TopPlan
Flatness and Levelness Measuring System

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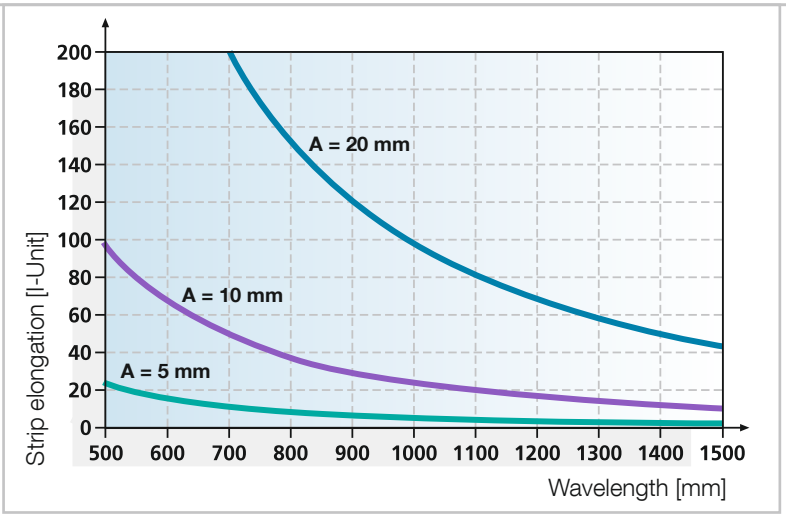
System Description

Flatness and Levelness Measuring System



Flatness errors at a given wavelengths and different amplitudes A, typical strip elongation in hot strip applications

Performance Features

- Non-contact, three-dimensional measurement of flatness, bowing and material width
- High measuring resolution over a large measuring range
- Measurement of stationary and moving objects
- Measurement at ambient and mill temperatures
- Flexible adaption to mill conditions

The topometric strip flatness gauge, TopPlan, produces a continuous, three-dimensional presentation of height distribution over a large defined area of strip by analysing pixel data from a fringe pattern projected onto the strip surface. The size of the measuring area allows for possible strip positions in horizontal and vertical direction. The evaluation of the measurement results distinguishes between flatness and levelness measurement An on-line CCD matrix camera records the pixel data from the illuminated area. The robustness of the system design and manufacture guarantees high system reliability in the most demanding industrial applications.
High material temperatures, position changes and adverse environmental conditions are taken into consideration in the design of the measuring systems.
Powerful image processing methods evaluate the projected lines mathematically and determine the flatness, levelness and shape of the material.

Applications

- Plate mills (reversing stands, hot/cold levellers, shearing lines and dressing and straightening lines)
- Hot strip mills (finishing mills and coilers)
- Cold treatment lines (pickling lines, zinc coating lines, cutting lines, tin coating lines, etc.)
- Off-line measurement – away from the production line – for quality management

Flatness Measurement

The measurement results are used as correcting variables to control the production line and therefore influence the roll gap of the stands. This minimises flatness errors to a considerable extent.

Levelness Measurement

Levelness is an important quality feature and therefore monitored and optimised over the complete production process. The measurement results are used as correcting variables for rolling, levelling and cooling processes.

Design

The gauge consists of the following main components:

- measuring position with camera and projector
- multiple computer system with components from the IMS MEVInet system
- calibration tool

Measured data from the matrix camera is transmitted to the processing computers along fibre optic cables. The processing computers, which fulfil a variety of functions, are housed in a separate cubicle.
The MEVInet-M computer system is responsible for data processing & management, and data exchange between the gauge computer and the host (customer) control computer.
The measured data are evaluated and displayed by an image processing computer.

TopPlan

Measuring Principle

The fundamentals of topometric 3D measurement have been known for many years and applied practically in the projected-fringe technique for decades. However, it was not until today's modern image processing systems and high-resolution CCD cameras became available, and the method of line analysis known from the field of interferometry was adapted, that the method of topometric measurement could be implemented in industrial systems.

