LTV Steel

TECHNOLOGY CENTER
DEPARTMENTAL CORRESPONDENCE

SUBJECT: Laser-Based Casting Speed & Slab Length Measurement Trial Results

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Currently, at SPE, the rate and number of revolutions of two or more machine rolls are used for measuring casting speed and slab length (inch-count). Measuring rolls, however, are maintenance items ($38,000/strand, year), do not work 30% of the time, are not very accurate (they may slip) and require frequent calibration (inch-count needs be adjusted 10-15 inches per heat). Considering these factors, a laser-based measurement device (on loan from American Sensors Corp) was tested from October 31, 2000 through January 9, 2001. Results follow.

HIGHLIGHTS

- The Laser Doppler system is a non-contact, non-intrusive, low-maintenance casting speed and slab length measurement device.
- The trials demonstrated potential benefits, such as: (1) improve precision of the cut-to-length torch cutting machines, (2) keep better track of quality events, (3) optimize shop pacing and, (4) help diagnose caster-related maintenance problems.
- Controlling slab length using the Laser Doppler system (laser data was directly connected to the Level-1 computer and fed into the torch cutting machine for 2-1/2 weeks) resulted in an error of ± 0.2 inch/slab vs. the current ± 2.5 inch/slab. This is more than 10 times more accurate (0.07% vs. 1% accuracy) and would, therefore, address an ongoing slab length inaccuracy problem.
- Currently, during a typical 15-hour casting period, the measuring-roll inch-count can fall back as much as 180 inches. This is equivalent to "missing or losing" one slab/strand/day.
- With added inch-count precision, quality-events on the strands (such as speed changes, rodding, manual mold level) and chem mixes could be more accurately located/traced making possible precise cause and effect. KIV/KOV defect analyses and preventing erroneous slab application.
- High-precision casting speed measurements should provide an opportunity to maximize casting speed and, therefore, machine productivity.
- Unfiltered laser data could be used to depict casting speed abnormalities caused by defective machine components (frozen bearings, dropped or broken rolls, failing withdrawal motors, eccentric mold oscillator). .
- With a purchase price of $85,000 per strand and its many potential cost savings benefits, the system presents a relatively short payback period. A comprehensive, quantitative evaluation of these benefits (feasibility/justification study) is, therefore, recommended.

LASER DOPPLER TECHNOLOGY

Measurement Principle - A Laser Doppler Velocimeter (Fig. 1) is a non-contact casting speed sensor that utilizes state-of-the-art laser technology. By intersecting two laser beams on the side of the slab, light fringes are created and produce what is known a "Doppler Effect". The speed at which these fringes move is directly proportional to the speed of the object passing through the point of intersection. By recording the speed of these fringes through receiving optics, the precise speed of the object can be determined. The laser under evaluation (on loan from the American Sensors Corp.) has,
confirmed accuracy of ± 0.02%, or
± 0.001 inch/min at 40 ipm.

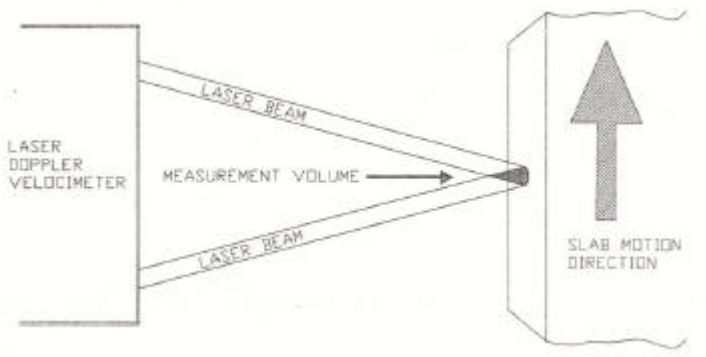

Figure 1: Principle of the Laser Doppler Velocimeter

Measurement Application - There are currently many Laser Doppler velocimeters available for steel mill applications, however, very few are designed for use in a caster facility because the device must be located within a certain distance from the strand and aimed at a 90° angle. This can only be accomplished directly above, below, or adjacent to the strand.

