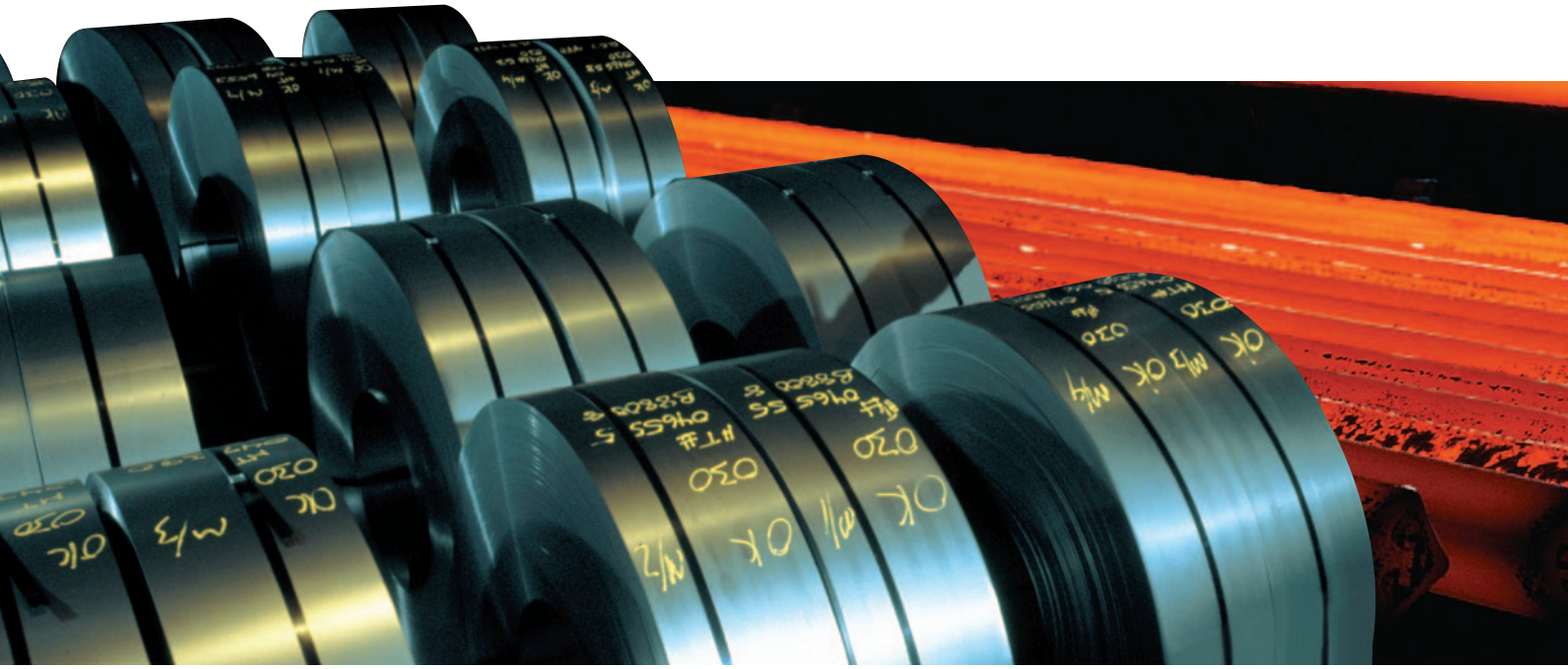
Polytec

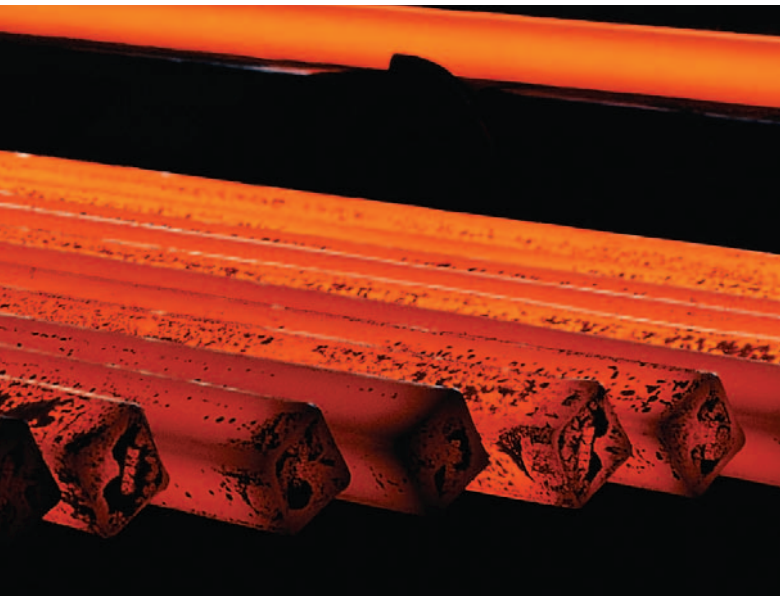
Laser Surface Velocimeter

LSV Series 6000

Precision, non-contact velocity and length measurements for mill automation and process control

Built Mill Tough





Increase Yield and Throughput – Decrease Downtime

Polytec's new Industrial Laser Surface Velocimeter (LSV) is specifically designed to measure the velocity and length of billets, slabs, plates, tubes and profiles for online control and inspection of hot and cold processes. The system replaces traditional, high-maintenance, problematic contact measurement techniques with accurate, low-maintenance, next-generation laser technology.

When average isn't good enough, the LSV Series 6000 answers the call. Without compromising important features such as accuracy, velocity direction (+/–) or zero speed measurement (stand still detection), Polytec designed and built a rugged and reliable instrument for velocity and length measurements in difficult mill environments. By incorporating advanced laser technology, the LSV Series 6000 eliminates common problems that plague traditional contact-wheel measurement methods such as slippage, chatter, changing wheel diameter and frequent maintenance. The