LENGTH MEASUREMENT METHODS AND APPLICATIONS

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Summary

Cutting precision in the continuous casting process is one of the key factors to reduce waste, optimize yield and assure customer satisfaction by accuracy and consistency in delivered goods. No matter if the customer is an external buyer or the rolling mill next door, assurance that volume and weight of the delivered slab or billet meets the specifications will increase efficiency, thru-put and profit. “Value added” will be obvious at an earlier stage in the production process. This paper will present three different methods of measuring length in the continuous casting process. The applicability of the methods depends on factors such as space, accuracy demands, available funding, company strategy, technical level, maintenance requirements etc. The methods are: A. pulse counting by a contact wheel; B. triangulation laser in combination with photo cells; C. laser Doppler technology.

Key-words: Length measurement, laser Doppler, speed measurement

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1 INTRODUCTION

As steel, aluminum, and non-ferrous producers are driven to become more efficient and improve product quality, their ability to measure length (and speed) with increasing accuracy has become essential. Accurate speed and length measurements are critical measurement properties required to improve process control automation.

Traditionally, speed and length measurements were obtained from tachometers and encoders attached to drive rolls, tension rolls, contact wheels, and idler rolls. However, contact measurements are prone to calibration changes due to wear and often experience measurement errors caused by slippage between the roller and the material being measured.

The non-contact laser based measurement technology was developed more than 25 years ago. It has divided into different measurement techniques where this paper will discuss length measurement by using either optical triangulation or laser Doppler technology. The applicability of these laser techniques has become greater during the last 5 years when development has improved accuracy, size and cost of installation.

2 THREE DIFFERENT METHODS

2.1 Contact Measurement

The traditional (also the simplest) method of getting some length and/or speed information is just to mount and encoder on a roller in the roller table. Installation requires a mechanical connection to a roller and the ability to receive an input signal (e.g a pulse train, CANbus, Profibus, etc). A software routine must be implemented to convert pulses to length.

Cut slabs or billets can be measured using a photocell trigging on the leading and trailing edge of the object to be measured. By using speed signals or the pulses from an encoder the length of the slab or billet can be measured with some accuracy (factors that decrease accuracy are: object is not parallel to the direction of transportation, speed, switch time for the photo cell and slippage between object and roller).

The more advanced method would be to make a spring loaded separate wheel arrangement that would more securely follow the slab surface.

Advantages by this method are low price, low complexity, all engineering can be made “in house” and little interference with existing line. Disadvantages are low accuracy, maintenance dependant, prone to mechanical wear.