- Above the strand, heat radiating from the broad face of the strand would be intense, thus a suitable cooling unit would be extremely costly; in addition, the containment structure would most likely be obtrusive and interfere with daily caster operations.
- Beneath the strand, heat would also be a problem as well as falling debris causing short service lives between lens cleanings.
- It would, therefore, seem that a position adjacent to the strand, facing the narrow face, is the only alternative, however, this cannot be accomplished easily because the Doppler system utilizes a single focal point which has to be maintained during slab width changes.

To address these issues American Sensors Corp. developed a laser velocimeter that is mounted on a movable actuator whose displacements are controlled by a time-of-flight laser-based distance meter. This is, in essence, an auto-focus feature that allows the laser to be mounted on the side of the strand and move in and out with slab width changes. Additionally, by mounting the unit adjacent to the strand and focusing on the narrow face, most of the intense heat is avoided, and the containment's cost and obtrusiveness are significantly reduced.

Trial - On October 31, 2000, a Laser Doppler velocimeter was installed on Strand 2 (Fig. 2, 3, 4). With the help of personnel from American Sensors Corp, the Technology Center, CPC, Electrical and General Mechanics, the installation went smoothly and was completed in only a few hours. Due to some software issues, however, laser data acquisition could not begin that same day. Within a few days, however, all the necessary software and computer hardware connections were completed and data acquisition began (Fig. 5).

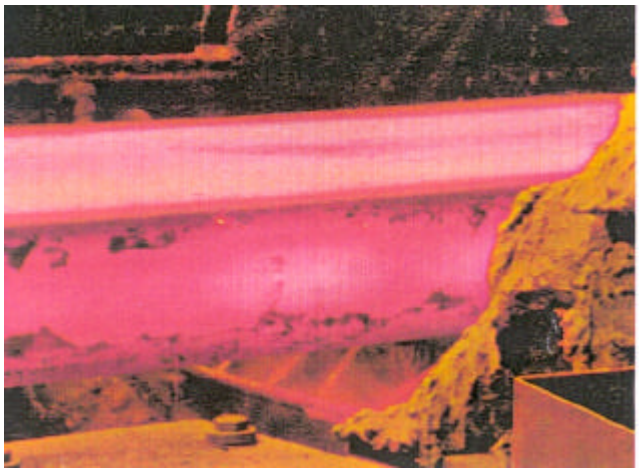

Figure 2: Two visible laser dots on the side of the strand. The left dot is actually the intersection of the two Laser Doppler beams. The Doppler system receives the refracted light from that dot and interprets it as a speed. The right dot is generated from the time-of-flight laser distance meter used to "auto focus" the laser Doppler.

Figure 3: Rear view of the Laser Doppler Velocimeter tested at SPE Caster # 1. The laser Doppler is sitting on the table to the left. The laser distance meter is sitting on the table to the right. The box below the table is the PLC controlling the "auto focus" feature.