LSV design includes an air wipe, a liquid cooled housing and a long 2.5 m (8.2 ft) standoff distance for protection from the intense heat, steam and debris of continuous casters, rolling mills and other process environments. Mills require operational efficiencies to survive in today's competitive environment. Make a sure bet and upgrade from a traditional contact measurement system to the cost-saving LSV Series 6000 Industrial Laser Surface Velocimeter. It is simple to install, setup and integrate into the mill process and is an essential step to reducing scrap, increasing uptime and improving material throughput.

Typical Applications

- Length/speed measurements in hot and cold rolling mills
- Online control of continuous casters
- Cut-to-length control of billets/slabs, plates, tubes, profiles, etc.
- Length inspection for quality assurance
- Measurements for automatic gauge control (AGC), mass flow and elongation control

Mill-Ready Technology

The LSV Series 6000 System

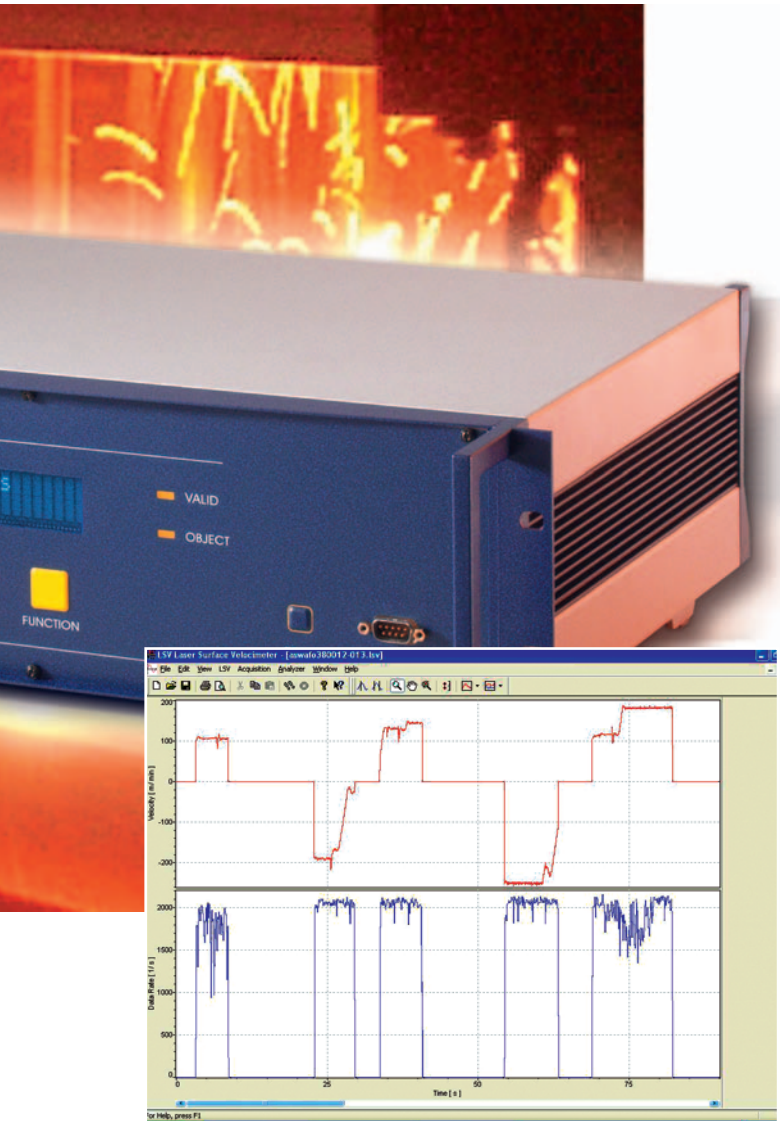
The LSV Series 6000 system combines a sensor head, a controller and software into a rugged industrial package designed specifically to measure velocity and length under the strenuous demands of mill environments.

