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COMPLEX PROFILE GAUGING[1]

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Abstract

The argument for on-line real time measurement of rolled profiles has never more important. In these times of high energy costs, environmental considerations and the need to produce a guaranteed high quality product, rapid feedback on size and shape are crucial in process improvement. Typical profiles that can be accurately measured are Rail, I Beams, H Beams, Channels, Angles, Tracks, blades etc

Key words: Complex shapes**;** Profile measurement.

AVANÇADO MEDIDOR DE PERFIL

O argumento para a medição *on-line* em tempo real de perfis laminados nunca teve tanta importância. Nestes tempos de altos custos de energético, questões ambientais e a necessidade de garantir a produção de alta qualidade, *feedback* rápido sobre tamanho e forma são cruciais na melhoria dos processos. Perfis típicos que podem ser medidos com precisão são trilhos, vigas, vigas H, canaletas, ângulos, trilhas, lâminas, etc.

Palavras-chave: Medidor de formas; Medição de perfil.

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1 METHOD

On-Line gauging provides the user with a real time feedback of the rolling process, this allows for the reduction in test bars and the confidence to roll product before the normal cooling and hand measurement cycle is completed.
The continuous monitoring of the product during rolling also allows for the quality to be monitored and recorded for every product produced, and this enables quality checks and production data to be analysed at a later date. This continuous measurement process also enables the detection of potential rolling defects e.g., dimensions approaching out-of-tolerance sections to be alerted to the operator before scrap material is produced.

2 TECHNOLOGY

The non-contact technology of choice for this type of measurement systems is the structured light technique. This involves "painting" multiple laser lines around the full product profile and then using high resolution cameras to view the product from oblique angles to recreate the shape within the image processing computer (Figure 1). Using triangulation measurement techniques and algorithms the system then recreates the shape of the product.
By applying dimensioning tools to this image the required dimensions are calculated and displayed to the operator.

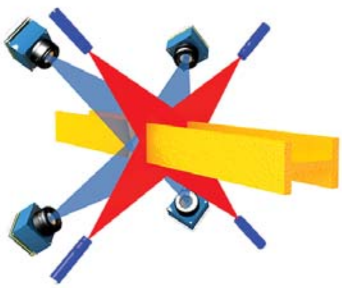

Figure 1. Schematic of the cameras and lasers layout.

2.1 Triangulation Measurement Technique

The illumination source is at 90° to the object and, as the object changes position, the reflected laser line also moves. The camera detects this as a change of angle which shifts the image on the detector.

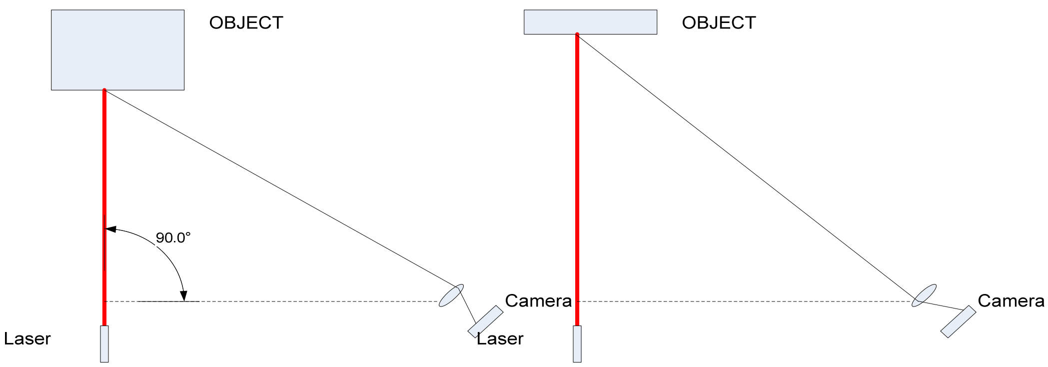

Figure 2. Triangulation method.

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As each camera is positioned at set angles relative to each other this provides, as indicated in Figure 1, a complete view of the product. Figure 3 is used to simplify the arrangement, just showing a single camera and laser pair which shows the individual camera's field of view.

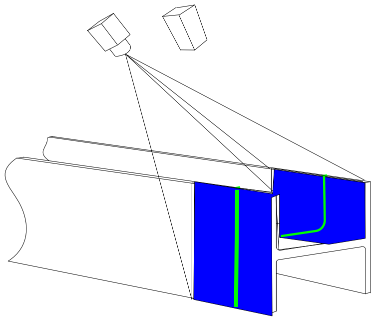

Figure 3. Individual field of view.

The resulting images from the four camera locations, when combined, provides the complete profile enabling full dimensioning (Figure 4).