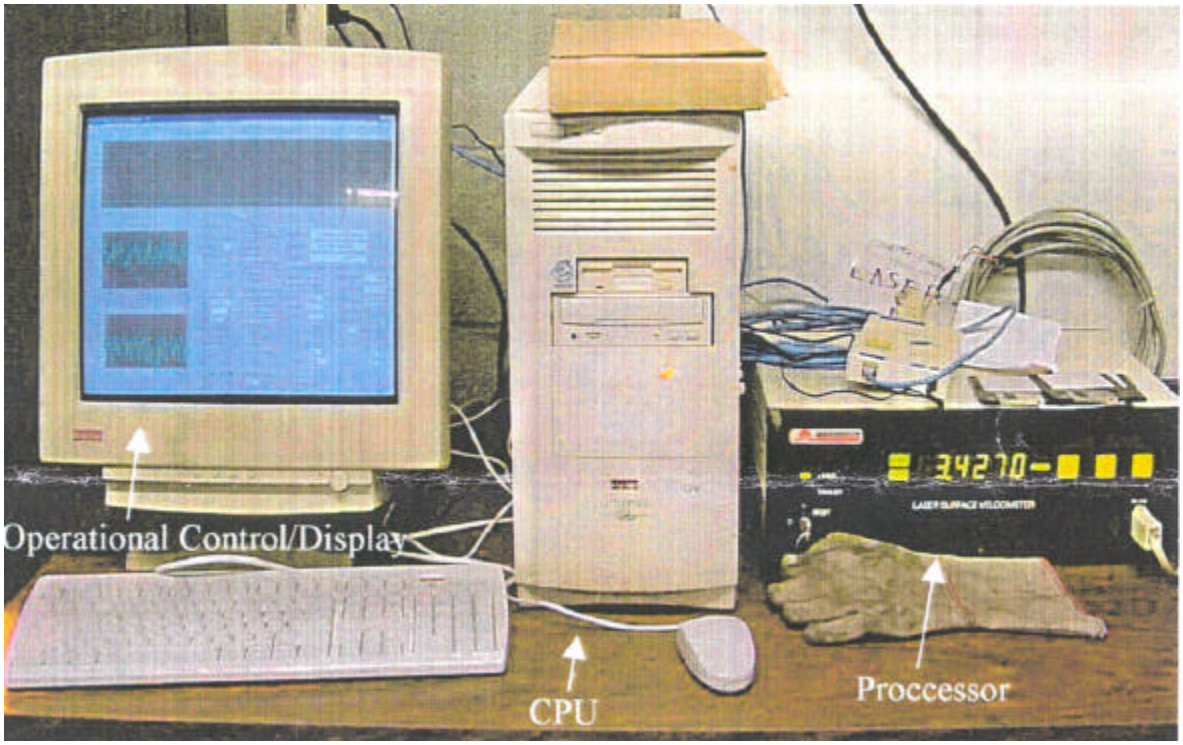

Figure 4: This set-up enabled easy initial configuration and monitoring of the Doppler system. The processor on the right reads all raw data from the Laser Doppler unit and has the ability to average the data and send it out via 2 analog outputs and 2 digital RS-232 outputs. This made connecting to the Level 2 computer system very easy. The computer program included with the system enabled the user easy access to all the system's parameters for easy configuration, however once the system is configured, there is no need to re-configure it.