The LSV Sensor Head

The LSV sensor head is the watchful eye of the system, measuring the in-plane movement of the material surface with the aid of Laser Doppler Interferometry (page 9). Its compact size allows for integration into the mill at any required orientation. Various standoff distances are available to enable positioning the sensor head at the most appropriate distance. The LSV head comes in two configurations: the compact, IP 65-rated (NEMA4) LSV-065 sensor head for light industrial duty or the liquid-cooled LSV-026 sensor head for use in extremely harsh mill environments. More on page 10.

The LSV Controller

The LSV controller powers the sensor head, provides signal conditioning and can be located up to 110 meters (360 ft) from the sensor head. It offers various output options including ethernet, RS-232/-422, quadrature encoder pulse and more for interfacing with monitoring and process control systems. Length and velocity data is simultaneously displayed and updated every millisecond at each output. More on page 11.



The LSV Software

The LSV PC Software provides system configuration, diagnostics, and data presentation/analysis in a Windows® 2000/XP environment.

More on page 13.

Superior Technology

- **Flexible system configurations** meet the requirements of demanding mill conditions
- **Simple, fast integration** into mill monitoring and process control systems
- **Automatic Surface Adaptation (ASA)** feature compensates for changing surface conditions providing a high quality signal on virtually any surface
- **Fast Burst Detector (FBD)** locks on to and follows true velocity, even during periods of high acceleration
- **Measure safely** with standoff distances up to 2.5 m (8.2 ft), and depths-of-field up to 200 mm
- **Accurate velocity measurements** indicate forward, backward and standstill conditions
- **Fast signal processing** outputs 1024 measurements/second for tight process control loops needing measurement accuracy and short cycle time
- **Many interface options** including ethernet, RS-232/-422, quadrature encoder and current loop
- **High performance setup and diagnostic software** to configure, program and process measurements
- **User-friendly,** two-line display shows velocity, length and status information on site; optional large display
- Visible laser beam

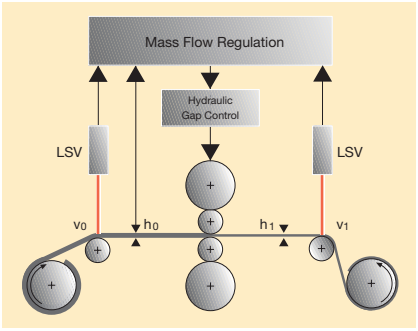
Detailed technical specifications for the LSV Series 6000 system can be found on pages 14/15.

For more and current information visit our website:

www.polytec.com

Mill Applications of the LSV Series 6000

Mass Flow Regulation in a Rolling Mill with a C-frame and an integrated Laser Surface Velocimeter



In order to meet the dimensional accuracy and tolerance specified by automotive and industrial consumers, modern rolling mills employ a technique called Automatic Gauge Control (AGC), which utilizes mass flow calculations to meet the precision tolerances on thickness.

