ON-LINE PROFILE MEASUREMENT OF HOT ROLLED BARS[1]

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Abstract

A new approach to on-line bar measurement is profile measurement using optical triangulation. Using this technique the actual profile of the bar will be measured. Calculated or estimated results will be eliminated. This paper describes the prerequisites, the constraints and the advantages of this method of bar profile measurement. In cooperation with Fundia Special Bar in Smedjebacken, Sweden the results of the installation of the Hot Profiler™ are reduced waste during product size change, reduced time for product change.

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2 *LIMAB AB, Exportgatan 38 B, 422 46 Hisings Backa, Sweden*

1 INTRODUCTION

On-line dimensional measurement of bars during hot rolling is important. The so far dominating technique is to use shadow based measurement principles, either static or moving solutions. The static solution is configured in one or multiple axis and the moving solution is oscillating or rotating. The shadow measurement sensor is in many cases a very accurate sensor that is used successfully in measurement applications where round products are the only or dominating final product. Diameters are measured in one or more axis and fitted to a circular shape. This gives a result where most of the bar is estimated. The shortcomings of the shadow measurement principle comes when other shapes are to be measured or even measuring on round material exiting a 3-roll RSB. In the RSB case the shadow based system will rely on the fact that no twist is applied to the bar between the exit of the RSB and the measurement position. In the case of measurement on bars with flat surfaces, a shadow based system will only be able to measure the corners or other maximum points.
The new approach to profile measurement of bars is using optical triangulation. The optical triangulation sensor measures the distance to the object. By arranging a number of sensors on a circular base plate, all facing the center of the wheel, and start rotating the wheel, the complete profile of the bar can be measured. This technique requires development of special data treatment and calibration functions.

2 OPTICAL TRIANGULATION

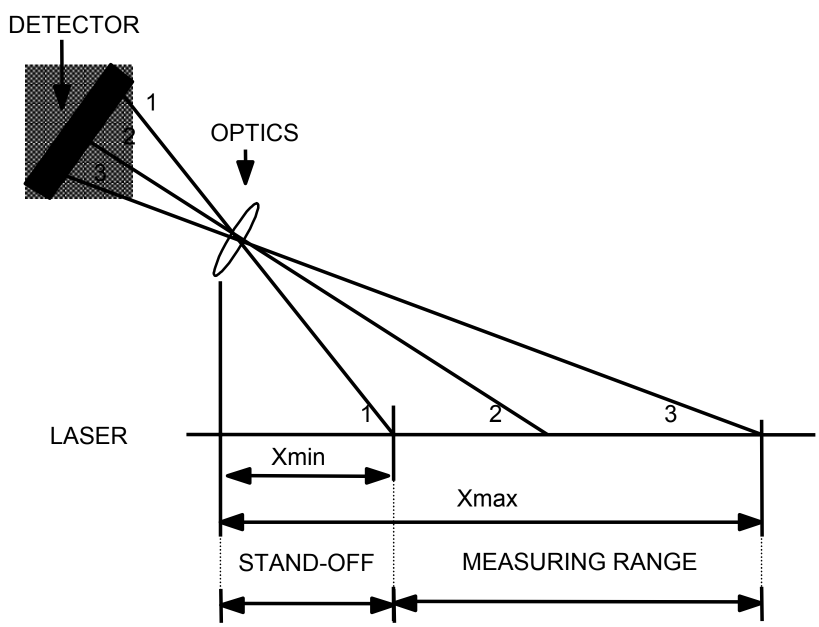

Figure 1. Display of measurement principle.

Optical triangulation is today a known and frequently used technique to measure distance at high speed and with high resolution and accuracy. Measurement sensors are normally built using a laser source generating a light spot that creates a diffuse reflection and with a digital (CCD or CMOS) detector for distance evaluation.