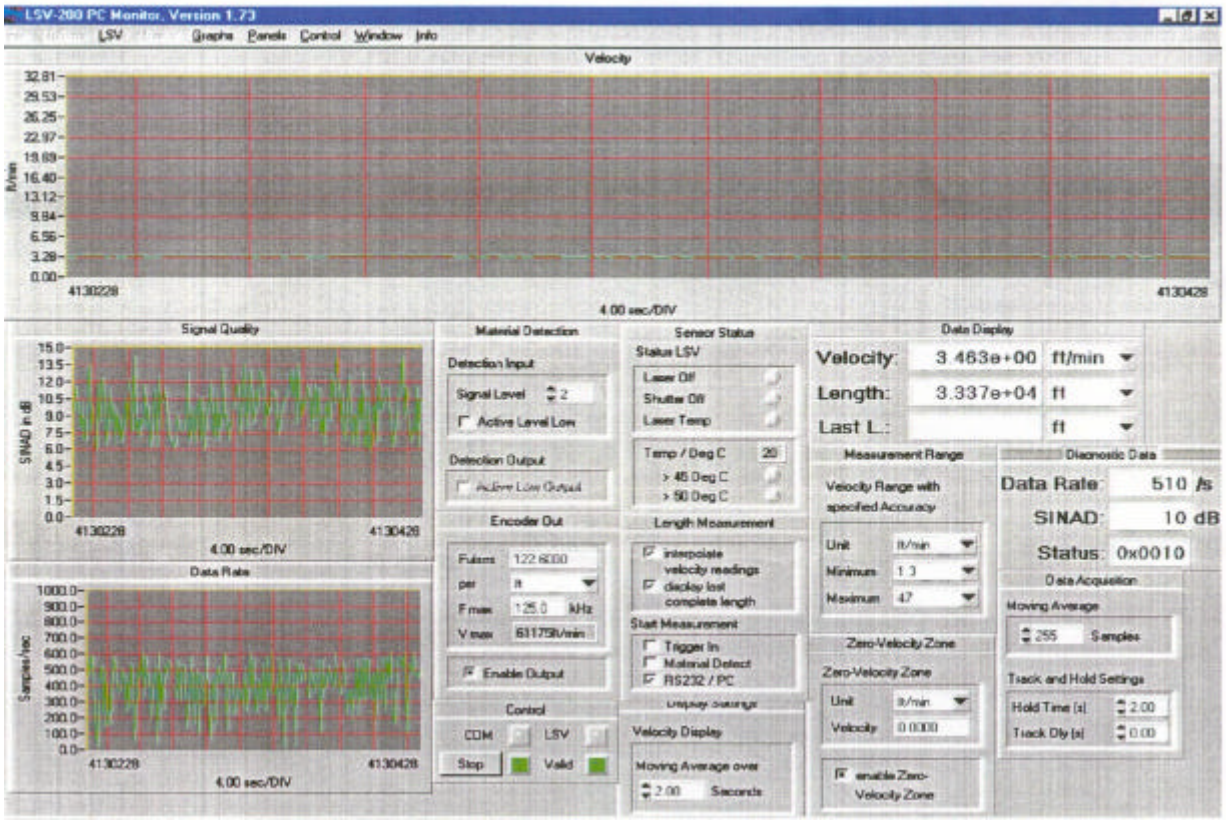

Figure 5 : Included with the Doppler system was software to adjust and monitor the equipment. The software monitors temperature with automatic shut-down capabilities, data rate from the Doppler's sensor head, signal quality, inch-count, and of course casting speed.

RESULTS

Accuracy in determining Casting Speed - The accuracy of the laser-based casting speed measurement was determined by comparison of the laser-based slab lengths (obtained by integration of the speed data) and the actual hot slab lengths (as measured with a ruler). A difference/accuracy of 0.02% was found, well above the accuracy of the current measuring-roll (tachometer) system which is approximately 3% (Fig. 6, 7).

Accuracy in determining Stab Length - To determine the accuracy of the laser-based slab length (inch-count), the laser information was directly fed into the torch cut machine for 2'/z weeks. During that entire period, every slab was cut to length based on the laser's inch count. After verifying (with a ruler) the length of every hot slab at the stamper it was found that the laser system consistently produced slabs to their ordered length ± 0.2 inch. This compares very favorably to errors up to ± 2.5 inches/slab with the current measuring rolls (Fig. 8).

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POTENTIAL BENEFITS

Currently, four tachometers are installed on the back of four different driving rolls to measure the casting speed (tachometers are also backups of slab length measuring rolls). Due to roll slippage, inconsistent contact and frozen bearings, the information can be significantly inaccurate (Fig. 6 and 7). The laser speed measurement system is independent of roll speed and, thus, completely avoids this issue.

More precise slab length - Currently, during a typical 15-hour casting period, the measuring-roll inch-count can fall 180 inches behind that of the actual lengths of the slabs (as measured with a ruler). This difference equates to one slab per strand per day. A better knowledge of slab length might improve our capability to provision orders.
More precise casting speed - Currently, production losses (or difficulty in shop pacing) may be incurred because we do not know the exact speed/throughput at which we are casting. A more precise casting speed should allow more accurate prediction of the ladle pour times and setting of actual casting speeds (closer to grade-specific or metallurgical-length recommendations). These are quality and productivity issues that need be reviewed.