The mass flow relationship makes it possible to calculate the strip thickness in the roll gap h_1 by measuring the velocity v_0 and thickness h_0 before the roll stand and the velocity v_1 after the roll stand. The LSV's high processing speed offers almost immediate control to thickness variations.

Until recently, thickness and speed gauges have been installed in mills as separate, stand-alone systems. Thickness gauging, for instance, is commonly done with X-Ray absorption systems mounted in so-called C-frames. However, with the development of the compact LSV-065 sensor head, integration of the LSV speed measurement system directly into the C-frame of the thickness gauge is now possible.

Integrating the LSV sensor head into the C-frame can reduce project costs by eliminating duplicate cable protection, mounting hardware and utilities. In short, it provides a clean, compact, cost effective installation of both thickness and speed measurement.

To facilitate the integration, Polytec constructed an additional cooling plate with a bending mirror for beam steering. The sensor head sits horizontally in the C-frame and views the surface of the strip through the 90° bending mirror and through a window in the bottom of the upper C-frame. By moving the LSV-065 sensor head relative to the mirror, the system can easily adapt to different passline positions and C-frame gaps. The clearly visible red laser beam makes alignment within the C-frame an easy job. The LSV's large depth-of-field tolerates production line fluctuations of ±30 mm.

Due to the significant advantages it provides, many mills in Europe, Asia and the USA have purchased a C-frame thickness gauge with an integrated Polytec Laser Surface Velocimeter.

Casting Velocity and Length Control

After a successful test phase at a large steel manufacturing plant, Polytec received an order for multiple Laser Surface Velocimeters to replace the existing water-cooled measuring wheels on a continuous caster.

Corrosion of the water-cooled measurement wheels combined with surface deposits often caused undesirable length measurement errors, a problem which can not occur with the non-contact LSV measurement process.

Flame cutters are linked to the length measurement and section the casting into slabs or billets accordingly. The high measurement accuracy and reliability of the LSV results in less maintenance, improved cut length tolerance and increased yield from the caster. Depending on the processs, the return on investment (ROI) is realizable after only a short time.

In one steel production plant we were able to achieve a cutting tolerance of ±11 mm or 0.08 % for 14 m long billets.

Measurements for Automatic Gauge and Elongation Control

Cold band is re-rolled in temper mills to produce the final degree of levelness and surface quality. The gauge is determined by the difference in the strip speed when arriving at and leaving the roll stand. The speed differences are very small, typically ranging from 0.3 % to 3 %. The required accuracy of the speed measurement is correspondingly high. Until now, the gauge has been measured using encoded rollers at the arrival and departure guide pulleys of the roll stand.

Slippage and contact problems between the strip and the sluggish guide pulleys lead to errors in measurement of the gauge, particularly during acceleration and deceleration of the strip. By replacing contact speed measurement with laser surface velocimetry, measurement errors caused by slippage and contact problems can be eliminated. The gauge measured using the LSV can be confidently used as the controlled value for setting the rollers.

At a large stainless steel manufacturer, the LSV was used to provide a measurement of the gauge to ± 0.02 %.

Mill Applications of the LSV Series 6000

Control of Flying Saws

Flying saws are being used increasingly in tube mills between the stretch reducing mill and the cooling rack. The advantage of the flying saw is that the crop length can be set individually for each moving tube, significantly increasing yield.