The generic term *topometry* covers a group of image-generating 3D measuring methods that have the following features in common:

- measurement with structured lighting
- imaging of 3D measured data
- dynamic recording of measured values
- computer-aided on-line processing

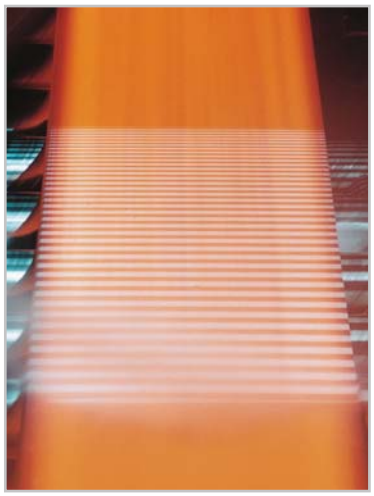
Projected-Fringe Technique

Using a slide, a pattern of lines is projected on to a target (e.g. strip) by a projector and recorded by a CCD matrix camera (CCIR standard). Deviations from the reference level (roll table) caused by waves in the target lead to distortions in the straight lines projected. This effect is used to calculate the strip flatness.

The slide has an aperiodic grating attached to it. The projected line pattern is filmed by the camera with constant line spacing over the complete measuring area.
The system resolution depends on the gauge geometry and optical components used.

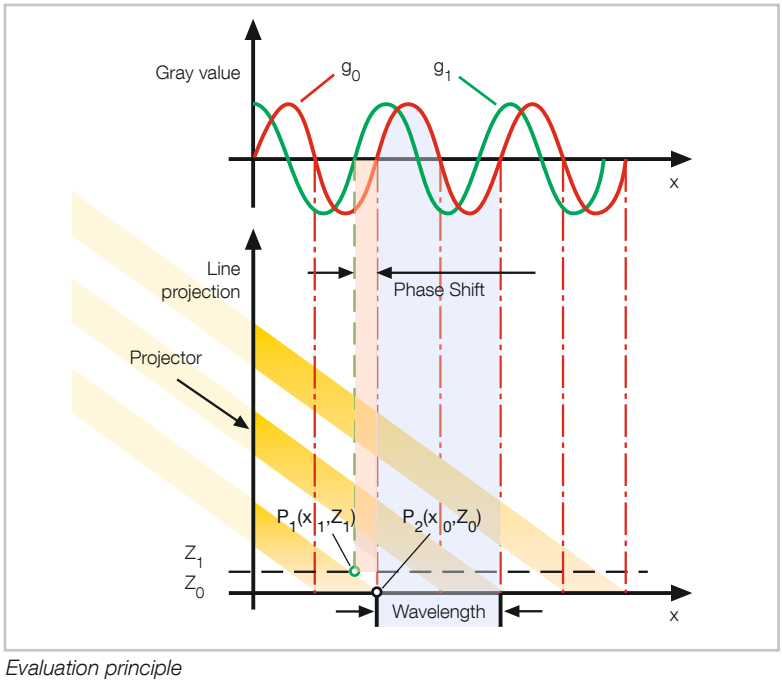
Phase-Shift Method

The distance between the lines corresponds to a height value characteristic of the gauging system and is referred as the *sensitivity*. In the line projection method the sensitivity is determined using a test body of known shape. A dynamic method based on the shift in phase between the reference level and the test object is used to analyse the lines (phase-shift method).



Evaluation Principle

Evaluation is explained on the basis of the following example (see fig. 6). A projector projects lines on to a flat surface (height Z=0, reference level) at an angle. A camera installed perpendicularly above the projection detects the line image.
The camera picture depicts the gray scale (g) of the individual lines as sinusoidal waves $g_0(x_0, Z_0)$. By lifting the reference level to a certain height Z1, the projected lines in the gray scale picture move $g_1(x_1, Z_1)$.
The height Z_1 can be calculated directly from the resultant shift in phase between the two gray scale curves g_1 and g_2 (see figure "Evaluation principle").