Preventative machine maintenance - During the trials, the laser data was digitally filtered in the Level-2 computer (in a permanent installation, a PLC would be used and the data fed into Level-1 for secondary water control). The comparison of filtered and unfiltered data could be used to alarm mechanical abnormalities due to frozen bearings, uneven rolls, failing motors, mold oscillator, or other moving parts in the machine directly contacting the steel (Fig. 9).

Defect Tracking - With a more reliable inch-count, defect-causing events such as nozzle changes, speed/width changes, manual level control, and chem mixes can be more precisely tracked as they move through the machine. A smaller buffer zone around these areas would reduce the amount of necessary downgraded steel and might possibly prevent certain slabs from entering secondary status. This should have a direct and positive effect on both production and steel quality.

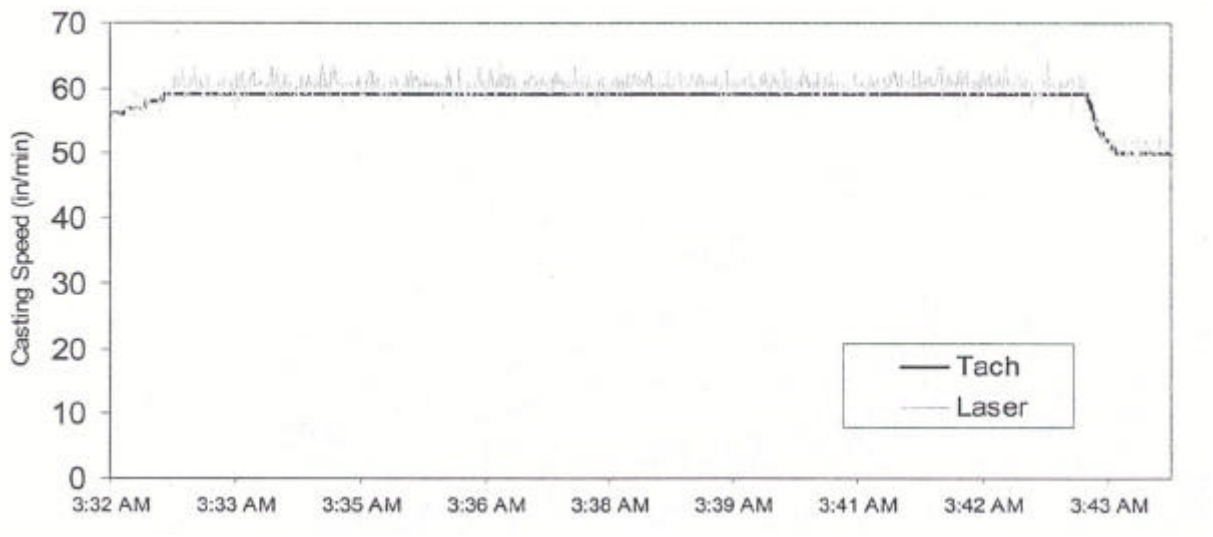

Figure 6: Speed Measurements. In this example which refers to a high casting speed situation, laser and tachometer speeds differ by approximately 2 ipm (i.e. a 3%-error for the current tachometer system).