2.2 LEADING EDGE MEASUREMENT WITH TRIGGER AT THE TRAILING EDGE

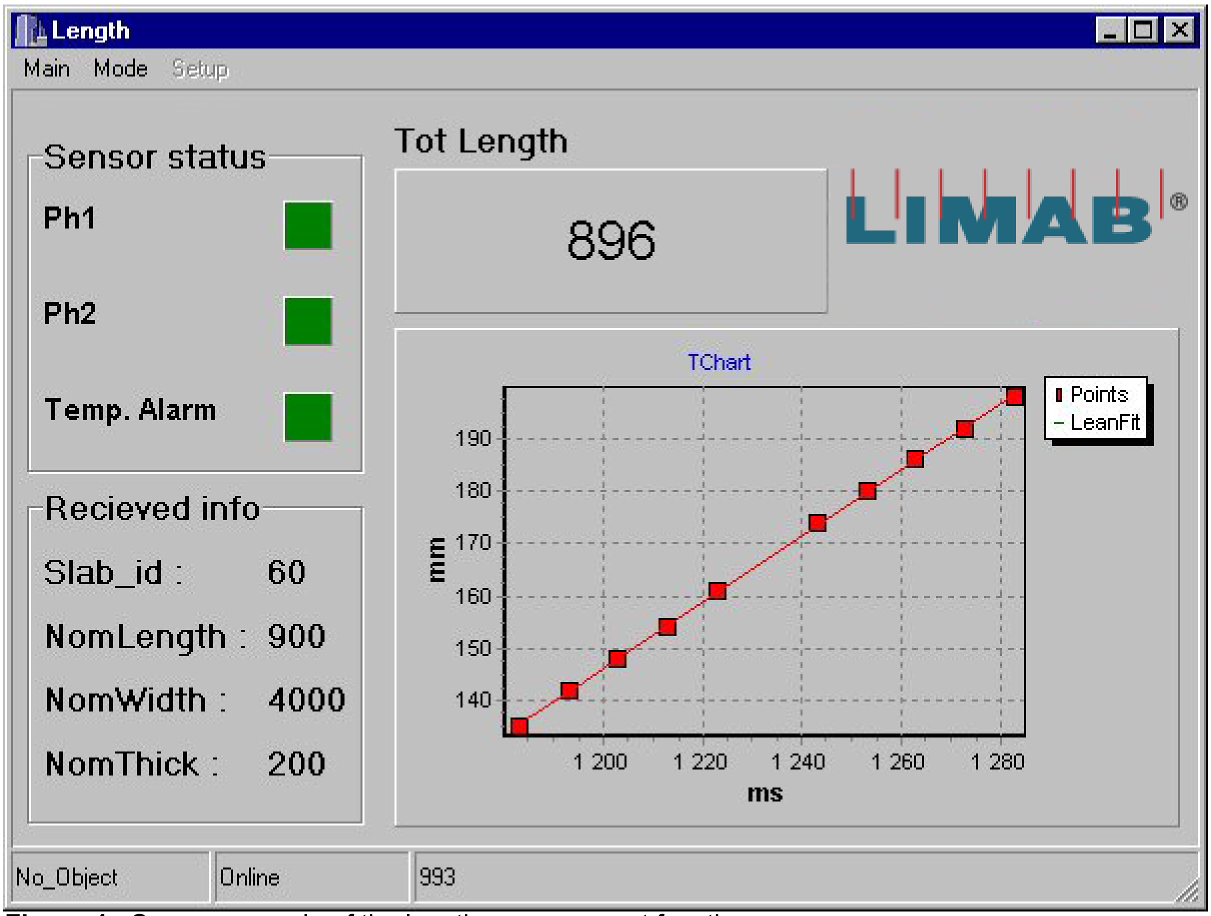

Figure 1. Screen example of the length measurement function

The technique has been developed by LIMAB for length measurement of cut slabs primarily where slab length differences are limited. The method can be implemented either at an end stop or anywhere along a roller table or a conveyor. The method uses one measuring laser triangulation sensor and photocells to measure the slab length.

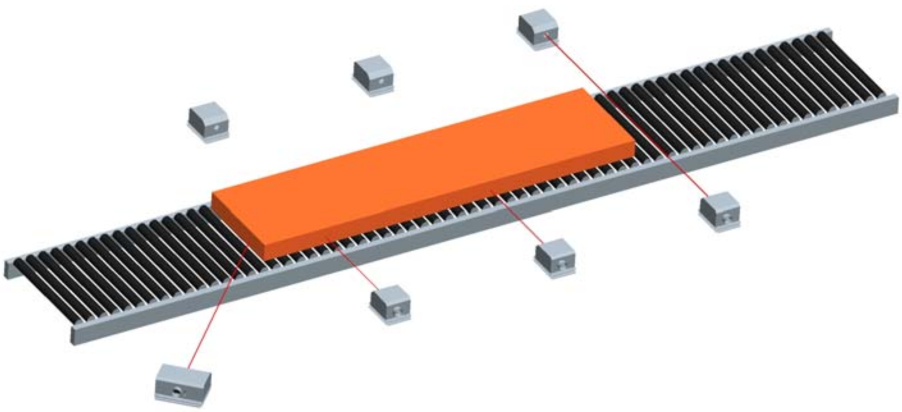
Figure 2. Principal layout

From a position next to the roller table, looking at the slab at an angle of approximately 25 – 30 deg, a laser triangulation sensor will typically measure the distance to the leading or trailing edge of the slab during 2.5 to 3 meters. The photo cells will be mounted next to the roller table at distances from the triangulation laser to be able to trigger while the laser is measuring slabs from the shortest to the longest lengths. When the range of slab lengths is big, more photocells will be needed (or if mounting possibilities of the triangulation laser is limited).
The triangulation sensor measures continuously the distance to the slab side and edge. When a photo cell trigs measurement data from before and after the trig will be used in a linear fit algorithm to increase accuracy. The length value at the time of the trig will be derived from this linear curve.

Figure 3. Photocell transmitters and length measurement sensor in the far back ground (courtesy of Siderar, Argentina)

Figure 4. Length measurement sensor in stainless steel cooling box (courtesy of Siderar, Argentina)

Advantages are mid-range price, high accuracy and repeatability, fast, low maintenance, no mechanical wear. Disadvantages comprise the fact that length accuracy will be dependant on parallelism with the conveyor transport direction, limited range of slab lengths due to calibration routines, limited ability to track direction of transportation or stopped slab, no ability to measure speed.

