

Improving Cut Length Tolerance and Long Term Consistency In Continuous Casters with Laser Velocimeters

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INTRODUCTION:

For more than 6 years, mills have been installing noncontact Laser Velocimeters to replace existing contact length measurement systems at Continuous Casters. Installations exist on billet, bloom, beam blank and slab casters and have proven to measure length and speed with high precision, reliability and long term consistency, improving throughput and yield at the caster, as well as, downstream rolling process.

Existing contact length measurement methods such as encoder wheels, tachs on drive rolls or tachs for motor speed are the typical techniques employed in controlling cut length tolerances. Each of these methods is susceptible to the typical issues associated with contact devices like slippage, changing roll or wheel diameter and wear & tear, resulting in long term, unpredictable drift of the length measurement. These issues are particularly challenging when trying to measure on a billet or slab at 1800F. In short, contact devices measure their own rotational motion, which is not necessarily the motion of the strand, while velocimeters directly measure the motion of the strand, providing a more accurate and repeatable measurement to the control system for cut length control and tracking.

In practice, contact length measurement techniques on continuous casters deliver cut length tolerances in the range of +/- 2 inches. Moreover, to achieve these results requires frequent service and time by maintenance personnel, as well as, continuous, online process calibration by operations personnel. Without this constant attention, cut length tolerances can quickly drift beyond the 2 inch range resulting in significant weight variation and thus loss in yield at both the caster and roll mills. In fact, due to the variation in length, many mills will add an additional "safety factor" of 2-3 inch or more to compensate for this long term, unpredictable variation to be sure the roll mill does not receive less than the length or weight specified. Since length is the only dimension that can be controlled in real time at the caster, optimizing length measurements and cut length tolerances over the long term optimizes long term weight tolerances, providing greater process control and tolerances for the roll mill.

In addition to cut length, cast speed serves as an important input for process and quality control. Documenting & tracking of events such as changes in chemistry, ladle changes, changes in spray practice or other quality and process events is often required to guarantee specified mechanical properties and offers significant insight into understanding the cause and effect of process events. Errors in speed and length measurements caused by slippage between the strand and roll, introduces errors in tracking these events. The ability to precisely locate these process and quality events is vital to quality control and provides a greater understanding of the unique characteristics of a particular process for continued efficiency, quality and process improvement.

LASER DOPPLER VELOCIMETER PRINCIPLE OF OPERATION

Laser Doppler Velocimeters are noncontact, optical sensors that measure the velocity and length of a passing material. They are used for noncontact length and speed applications throughout the steel process including Continuous Casting, Hot Rolling, Cold Rolling, Pickling, Galv Lines, Tube/Pipe Mills, Rod/Bar and more.

Doppler Shift states that waves emitted or scattered from a moving object will undergo an apparent shift in frequency, proportional to the velocity of the moving object. As with sound emanating from a moving vehicle, light waves will also appear to compress or

increase in frequency as the object is moving toward the viewer and appear to “stretch” or decrease in frequency as the object is moving away from the viewer. Velocity is determined by measuring this frequency shift. Laser Velocimeters are designed to measure this Doppler frequency shift of laser light scattered from the object and provide a direct output proportional to velocity. By integrating the velocity in real time, these systems will also determine the accumulated length of material that passed by, in real time.