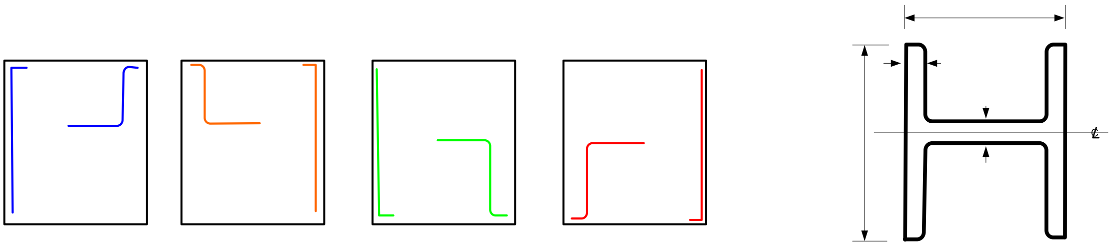

Figure 4. Individual fields of view for each of the four cameras.

Each camera position can be made up of multiple cameras to provide higher resolution measurements over extended field of views, allowing for large products to be measured to high dimensional accuracies; the resolution of the cameras can also be changed to suite the specific application. Each camera is provided with an optical filter to remove the back ground and radiated signal from the product.
The use of field programmable gate array (FPGA) technology built in to the camera performs pre-processing, only sending data which contains the valid profile information to the next stage of processing; this has a dramatic effect on the effective frame rate of the cameras; being up to 400 frames per second.
Safety interlocks prevent the lasers being turned on until a product enters the gauge, and override for maintenance is provided from the control cabinet. The laser spot is expanded through a cylindrical lens to provide a thin uniform line; feed back is provided within the system to maintain the laser at a constant operating temperature using peltier cells.
A scanning pyrometer is used to profile the product temperature; accurate, cold-corrected dimensions are then calculated and provided to the operator enabling quick judgements to be made on the quality of the product being produced.
The ProScan gauge has 4 basic models available; the choice of model of a particular application is based solely on product size.
This structured-light solution differs from the Siemens Siroll Orbis which is a fully rotating shadow-based device and is therefore limited to solid profiles such as rounds, squares, flats, hexagons and rebar. The ProScan gauge can measure simple, solid shapes as well as products with re-entrant features (providing the shape is not self masking).

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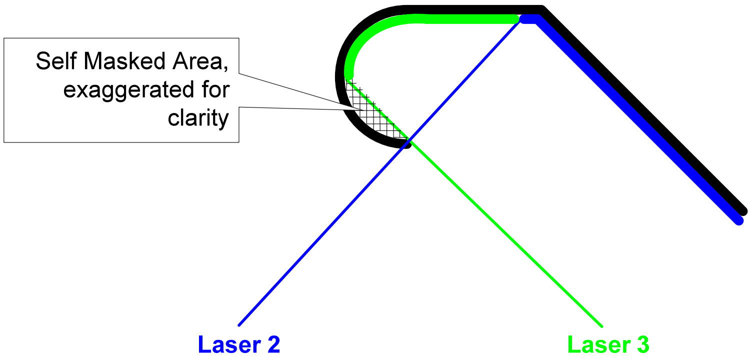

Figure 5. Effect of self-masking.

2.2 User Graphical Interface (GUI)

The user interface can be in the form of individual graphs providing information for each required dimension, this allows for the display of multiple dimensions to be shown on the screen at the same time. The benefit of this enables trends to be spotted before a major problem manifests itself in out-of-tolerance product or a catastrophic mill breakdown.

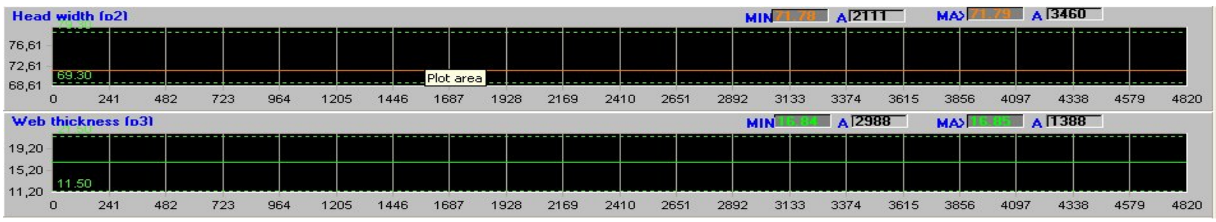

Figure 6. Graph of measurements vs. distance.

Other options for the operator can be in the form of a pictorial and numeric display; this option presents the operator with a stylised "AutoCAD" style drawing showing the actual measured dimensions and the graphic shows colour marks to show out of tolerance areas.