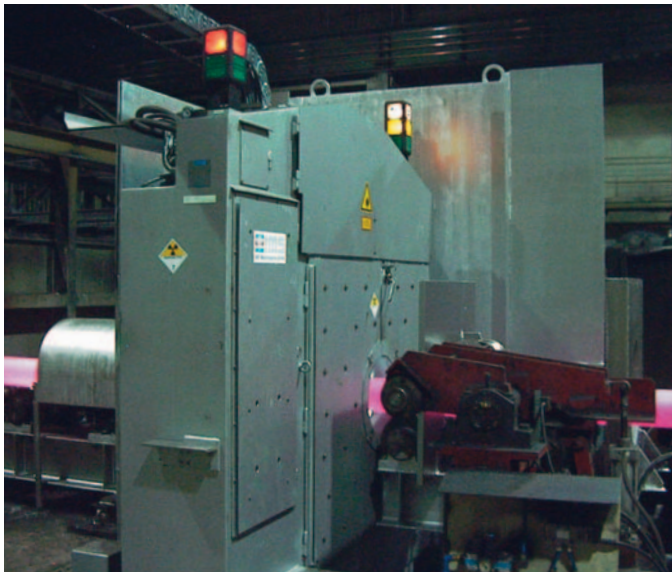
In order to hit the cut-length value, with minimum wear to the saw blade and other mechanical components, the track speed of the flying saw must be matched with the linear speed of the tube.

The LSV can measure tube speed and length directly, without the issues related to contact measurement devices, such as slippage, chatter and changing wheel diameter. The improved feedback to the flying saw results in tighter cut length tolerance, better synchronization of the saw track speed to the tube linear speed and increased saw blade life.

Length and Velocity Measurement in Tube Mills

Online, high-precision, laser-based velocity and length measurement reduces the manufacturing costs, improves quality and increases yield in tube mills.

Cut length tolerance, tube wall thickness and synchronizing equipment speeds (saw speed to tube speed) are important parameters for improving product quality and process efficiency. Tube wall thickness, diameter, eccentricity are measured by passing the tube through multichannel x-ray or ultrasonic measuring frames. Integrating the Polytec LSV length measurement with these quality measurements enables precise allocation and positioning of quality data along the length of the tube.



The Physics behind Laser Surface Velocimetry

The Laser Doppler Effect

The Doppler principle states that light scattered from a moving object is frequency shifted proportional to the speed and direction of the object relative to the observer (detector). Laser surface velocimeters measure this frequency shift. From the measured frequency shift, the instantaneous surface velocity can be calculated.

Polytec velocimeters use a modified Doppler technique to measure an object's in-plane motion orthogonal to the instrument's optical axis. This technique superimposes two laser beams, separated in angle by 2 φ, on the measurement surface. The optical axis bisects the separation angle and is aligned perpendicular to this surface. The overlapping laser beams form an interference fringe pattern on the surface. Surface velocities orthogonal to the fringe pattern are measured from the modulation frequency of the scattered light collected by the photo detector located along the optical axis.

Sensor Head Design

Based on heterodyne detection, the sensor head incorporates a Bragg cell (acousto-optic modulator) to split the laser probe into two beams of equal power but shifted in relative frequency by f_B = 40 MHz. Both laser beams intersect at the specified stand-off distance with an angle φ to the optical axis. The light scattered back from the object is collected using the receiving optics and focused on the photo detector. The detected signal is transmitted to the controller and processed to determine velocity and length.