Evaluation principle

Application

Heavy Plate

From top to bottom:
Line projection on a measuring table
Levelness and outer contour measuring system at the exit of a cooling bed

Fundamentals

Levelness is an important quality feature in the field of heavy plate. Levelness is determined by way of elongation differences across the width of the plate and shape defects such as turn-up/turn-down, ripple or cross bowing.

Heavy plate is normally an end product. A multitude of processing steps influence the levelness of the plate in the course of production:

- rolling
- heat treatment
- cooling
- cutting / trimming
- hot and cold levelling processes

However, the automated levelness control does not only document the quality of the finished plates. It also enables systematic examination of the production process. A joint evaluation of the measurement results of various levelness measuring systems (e.g. behind the finishing stand and cooling section) can significantly improve the development of levelness over various production stages.

Measuring Points

In order to assess the influence of the individual processing steps and derive further processing steps, the following measuring points are ideal for measurement of levelness:

- exit mill stand
- entry / exit hot leveller
- entry / exit cooling section
- entry shearing line
- entry / exit cold leveller
- dressing and straightening line

System Configuration

The measuring area covers the complete width. With material widths up to 6 m, the geometries of heavy plate are much more complex than in the case of hot and cold strip. For this reason, applications using numerous projectors and/or cameras were developed on the basis of the basic configuration of one camera and one projector. A wide range of sensors also enables flexible adaptation to local conditions such as available space and crane traffic.

Outer Contour Measurement Before the Shears

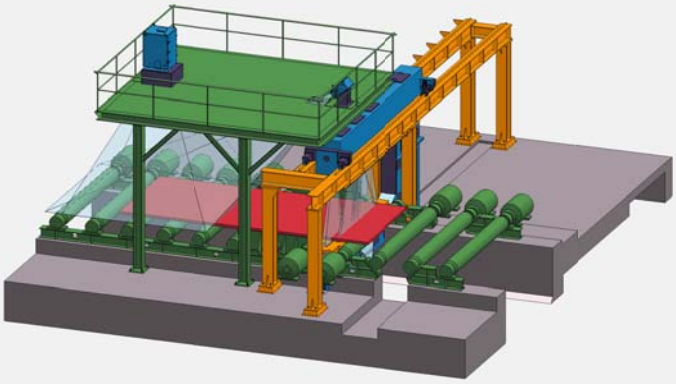
The measurement of outer contour is one case of application for a levelness measuring system in conjunction with a width gauge. Apart from measuring the levelness, this measuring system also delivers the outer counter of the plate. The optimal cuts in subsequent plate division and trimming are then determined from these values and other information (e.g. thickness and temperature profiles).

Measurement on Stationary Plate

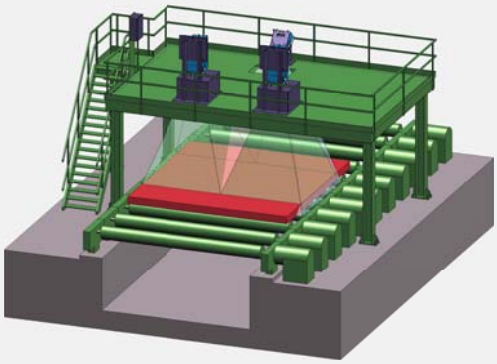
Depending on the task, the levelness must be determined either while the plate is moving or stationary. Measuring systems with combined pairs of projectors and cameras with identical individual geometries have proven effective for stationary measurement. Such systems inspect the complete surface of heavy plates with four individual systems and combines them to form an overall picture.