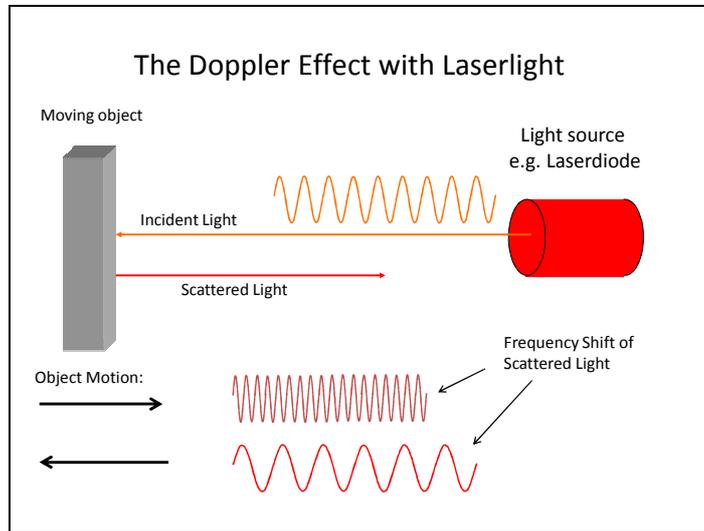


Fig. 1: Principle of Doppler Shift

Laser Velocimeters utilize a Differential Doppler Method to measure velocity, where the laser beam from a single laser diode is split into two beams and then directed so as to intersect at a fixed point in space, forming an “X” pattern, Fig 2. This fixed focal point is called the Standoff Distance of the sensor system. As the beams intersect, they overlap in the area around the standoff distance forming what is called the Measurement Volume or Depth of Field of the sensor systems. The sensor will measure the speed and length of any surface passing within this depth of field.

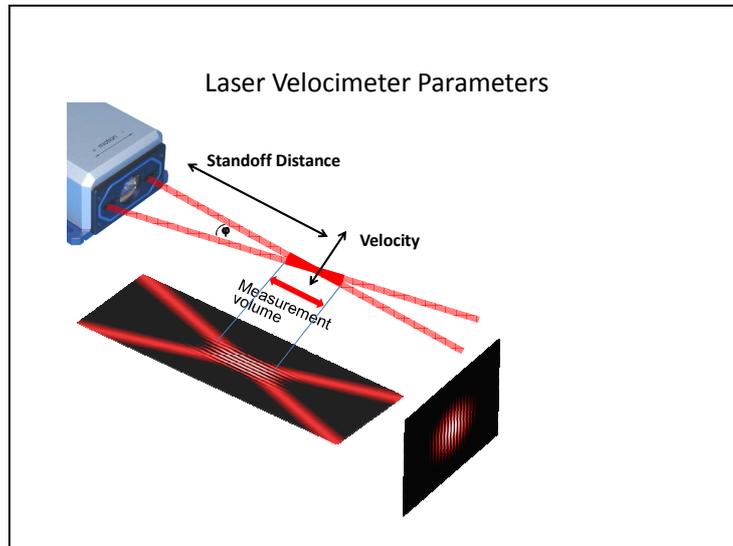


Fig. 2:

Constructive and destructive interference of the light waves occurs in the Depth of Field area, where the two beams overlap, to generate what is called a “fringe pattern”. This is a pattern of parallel light and dark fringes. A detector at the sensor head is aligned along the center line of the system to view this pattern and to measure the intensity of light that is scattered from the area. As a surface moves through this fringe pattern, Doppler shift of the two scattered beams occurs causing the intensity of light at the detector to modulate. This modulation in intensity or “beat frequency” corresponds to the Doppler shift and thus the velocity of the moving surface. Length & Velocity data is then made available as process outputs in the form of quadrature encoder pulse, RS232, RS422, Ethernet and more.

Due to the slow speeds found on continuous casters, it is imperative to use a so called “frequency shifted” system for highest accuracy, Fig 3. This is a system that shifts the optical frequency of one of the exiting beams. This technique enables the system to measure very accurately at slow speeds, down to standstill ($v=0$), as well as to internally determine the direction of the material