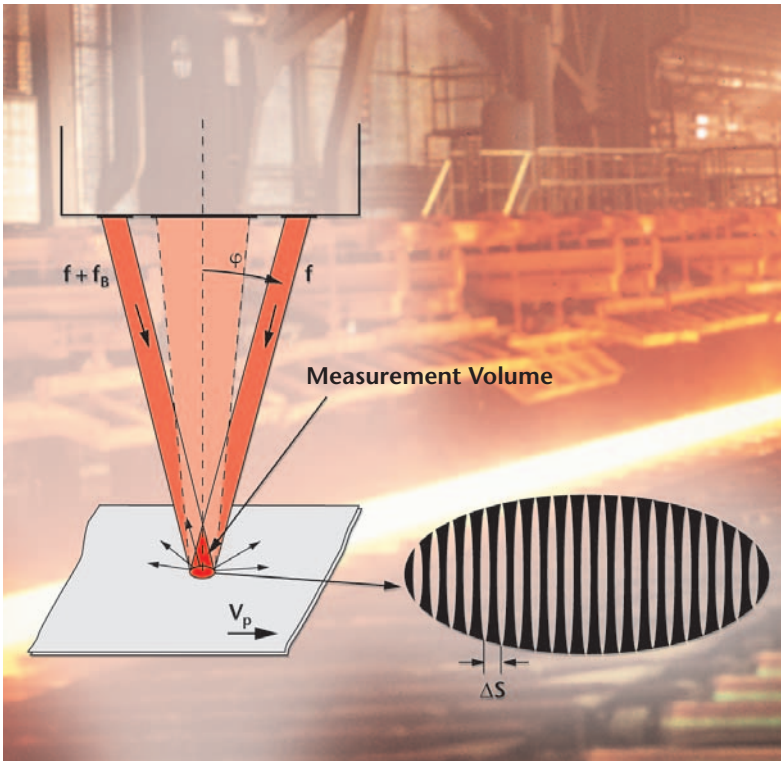
Creation of the Measurement Signal

At the point of intersection of the two laser beams, interference creates bright and dark fringes on the surface of the object. The fringe spacing, Δs, can be calculated from the angle φ and the wavelength λ:

$$\Delta s = \lambda / (2 \sin \varphi)$$

When a scattering center on the surface transverses the interference fringe pattern, it reflects light from each fringe into the receiver lens. The detector experiences an intensity modulation at the Doppler frequency f_D, which multiplied with the fringe spacing Δs results in the velocity of the surface v_p:

$$V_p = \Delta s \cdot f_D$$



The fringe spacing remains constant, even if the standoff distance changes within the depth of field of the system. Length is derived from high-precision, real-time integration of the instantaneous velocity.

Heterodyne Detection

The fringe pattern just described is not stationary but moves one fringe position with a frequency of f_B, the Bragg frequency. The direction of this motion is determined by which laser beam is up shifted relative to the other. This modulation frequency is the carrier that is always present at the detector. The Doppler shift rides on the 40 MHz carrier as a frequency modulation:

$$f_m = 40 \text{ MHz} \pm f_D$$

This is known as a heterodyne detection and makes it possible for the LSV to recognize the direction of the speed (+ or –) and to make measurements down to standstill (v=0). Another advantage is that the measurement accuracy is not affected by changes in the ambient conditions, as the fringe spacing Δs is only dependent on the angle φ and the wavelength λ.

System Components

The Optimal Sensor Head for Every Mill Application

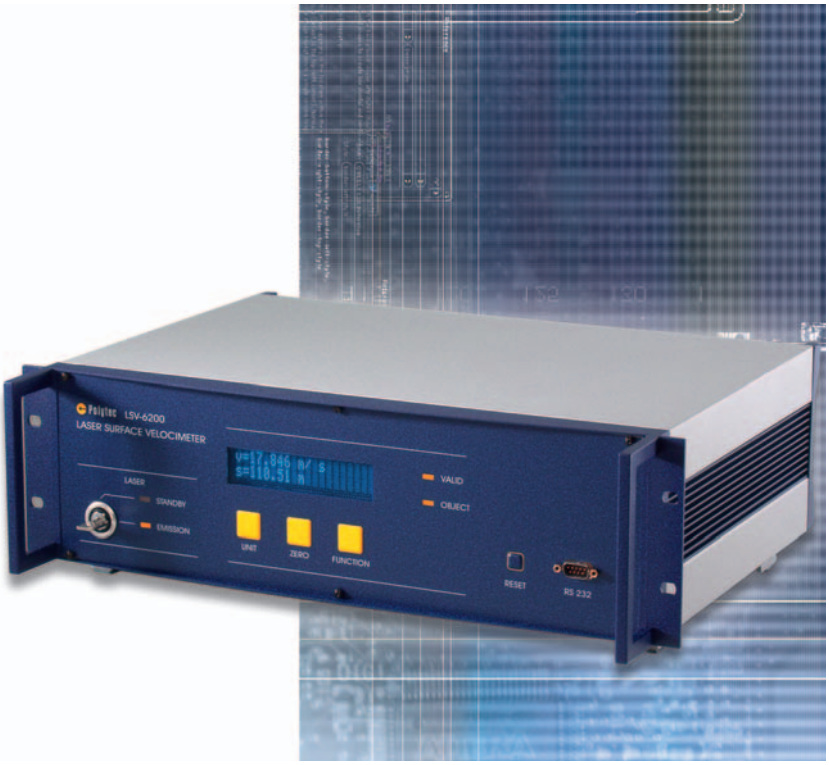
The LSV Series 6000 is designed to accept the LSV-065 compact optical sensor head for light industrial applications, and the LSV-026 liquid-cooled sensor head for harsh industrial environments. Both sensor heads perform to the same technical specifications – making measurements from standstill to speeds of more than ± 7000 m/min. The standoff distance can be factory set from 0.3 to 2.5 m. The output beam spacing is either 57 mm or 44 mm. The latter provides a greater depth-of-field so that large production line fluctuations are tolerated without repositioning the sensor head.