Gauges

Heavy Plate



Basic version of the TopPlan system (one projector and one camera)



TopPlan system on a platform (two projectors and one camera)

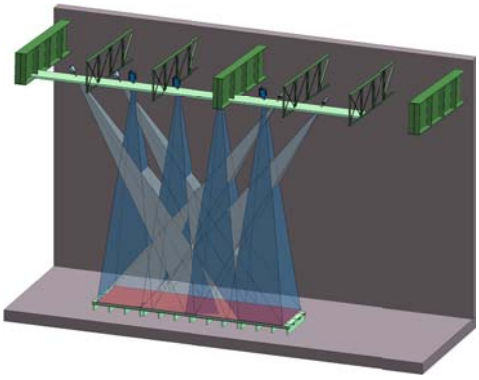
Due to its modular construction, the TopPlan system can be adapted flexibly to measuring ranges and environmental conditions.

The basic version uses one projector and one camera. In the example above the levelness measuring system is integrated with the thickness profile measuring system at the exit of a finishing stand.

Where space is limited, two projectors can be used in conjunction with one camera (see figure at top right).

In this example a width measuring system is integrated between camera and projectors alongside the levelness measuring system. Apart from levelness, this combination of measuring systems also delivers the outer contour of the plates.

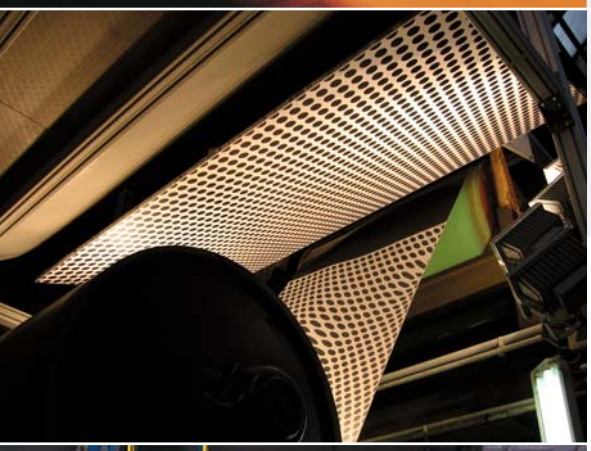
An important prerequisite in the specific application shown below is that measurement of the complete plate is effected on a flat supporting surface (measuring table) while the plate is stationary. To solve this problem, four systems are combined.



Measurement on stationary plate

Application

Hot and Cold Strip



From top to bottom:
TopPlan
TopPlan Reflect/Hybrid
TopPlan finishing line

Fundamentals

One of the main quality features for hot strip is flatness directly after the finishing line. Changes in flatness here are predominantly the result of cooling of the strip, coiling and uncoiling and other process steps.

High-precision, high-availability flatness measurement can only be realised in a hot strip line in the absence of strip tension. The flatness must be measured and corrected en route of the front end of the strip from the last stand to the coiler. This requires a quick and reliable measuring technique such as that offered by TopPlan as well as powerful control systems for stand adjustment.

Hot Strip Line Gauges

Generally speaking, the flatness measuring system is installed at the exit of the finishing line after the last stand. The projector and camera are installed either in a measuring house or on a platform.

It is also possible to install the flatness measuring system near the coiler. This system measures the flatness of the tensionless strip end after cooling in the laminar cooling section.

Pickling Line Gauge

Vor der Beize wird das einlaufende Warmband im zuglosen Zustand gemessen. Ein idealer Messort, um die Planheit zu erfassen und den Streckbiegerichter einzustellen.

System Configuration

The measuring area covers the complete width of the roller table. One projector and one camera are needed for medium and wide-strip lines in order to attain the high resolution required in all three dimensions.

The arrangement of these components is very variable and adaptable to the conditions that exist.