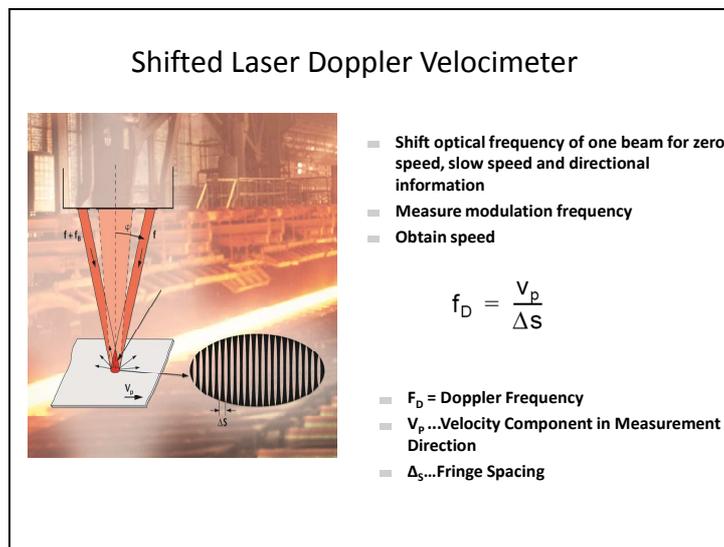


Fig 3:

POSITIONING THE SENSOR HEAD

These sensors are designed to be installed such that the optical axis is perpendicular to the target and at a standoff distance such that the measured surface remains within the Depth of Field. As shown in Fig. 4, there are three angles that can influence the measurement. Angles θ_y and θ_z will influence the measurement by introducing a known, predictable offset that follows the well known Cosine rule. This does not affect the repeatability of the system and can be corrected through a simple, one time process calibration as long as the angles are not changing. The third angle, θ_x , has no influence on the accuracy of the measured value, but rather the signal level returning to the sensor. It is recommended to keep this angle close to perpendicular, but, here, greater flexibility exists.

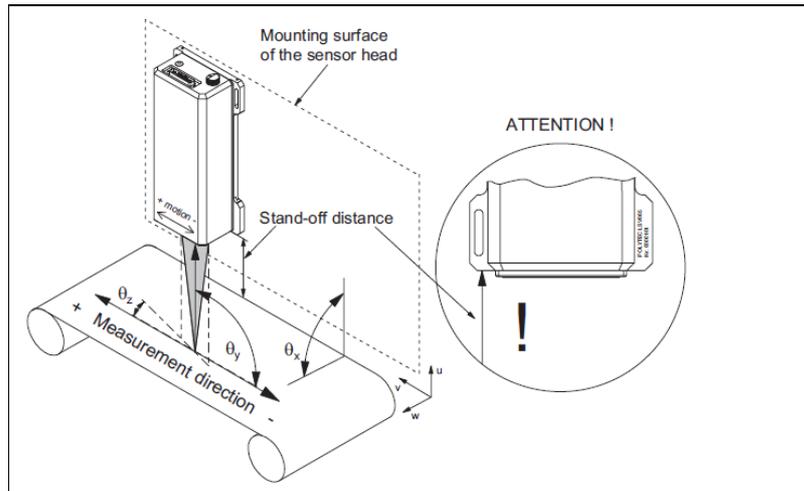


Fig 4: Positioning of the sensor head:

APPLICATION & INSTALLATION CONSIDERATIONS: CUT LENGTH TOLERANCE AND CAST SPEED:

In addition to accurate length measurements, there are many other events involved in controlling the cut length of strands at a caster. In short, the torch machine must be back to its home position or at least be at a precisely known location for slab casters. An accurate length measurement must be fed into the control system and used to activate the clamping action of the torch machine. The clamp response time must be known and repeatable and must maintain the correct pressure to prevent slippage from occurring during the cut. The torch machine must move freely with the strand. The torch must be in a fixed position and the flame itself must be considered, as it can remove on the order of 0.25 to 0.5 inch or more of steel due to its shape. After the cut is achieved, the torch machine must reset and prepare for the next sequence. These and other controls issues must all be considered when optimizing cut length control.

Assuming all the mechanical and controls issues are addressed, installation of Laser Velocimeters will then allow mills to achieve and maintain cut length tolerances in the range of 1.0 inch or better on lengths up to 480 inches, with little to no maintenance. The improved length accuracy and long term consistency from the Laser sensors results in similar improvements in achieving and maintaining weight tolerances, a key specification for the rolling mill.