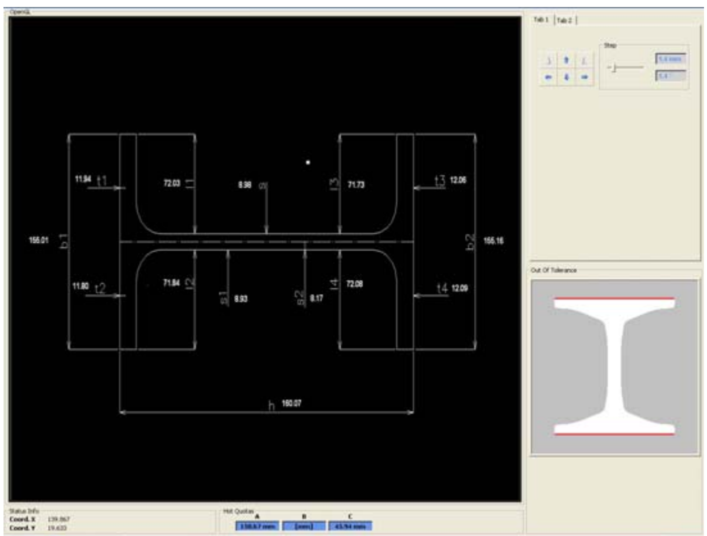

Figure 7. Pictorial user screen showing actual dimensions at indicated points.

2.3 Gauge Head

The gauge head is usually positioned after the final stand and provides a temperature stable environment to house the laser and camera assemblies. This stable environment is achieved by a multi-layer approach; firstly, a stainless steel barrier, then water cooled face-plates and finally an air-purged body with positive air pressure to maintain both the temperature and, by exhausting air via the window apertures, keeping dust from building up on the glass surfaces.

Figure 8. Gauge head on line.

Contained within the gauge structure are the 4 laser modules, 4 camera modules (which can have more than one camera each), material present detector and a scanning pyrometer, all mounted in this stable, protected environment. Provision is also made for an additional, surface-defect option.
Connection to the control cabinet is made via fibre-optic cables. These are constrained within a flexible cable management system allowing the gauge to be moved to a maintenance position using the integral trolley mechanism.
A feature of the gauge is the calibration system; housed inside the structure is a high tolerance calibration sample which, on command and safe status inputs from the mill's interlock system, the sample is lowered from the roof of the gauge in discrete steps by a stepper motor and slide passing through the cameras field of view, allowing for the complete field of view to be calibrated in a time which is measured in minutes.

2.4 Peripherals

The system is provided with a control cabinet which contains the PCs for the image capture and processing related to the cameras modules. A maintenance screen is also provided to allow for the monitoring of the system interlocks and system parameter setup.
The system requires controlled conditions to maintain the accuracy and is therefore supplied as a complete package with a closed loop water chiller. A heater option can

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be provided for those installations which require it, and a high volume air blower as part of the standard equipment, as well as all interconnecting cables and hoses,
The gauge head has wheels built into the frame thus creating a simple trolley to allow for the gauge to be removed from the line for routine maintenance and cleaning. The smaller gauges can be moved manually and the larger gauges have the option of being powered.

2.5 Options

The design of the gauge is application ready to accept additional hardware to add the function of Surface Defect Detection.
This allows the mounting of 4 additional cameras inside the existing structure which will provide all-round inspection. This is especially useful in critical sections such as rails and architectural products. This provides the user with an additional function without needing to provide a separate inspection station thus saving the costs of further line modifications.
The technique used for this function is called "temperature differential". Even small defects such as peeling or scratches can significantly increase cooling of the defect edge, due to the increase in surface area.
The software uses edge-detection to determine size and shape, presenting the information as captured images to the operator, together with a frequency indication and positional information which enable decisions to be made on quality in real-time.

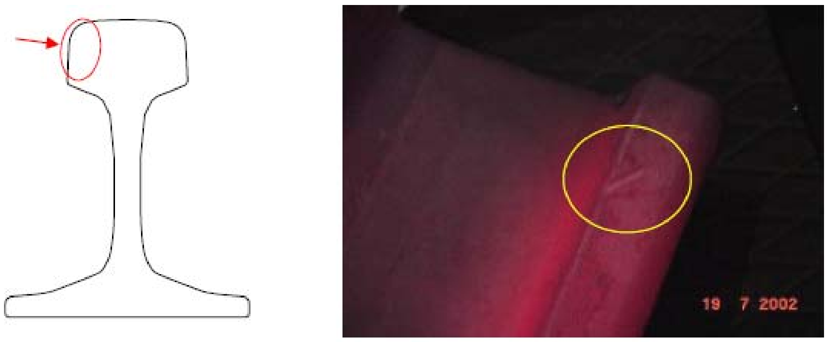

Figure 9. Indication of defect on a rail profile.