TopPlan Reflect/Hybrid

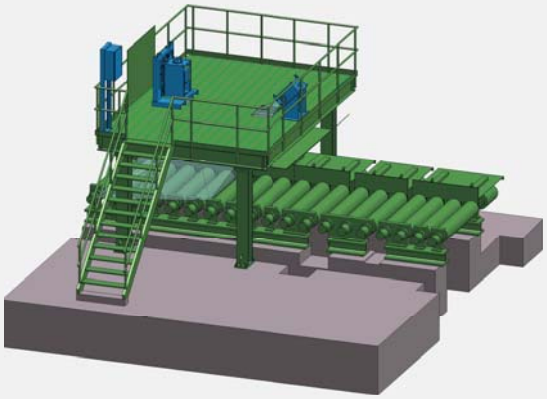
A different measuring principle is needed for shiny, reflective surfaces. A plate with a defined pattern is placed in the production line such that it is reflected on the surface of the strip. The distortion of the pattern in the camera image when the strip moves is a measure for the height distribution and thus the flatness. In the case of changing surface properties TopPlan and TopPlan Reflect are combined to form TopPlan Hybrid. This system is used in the field of stainless steel, aluminium and non-ferrous metals.

Measurement on Stationary Strip

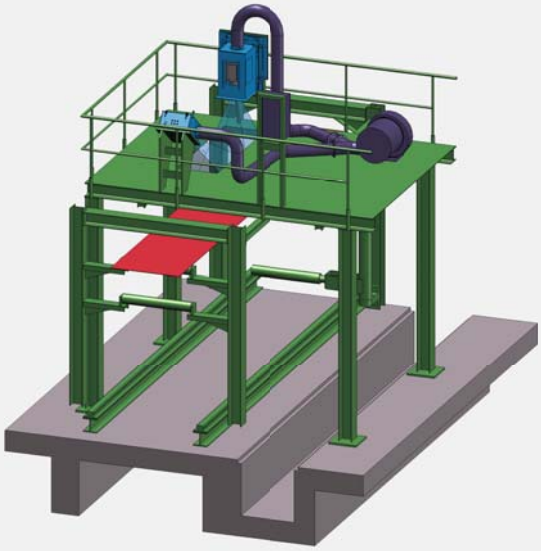
Compared to systems that are based on laser triangulation and only measure specific points, TopPlan offers the possibility to measure the surface on stationary strip. It then measures the height distribution over a larger area at one time and not just at specific points on one line. This benefit is used for sample measurements in dressing and straightening lines or for final product control.

Gauges

Hot and Cold Strip



Example for a hot strip line



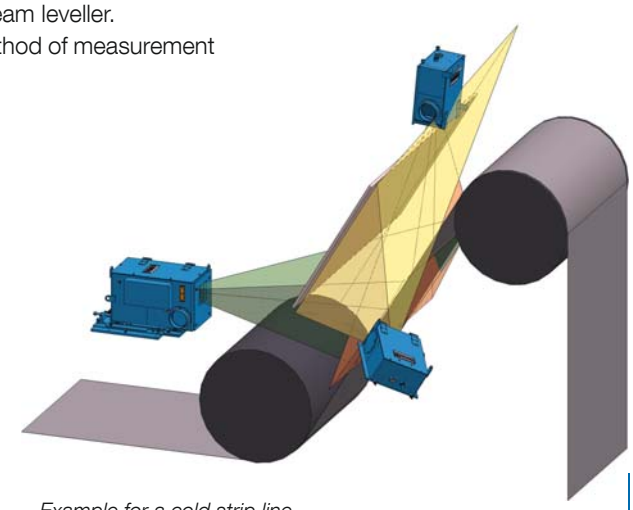
Example for a cold strip line (pickling line)

Hot Strip

Hot strip mills usually have at least one optical flatness measuring system at the exit of the finishing line.
When planning the measuring systems, the available space is analysed and the installation points for the components fixed.
The camera and projector are very variable as far as the optical components are concerned. This makes the geometric arrangement of the components very flexible.
Housings suitable for the environmental conditions prevailing at the point of installation are used and placed in measuring houses and/or on platforms.