A number of mills have successfully installed Polytec LSV Laser Velocimeters on slab, billet & beam blank casters with excellent results. In almost all cases, the sensor of choice is one with a 1500mm standoff distance and 150mm depth of field. This provides a good balance between the desire to be away from the hot strand, while also maintaining excellent signal quality, even on surfaces with heavy scale. The system is provided with a watercooled housing and air wipe to keep the quick exchange protective window clean. It provides a quadrature encoder output for easy integration into existing control systems, as well as, serial and Ethernet interfaces for additional data acquisition and control. It is recommended that the user monitor coolant flow to the sensor head to ensure proper water flow to the watercooled housing, as well as, install coalescing air filters near the sensor head to maintain clean, dry air flow to the air wipe. The sensor system monitors its own ambient temperature at the sensor head, within the watercooled housing. This value should be checked, certainly during startup, and monitored regularly through one of the various outputs from the system to verify proper cooling.

Since billet casters typically have 3 or more strands, sensors are typically installed above the strand, looking down. Fig 5a & 5b show an installation on a 5 strand billet caster. Installations on slab casters may vary. The sensors can be located above the slab in a fixed position; they can be mounted to the side of the slab, but will require a mechanical system to reposition the standoff distance in order to accommodate the slab width variations; or could be mounted directly on the torch machine, which improves cut length tolerances for those shorter slabs that are cut before the torch machine is able to reach the home position.

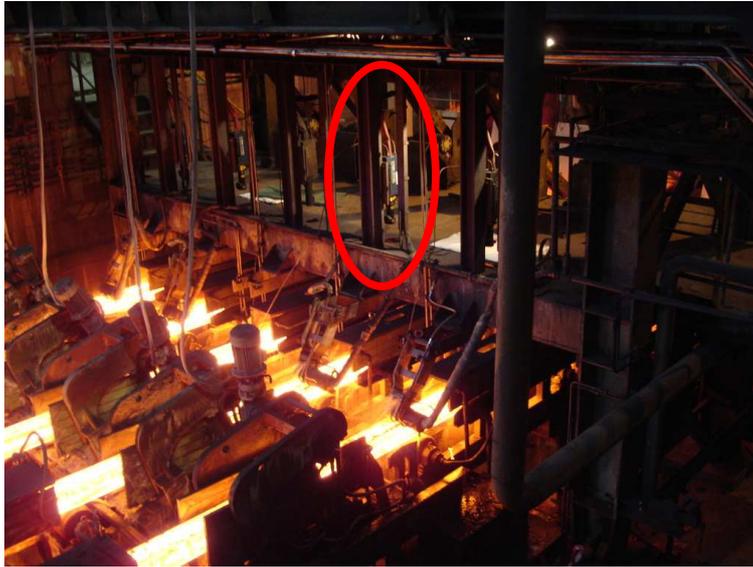


Fig 5a: LSV Installation on 6 Strand Billet Caster



Fig 5b: LSV Installation on 6 Strand Billet Caster

CASE STUDY: TMK-IPSCO KOPPEL STEEL:

The melt shop of TMK-Ipsco Koppel Steel in Koppel, PA has a 4 strand billet caster producing rounds in the range of 5.5 and 6.5 inch diameter for seamless tube products. The mill identified cut length repeatability and thus billet weight repeatability, as an area for ongoing process improvement. The first phase of the project was to find a length measurement solution, requiring minimal maintenance that would improve yield and scrap rates at the caster by improving cut length tolerance and long term repeatability by a minimum factor of 2, to better than 4 inches (± 2 inch). Following phases will address issues related to the torch home position, clamping time, torch track motion and more.

An initial study by Anna Overdorf, Sr. Process Engineer, indicated that, although the cut length repeatability for short time periods could approach ± 2 inch with the existing contact system, the long term cut length repeatability was in the range ± 4 inches. Because of this wide variation, operators had to enter a large safety factor to be sure the billets were never too short.

An evaluation was conducted by installing a single LSV laser velocimeter on one strand. The result was cut length tolerances approaching ± 1.0 inch. These overall variances in cut length, included not only the length measurement, but also the issues mentioned above, related to clamp timing, clamp pressure, torch track motion and more, which are to be addressed in the future. More importantly, continued evaluation demonstrated long term consistency in the measurement, enabling operators to significantly reduce the safety factor. The long term stability of the LSV laser demonstrated a significant improvement upon the existing contact wheel, which from experience provided cut length tolerances with variation up to ± 4 inches over time.