Important when building an optical triangulation sensor is that the distance between all optical components is kept constant. This is accomplished by using a stable mechanical base plate as the carrier of the laser, detector and optics. The base plate should be free of thermal stress and rigid in its design.
One of the big problems with on-line measurement in hot rolling mills is the differences in background radiation. The sensor must in each measurement situation be able to evaluate the ratio between the reflected light from its own laser spot and the background radiation from the hot billet or slabs. The background radiation will vary over the surface due to temperature differences. When measuring on billets or slabs, the corners of the edges will be cooler than the center part and will thereby have different amount of background radiation. The necessary exposure time of the detector will vary with the background radiation.
To be able to have fixed mounted sensors that covers the product range without need for sensor re-positioning or calibration between size changes means that the CCD will have to have sufficient laser light coming back to it even from the far end of the measurement range. In reality this means a distance between the sensor and the hot surface of up to 300 mm. In other applications, e.g. profile measurement of billets during continuous casting, the distance may be as large as 6000 mm. As diffused light spreads with the cube of the distance (r^3), laser power must be sufficient to keep the dynamics of the receiver intact.

3 OSCILLATING OPTICAL TRIANGULATION

The Hot Profiler™ is equipped with 18 optical triangulation sensors mounted on a wheel that can either oscillate or rotate while the bar pass through the center of the wheel as it is being rolled. The first challenge is to create a calibration function for the system that is quick and easy to use for the personnel and that allows a sufficient amount of misalignment when replacing faulty parts, still creating accurate and stable calibration tables for the different sensors and for the wheel eccentricity. The second challenge is to track, quantify and compensate for movement of the bar as it passes through the measurement frame. Movement will come from:
A, vibration caused by the rolling mill
B, twisting of the bar
C, bouncing caused by the tip of the bar hitting rollers on the roller table
D, bouncing caused by shears
By taking snapshot values from all measurement sensors simultaneously the measurement points can be fitted to the theoretical shape of the bar being rolled. With mathematical methods the movement component can be eliminated from the bar and the profile of the bar can be presented in real time.

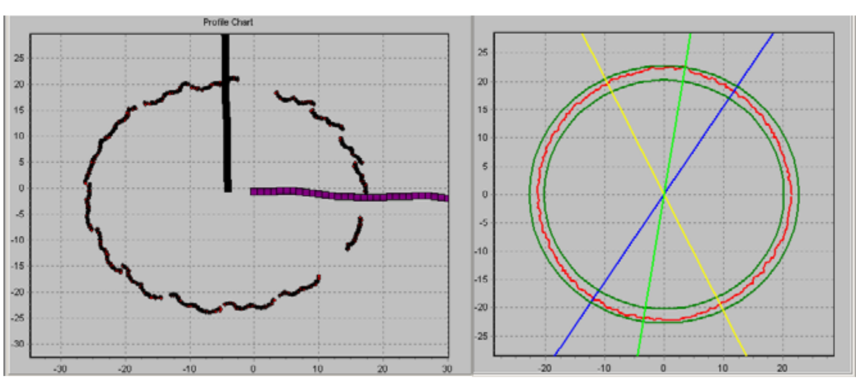

Figure 2. Raw data graph and movement compensated presentation

4 ACHIEVEMENTS

The system solution presented today has achieved the following:
Measurement range (MR): Ø 20 - 300 mm
Time to complete 1 profile: 200 ms
Sensor measurement rate: 800 Hz
Resolution: 0.01mm
Measurement accuracy,
averaged numerical values (round): ± 0.05 mm
averaged numerical values (square): ± 0.1 mm
averaged numerical values (thin flats): t ± 0.2 mm, w ± 0.2 mm
The benefits of on-line profile measurement using the Hot Profiler™ include:

4.A, Measurement of concave surfaces.
Using distance measurement technology it is possible to identify and measure concave defects. This is especially interesting for square and flat products. Semi-finished products can also be accurately measured.

4.B, Immediate feedback on out-of-tolerance production.
On-line measurement provides data for supervision of settable key figures. Early warnings can be given by trend curves and logged data. Product change times are reduced and material is saved.

4.C, The Hot Profiler is designed to be moveable between different measurement positions in the line.
The measurement unit is designed as a module with crane hooks and only one connection for air cooling and one electrical connection. This means that the Hot Profiler can be moved between different locations in the rolling mill and also be taken out of the line for service and maintenance.