Cold Strip

TopPlan is installed in cold strip production lines at places where low strip tension prevails.
As in hot strip applications, the measuring geometry is realised with a combination of suitable lenses and geometric arrangement.
The example above shows TopPlan in a pickling line. The measured values are used as correcting variable for a downstream leveller.
A different method of measurement is needed for materials with reflective surfaces because the projector light is not scattered diffusely here.
A method that works on both reflective and diffusely scattering material has been developed for this case (see figure below).
This combined application covers a changing product spectrum without the need for changes or pre-settings by the operator.



Example for a cold strip line

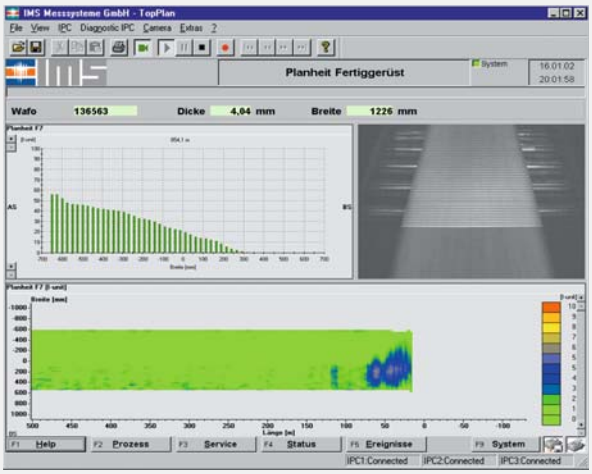
Visualisation

Flatness and Levelness

Process

The operator screen shows actual TopPlan measured data. The bar chart at the top left of the screen shows the strip length distribution across the strip width. The live picture at the top right continuously shows the current situation at the gauge as filmed by the camera. This allows a direct comparison between the chart and the measured object.

In the bottom half of the screen the length distribution is shown in pseudo colours. All flatness pictures are stored in sequence along the length of the coil thereby ensuring a detailed presentation of the strip shape along the complete coil length.



Operator screen

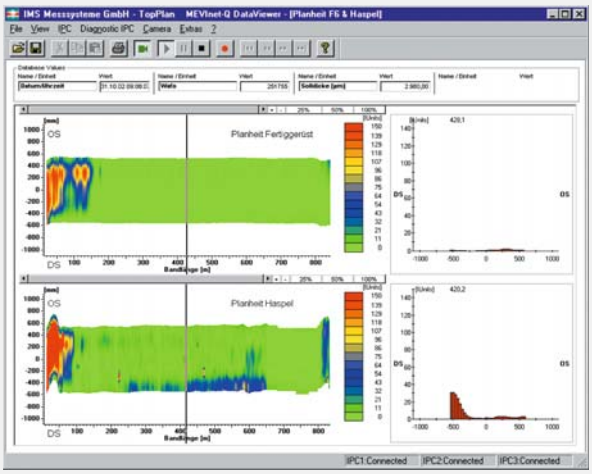
Long-term data storage system

The figure shows typical displays of strip flatness stored in the long-term archive from two TopPlan gauges installed respectively at the exit of the last stand of the Finishing Mill and before the Coiler.

Top half of screen: Exit Finishing Mill

Bottom half of screen: Entry Coiler

Any point in the display of the strip can be selected using the cursor. The bar charts at the right of the screen show the corresponding degrees of elongation.

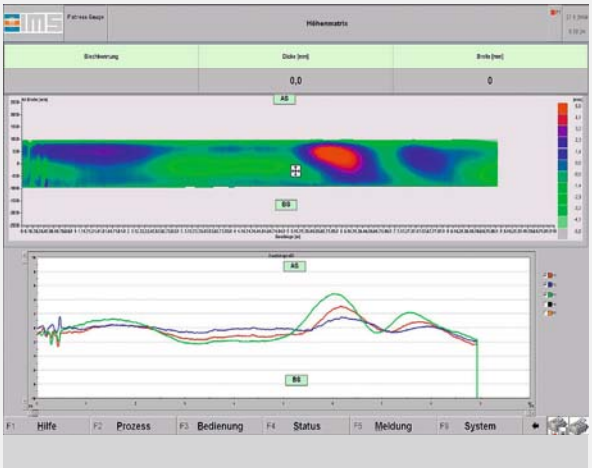


Typical displays of strip flatness stored in the long-term archive

Levelness

The height matrix of the plate is shown in the top part.