In May of 2010, TMK-Ipsco Koppel installed 4 Polytec LSV laser velocimeters on the 4 strand caster. The lasers have a standoff distance of 1500mm, a depth of field of 150mm and include a watercooled housing with air wipe. See Figure 6a, 6b. Introduction of these Laser systems has since resulted in a significant reduction in safety factors, improved process repeatability and has eliminated the need for continued process calibration and correction factors for each strand. In addition, they have proven to offer long term reliability with little to no maintenance required.



Fig. 6a: Laser Velocimeters on TMK-Ipsco 4 Strand Caster

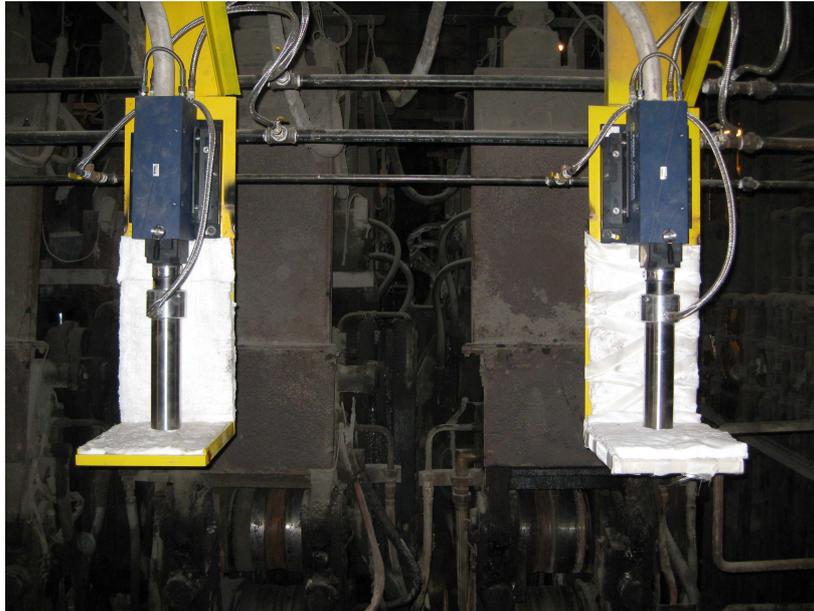


Fig. 6b: Laser Velocimeters on TMK-Ipsco 4 Strand Caster

Upon startup, mill personnel again began collecting data for further project justification and completion. This time, they recorded the scrap rate from a secondary “multing” process that cuts the mother billet from the caster long bars into several daughter billets. Figures 7a, 7b, 7c, 7d illustrate the reduction in scrap realized, for each strand, from the combination of the two processes, before and after installation of the lasers. The scrap rate at this point in the process includes the variations from the cut length at the caster as well as variation in cut length from the secondary multing process. More than 1500 billets were measured.

The improvement in tolerance before and after the installation of the Laser Velocimeters is clearly illustrated in the following charts and is attributed to a more consistent, repeatable and accurate cut length measurement at the caster. TMK-Ipsco will now address the remaining mechanical issues related to torch machine home position, clamp timing, clamp pressure, torch machine tracking and more.