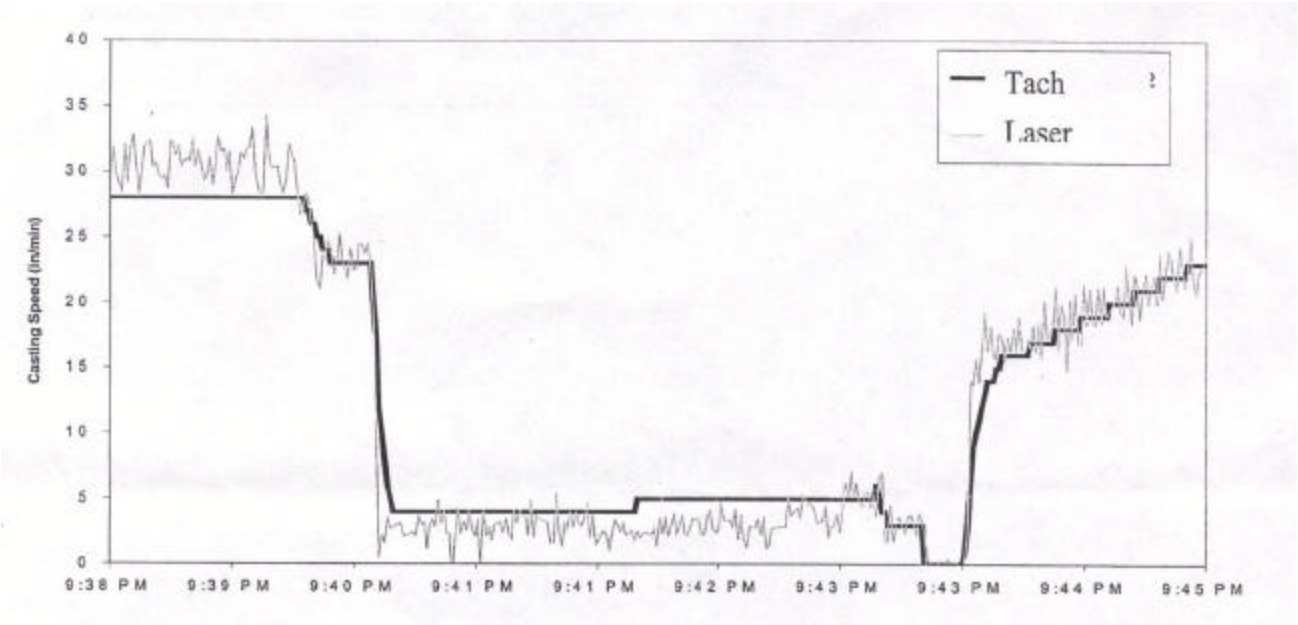

Figure 7: Speed Measurements. Even at slow speed (when there is less chance for roll slippage) the current tachometer has difficulty reading accurately.