2.3 Speed and Length Measurement Using Laser Doppler Technology

The operating principle of this example gauge is based on the dual-beam Laser Doppler Velocimetry. When two laser beams intersect, an interference pattern of both light and dark fringes is created. This is called the measurement region and is illustrated in the Figure 5. The distance (d) between the fringes is a function of the wavelength (λ) of light and the angle between the beams (2Κ). It is represented in the following equation:

$$d = \frac{\lambda}{2\sin\kappa}$$

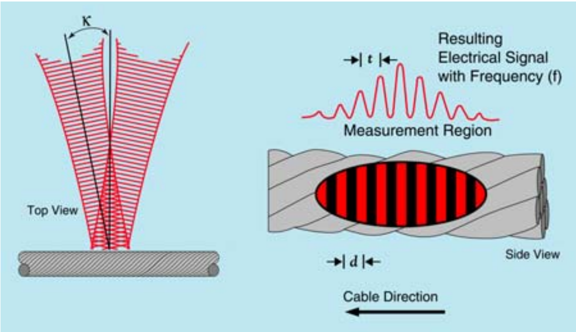

Figure 5. Measurement Region

Nearly all materials have light scattering sites — particle and minute facets that make up the surface microstructure. As a light-scattering site passes through the measurement region, light is scattered every time it passes through a light fringe. The scattered light is collected and converted to an electrical signal that has a frequency (f) proportional to the material velocity.

The material velocity (v) is obtained by dividing the distance between the fringes by the time (t) it takes the light-scattering site to move from one fringe to the next:

$$v = \frac{d}{t}$$

Since the time is inversely proportional to the frequency of the signal, the material velocity can be obtained by multiplying the distance between fringes by the measured frequency.

$$t = \frac{1}{f}$$

Therefore, v=d x f

Having measured the material velocity, the length can also be provided by integrating the velocity information over the total time.

$$L = \int_0^T v\,dt$$

Essentially, this example gauge measures speed and integrates the speed value over the total length of the material to obtain accurate length measurements. As material passes through the measurement region, the frequency of the scattered light is directly proportional to the speed of the material. The scattered light is then collected by receiving optics within the gauge and converted to an electrical signal. Such electrical signals are then processed by a state-of-the-art DSP to obtain frequency information, subsequently measuring speed and integrating it to measure length. The DSP also formats the instrument's user input and output functions.

Variations in the measurement are affected by the quality of the laser's Doppler signal and the ability of the signal processor to determine the exact frequency from a noisy optical signal. The LS8000 gauge uses the latest in signal processing algorithms to extract the most accurate frequency measurement from the optical signal. The Gauge employs a "Double Clipped Autocorrelation" function with 10 to 15 times over-sampling to achieve unparalleled measurement accuracy. Using this algorithm ensures an accurate and repeatable measurement under all conditions. The autocorrelation algorithm is:

$$A(r) = \sum_{k=0}^{N-1-r} X(k)X(k+r) \qquad r = 0,1 \ldots N/2-1$$

The algorithm is specifically engineered to operate on large-scale digital integrated circuits and is capable of making up to 50,000 individual speed measurements per second.

Figure 6 shows actual repeatability data from a LS8000 Gauge measuring on a NIST-calibration standard length.

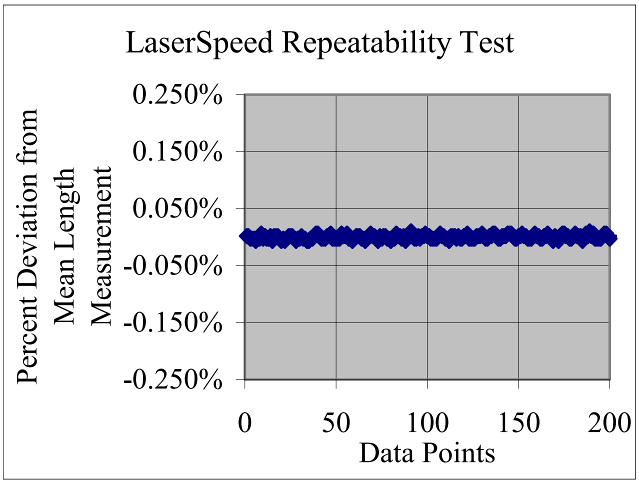

Figure 6. Repeatability Data

As can be seen by the graph in Figure 6, the repeatability offered is better than ±0.01%.