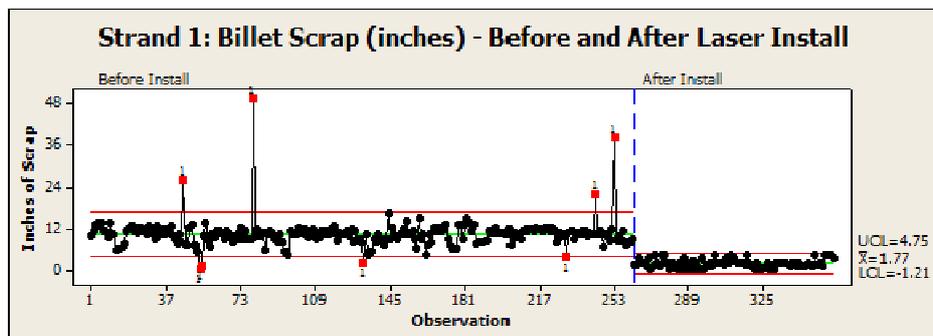
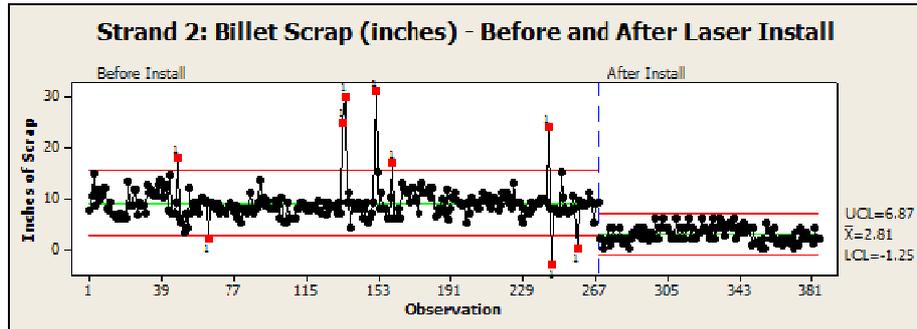


Figure 8a



Fig, 8b

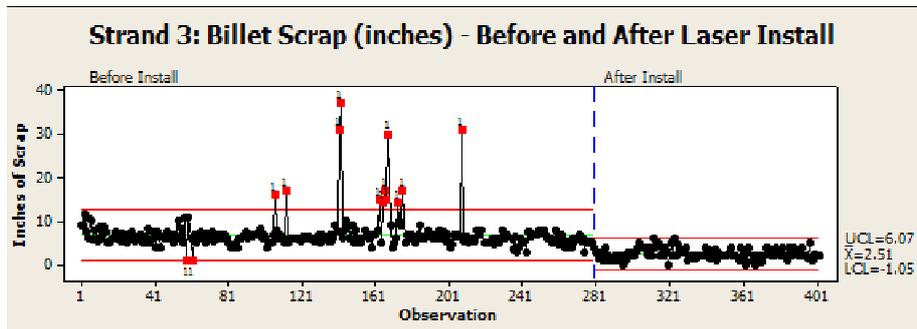


Figure 8c

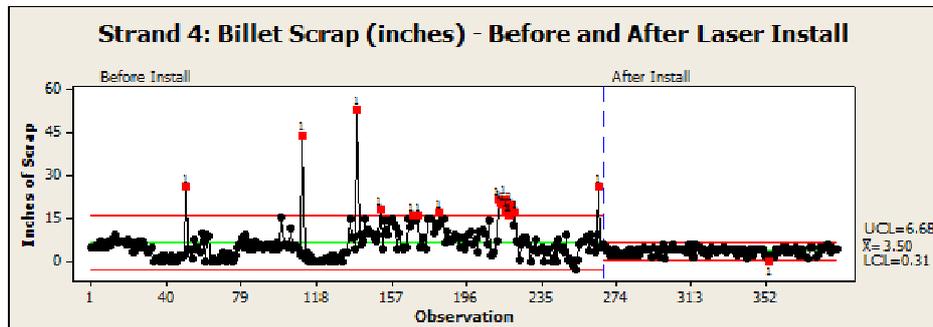


Figure 8d

SUMMARY:

In recent years, Polytec LSV Laser Velocimeters have been installed successfully in a number of slab, billet, bloom and beam blank casters, replacing contact methods for controlling billet length measurements and tracking of quality and process events. They have proven to be more accurate and repeatable than contact devices over the long term, with little to no maintenance required and provide greater long term consistency and predictability for process control and operations. This solution, in conjunction with good mechanical operation of the torch machine, significantly improves cut length tolerances, reduces process correction factors and improves weight consistency to the rolling mills, resulting in improved yield at the caster, as well as, the downstream rolling processes.

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