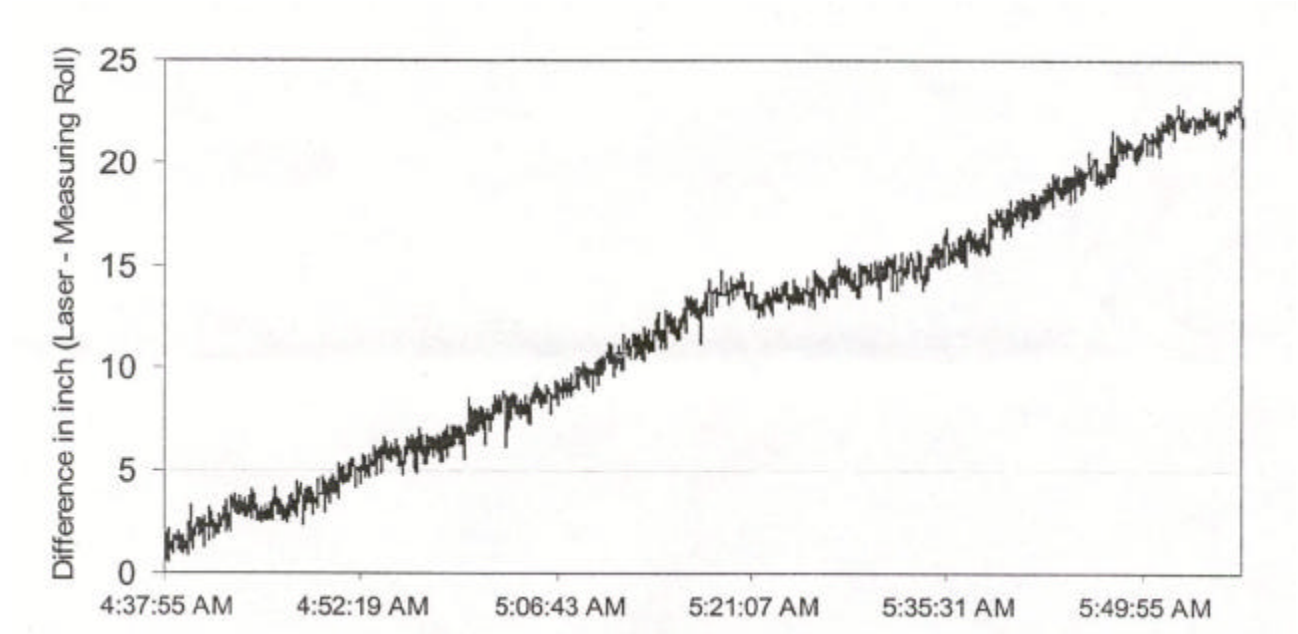

Figure 8: Length Measurements (Dec, 1, 2000 strand 2). The current measuring-roll system has accumulated a 22-inch error in less than 1:30 hours, i.e. approximately 2.2 inches/slab, equivalent to `losing" one slab/strand/day.

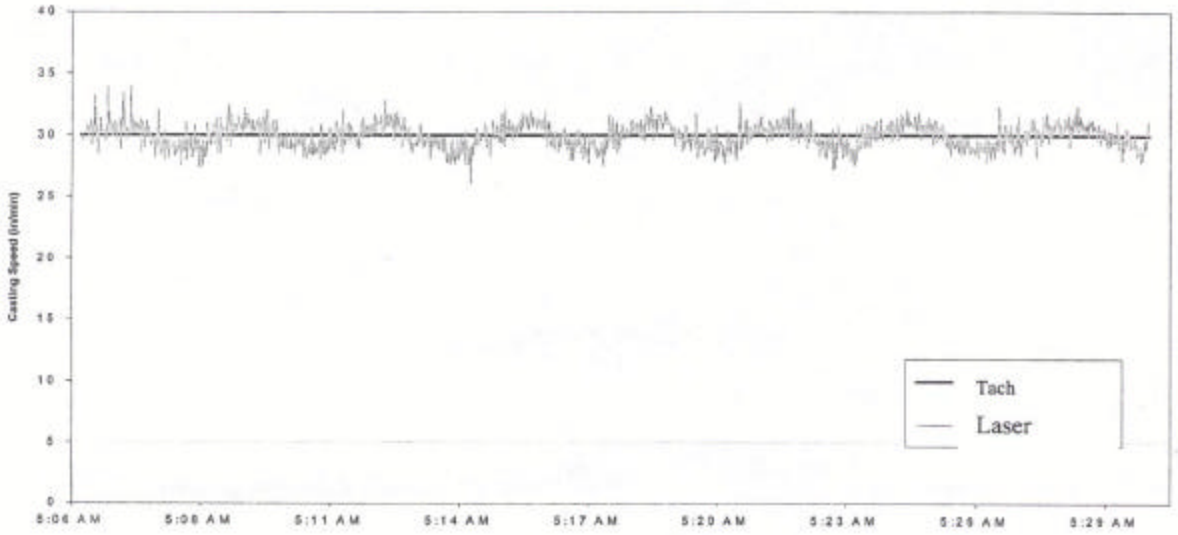

Figure 9: Preventative Maintenance. The unfiltered laser's output is much more variant than the tachometer's, and is so because of its precision. The caster does not run at a constant speed as the tachometer has always reported. Instead, casting speed changes all the time, in small amounts. Here, mold oscillations are very evident in the casting speed readout.

CONCLUSION / RECOMMENDATION

The Laser Doppler Velocimeter tested at the SPE #1 caster proved to be very effective.

With a purchase price of $85,000 per strand and its many potential cost savings benefits, the system suggests a relatively short payback period. A comprehensive evaluation (feasibility/justification study) is, therefore, recommended.

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