In the bottom part height progressions can be displayed in up to five longitudinal tracks.

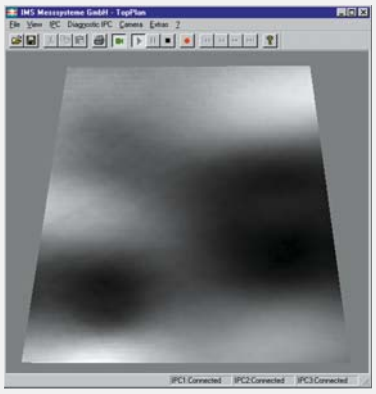


Height distribution as pseudo colour chart and height progressions over the plate length

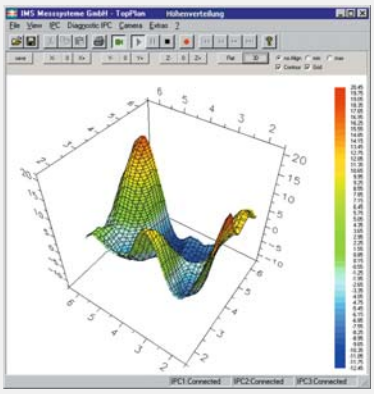
Evaluation

Flatness and Levelness

Hight Distribution
Screen displays

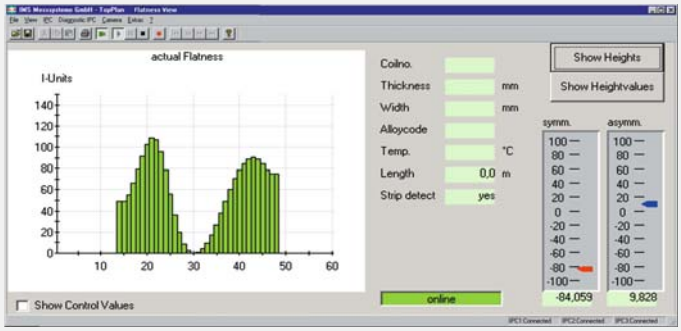


Gray scale picture



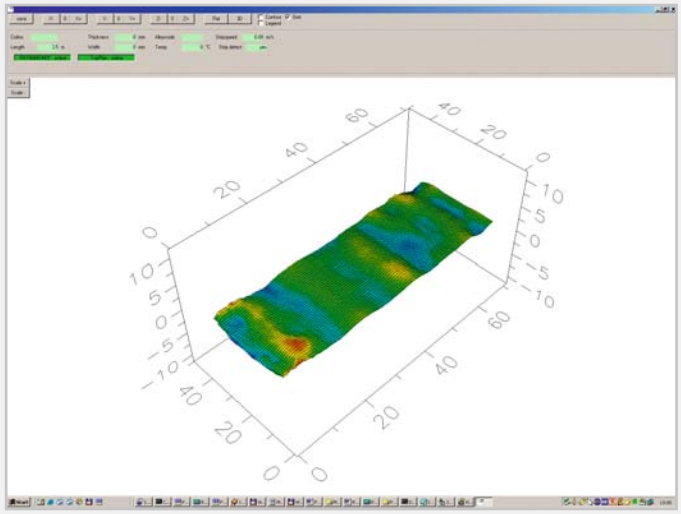
3D height distribution

Strip Flatness
Fast, live display of strip flatness with Symmetry and Asymmetry values for the flatness control system.



Display of actual measured values

Plate Levelness
After the pass the individual pictures are put together to form an overall picture.



Height matrix of a heavy plate

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