The results of the inspection are displayed on a separate workstation screen (Figure 6) and allows the operator to see the pattern of defects along the current and previous sections then, by pointing at the defect marker, a picture of the defect is displayed along with a graphic showing position.

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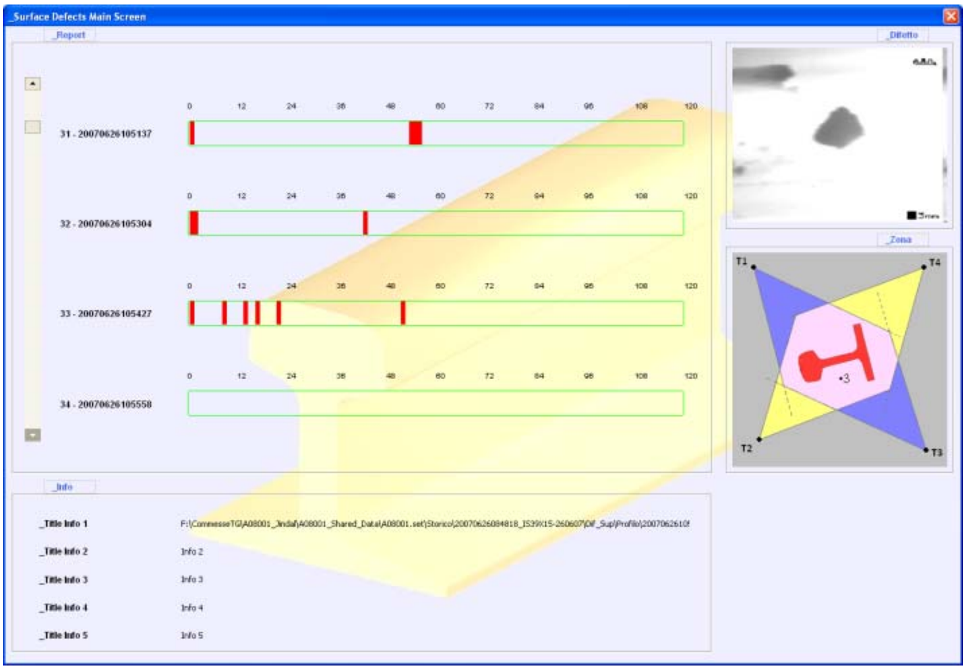

Figure 10. User screen for defect detection.

2.6 On-Line Gauging Advantages

- high measurement accuracy – the design of the gauge incorporates several levels of thermal management and the ability to have multiple cameras at each measurement position; with the added option of either standard 1M pixel or 3M pixel resolution provides the basis for the high measurement accuracy;
- very high measurement speed – utilising on-board processing of the video data enables high speed transmission of the captured signal, providing frame rates of up to 400 frames per second;
- continuous monitoring of sections being rolled – as the gauge is providing measurements of every profile which passes through the gauge, continuous measurement and recording is provided;
- ease of calibration – the in-built calibration feature allows for non-specialist calibration of the gauge;
- Simple to use – automatic download of rolling parameters from mill computer system removes the need for operator intervention;
- good HMI presentation – various options of screen layout and presentation options available to give the operator the information to make decisions on rolling process;
- low maintenance – designed for the mill environment, designed for minimal maintenance;
- on-line support – on-line support via the internet is available allowing the technical centre to intervene of provide software updates.

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2.7 Model range

Table 1. Standard model type indication size range

Model	140	320	520	820
Product size mm	105	270	460	760
Product size In	4	10.5	18	30
Accuracy mm	+/-0.05	+/-0.1	+/-0.2	+/-0.2
Accuracy In	+/-0.002	+/-0.004	+/-0.008	+/-0.008
Sample rate	Up to 400 frames per second			

3 CONCLUSIONS

The benefits of continuous product measurement which provides fast accurate dimensional information direct to the operator enables to mill to realise its full potential, including the following direct indicators:

- increased profitability;
- increased productivity;
- reduced change over time;
- early detection of rolling faults;
- reduced production downtime;
- measurements displayed as cold corrected dimensions;
- calculation of weight per metre;
- scrap reduction.

Second to this is the cost savings associated with scrap reduction in terms of both energy costs and manpower savings and of course the environmental impact of unnecessary processes.

Return on Investment (ROI) is normally measured in months, this is dependant on mill tonnage, material and costs, a full ROI assessment can be carried out to show potential savings on an individual confidential basis.