction of the width and length information the shape data are collected and sent to a server-PC. This PC has four main tasks to fulfill:

- Visualization of the results
- Data link to the plants data layer for necessary slab information and disposal of measured data
- Calculation of parameters necessary for the optimization of the rolling process (e.g. maximum possible rectangle, special size-parameters for width and length)
- Plan for the positions of the customers’ specific plates and prescribed sample plates to be cut

Shapescanner is designed for the same features. It is erected close to the stand. So it is possible to
measure the shape after every second pass. Shapescanner is based on the self-radiation principle. Although the system is quite robust against environmental influences, heavy steam in the field of view and a large quantity of water and scale on the block have to be avoided. Figure 5 shows two possible situations: In the left picture the slab can be measured by the system in spite of the bad environmental conditions. In the right picture the environmental situation is too bad for a correct measurement.

![Figure 5: good and bad conditions for measurement](image)

Like geomecs shapescanner has the same features. The typical field of view depending on the roller table is 4 m x 5 m. The achieved accuracy is +/- 6 mm for width and length measurement in block-mode. The length accuracy in strip-mode (blocks longer than measurement field) depends on the available speed signal and is typically 0.05% of the length of the strip. Figure 6 shows a screenshot of the MMI of shapescanner.

![Figure 6: geomecs, shapescanner: MMI](image)

**Position and Straightness Measuring Devices**

To get a proper profile of the strip it is necessary to keep it centered in the line. This is important in both kinds of mills in reversing mill stands and in finishing mills.

Centerliner determines the deviation from the centerline position with an accuracy up to +/- 1 mm. Two measurement principles depending on the local situation can be applied: Stereoscopic measurement based on the self-illumination principle; Light Cutting Method with the use of a structured line projected (e.g. by a laser) on the edge of the strip [2];

Camber is a phenomenon that occurs in plate mills (mainly concerning the whole plate) as well as in hot rolling mills (mostly limited to the crops). Camber is often the reason why plates can’t be processed to get products of good quality. In hot strip mills this problem is mostly restricted to the first and last 30 m of the strip. Camber leads to a so called coil telescope during coiling which causes damage during transportation and storage of the coil.

Cambermecs (Figure 7) offers a solution for measuring this phenomenon. It can be installed behind the finishing mill or close to a reversing mill stand.

![Figure 7: cambermecs](image)

The algorithm of cambermecs considers lateral shift of the plate on the roller table. The field of view of the CCD-Sensor is about 4 m x 3 m. The sensor takes shots of the scene every 0.5 m in length direction, which means that the recorded pictures overlap. So the same measurement spot (or generally a couple of equal measurement spots) can be found in several images. By assuming that the strip doesn’t change its geometry it is possible to correct lateral shift or twist of the strip on the roller table caused by the forces of the stand or other influences on the roller table [3] with an accuracy of +/- 4 mm. This situation is illustrated in Figure 8.
We are grateful for their support of this research work.

REFERENCES


CURRICULUM VITAE

Helmut Hlobil completed his studies in Mechatronics at Johannes Kepler University in Linz in 1998. Immediately after graduating, he joined voestalpine Stahl GmbH and began in the Research Department for measuring devices. Helmut Hlobil currently works at voestalpine mechatronics GmbH which is an outsourced company from voestalpine Stahl GmbH and VOEST-ALPINE Industrieanlagenbau GmbH & Co. He is responsible for development and implementation of optical measuring systems.