4.D, Measurement redundancy – system up-time.
Using 18 discrete measurement sensors means that measurement of the production will continue even if one or more sensors are out of service. Profile measurement of round products need only 6 available sensors to provide profile measurement data, measuring flat products are more difficult and need more sensors available to guarantee profile measurement results.

4.E, Quality assurance.
By on-line measurement, 100 % of the bars will be measured and accurate reports can be created. This reduces need for manual measurements and removes the waiting time for getting measurement results, i.e. reduces possibility for production under wrong presumptions resulting in unnecessary waste production.

5 SYSTEM SOLUTION

The Hot Profiler™ system solution consists of:
1 Measurement frame
2 pcs Fan / Filter unit with air hoses for air purging of the frame
1 pcs Measurement PC with necessary I/O-cards and Hot Profiler software installed
1 pcs Industrial cabinet for the measurement PC

1 pcs Operators PC with Hot Profiler software installed
1 set System internal cables

Options include:
1 – 3 pcs Big displays for key figure presentation

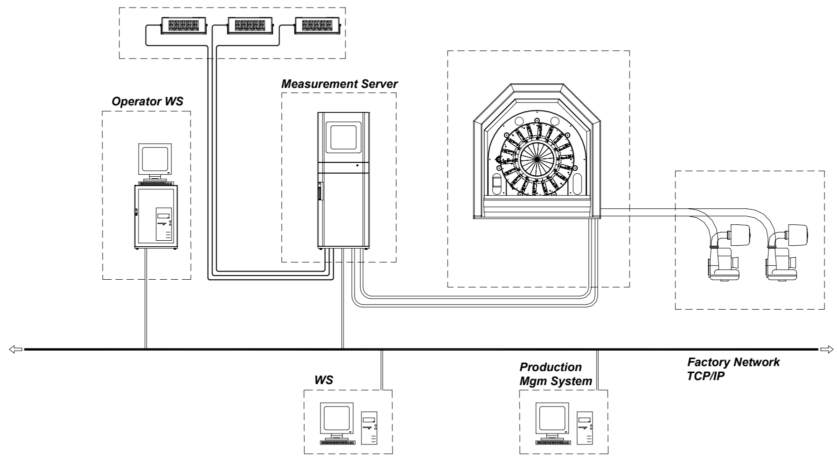

Figure 3. Block diagram of the Hot Profiler™ system.

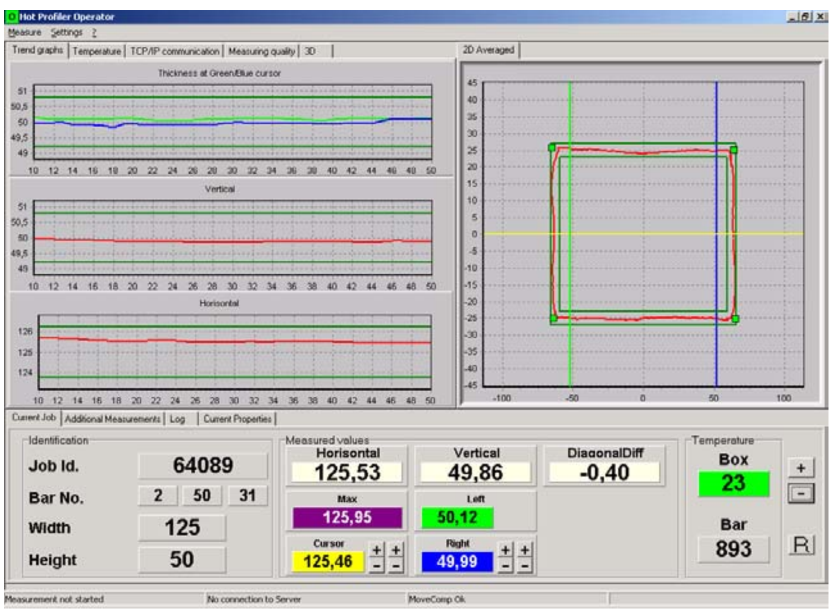

Figure 4. Example of the Hot Profiler™ operator screen.