The measurement accuracy of a laser gauge is affected by several factors. The most important factors are:

- Laser collimation
- Rotational angle of gauge versus product line travel
- Perpendicularity of gauge to product
- Temperature

Collimation is the consistency of the fringe spacing, "d", throughout the measurement region or depth-of-field of the gauge. The depth-of-field is defined as the length of the intersection of two laser Doppler beams. Collimation is determined by the optic's ability to make the laser beam wave fronts completely parallel and flat. High quality optics must be used to maintain constant fringe spacing throughout the depth of field of the gauge.

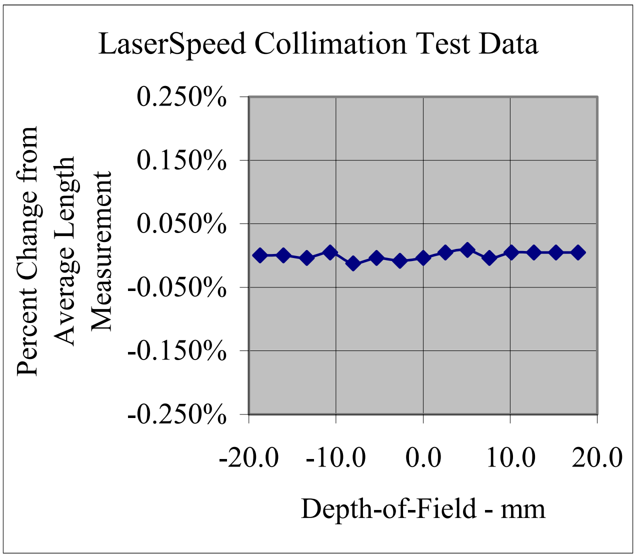

Figure 7. Actual Collimation Test Data

Movement of the product within the depth-of-field will affect the accuracy of the measurement if the fringe spacing changes along the depth-of-field. Figure 7 shows the effect of product position within the depth-of-field of the LS8000 Gauge. The test to determine the effects of product positioning within the depth-of-field is called Collimation.

Different depth-of-field lengths can be obtained by changing the angle in which the laser beams cross and the size of the laser beams. Depth-of-field values can range from a few millimeters to more then 300mm. Different models of the LS8000 Gauge offer depth-of-fields ranging from 15 mm to 75 mm.

The standoff distance is the distance from the front of the gauge to the middle of the measurement region or depth-of-field as shown in Figure 8 The standoff distance and depth of field are directly related. The longer the stand-off distance is, the longer the depth-of-field. Measurements can only be made when the target product lies within the depth-of-field of the gauge. If high-quality optics is used to collimate the laser beams, the effect of the product position within the depth-of-field has negligible effect on accuracy. However, if poor quality optics is used, different product positioning within the depth-of-field can cause measurement errors up to 2% or more.

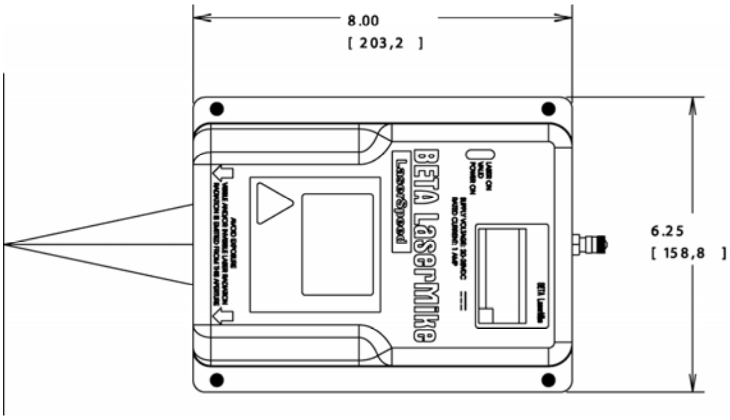

Figure 8. Depth-of-Field and Standoff Distance

Figure 9. Example of a LaserSpeed 8000E with Quick Change Window and Air Wipe

3 SUMMARY

The different length measurement solutions for continuous casters can be summarized in the following table:

Table 1

Method	Advantage	Disadvantage	Price range
1, Contact	- Cheap - All know-how in the company	-Inconsistent and inaccurate -Maintenance dependant	5-10000 USD
2, Triangulation laser/photo-cells	- High length accuracy at an affordable price - No moving parts - Most of the system can be serviced “in house”	- Limitations in practical slab length handling - No speed information	15-50000 USD
3, Laser Doppler	- No moving parts - Single unit - Measures speed and length - High accuracy	- High investment - Need to go back to the factory for service and repair	30-100000 USD