LSV-026: Mill Tough

To handle the hot and hostile conditions surrounding rolling mills and continuous castors, Polytec developed the LSV-026 sensor head. The sensor has a diecast aluminum housing with integrated stainless steel cooling spirals. The coolant can either be water, mill oil or paraffin oil. An aerodynamically optimized air wipe unit keeps the sensor´s optical window free of dust and rolling oil. Should the window ever get dirty, the quick release window can easily be exchanged for a clean one.

LSV-065: OEM or Light Industrial Duty

The LSV-065 sensor head is a cost-effective solution for OEM applications in which the sensor head can be integrated into existing protective housings or for measurement tasks on strip goods with normal ambient conditions. Its compact design makes it possible to install the LSV-065 sensor in tight spaces as well.



Signal Processing Speed

The LSV-6200 Velocimeter Controller

The velocimeter controller powers the sensor head, manages signal demodulation and communicates the data to external process control systems. The industrial housing can be installed into a 19" rack-mountable control panel or can be operated as a free standing unit. Its digital and analog outputs make it easy to interface the LSV-6200 controller to any kind of industrial process controller or monitoring system. It can be programmed via the serial interface and its ethernet interface (optional) makes it possible to operate almost any number of devices in a network.

State-of-the-Art Technology for High Quality Measurements

The LSV-6200 controller offers several exceptional features that enable accurate, repeatable, reliable measurements, regardless of surface conditions or process acceleration rates.

- Due to the speckled nature of the scattered light, the Doppler frequency information is not available continuously but only periodically – in the shape of so-called bursts. In the LSV-6200 controller the Doppler frequency is identified by the **Fast Burst Detector (FBD)** which sets the internal A/D converter to optimal measurement accuracy (0.05 %).
- **Fast Fourier Transformation (FFT)** has proven to be the best method of filtering Doppler frequencies out of detector signals with a high level of background noise. In the LSV-6200, a powerful digital signal processor (DSP) works with a 32-Bit microcontroller to calculate the Doppler frequency using FFT.
  The advantages of this technique are particularly obvious in cases where the velocity of the object under investigation changes quickly. Even if the material briefly disappears from the measurement zone or the surface reflection weakens too much, the FBD ensures that the LSV-6200 controller acquires the velocity again within milliseconds.
- Without any user input, the **Automatic Surface Adaptation (ASA)** feature adjusts the signal processing to changes in the material surface, such as color, roughness, milling oil vapor in the beam path or thickness variation.
- The **Heterodyne detection** described in more detail on page 9, makes it possible to recognize forwards and backwards movement and to measure very low velocities right down to standstill (v = 0).
- The optional **Material Present Function** utilizes the LSV laser to detect the presence of material in the field of view. It is used when a start/stop trigger is required, but not possible or practical to trigger with light barriers, hot metal detectors or other proximity sensors.

Simple Integration

- Simple interface to existing networks and process control systems via ethernet interface (optional, with TCP/IP or UDP) or RS-232/RS-422-interface at 230 kbit/s
- Simple configuration with user-friendly LSV PC software
- Easy-to-read, two-line display with adjustable units for velocity, length and status information; can be extended with an external large display via the optional RS-422 interface
- RS-232 interface on the front provides a convenient port for system configuration and diagnostic; extended internal diagnostic function
- Freely scalable 16 bit analog output (± 10 V) and TTL interfaces (4 outputs/3 inputs)
- Optional interfaces (opto-insulated):
  – encoder output
  – parallel data interface
  – analog current output
  – process coupling module

Accessories

LSV-027 Mounting Plate with 3 Axis Tilt

The LSV-027 mounting platform makes it easier to realize precise and reliable alignment of the LSV-026 sensor head in relation to the object.

Sensor Head Cables

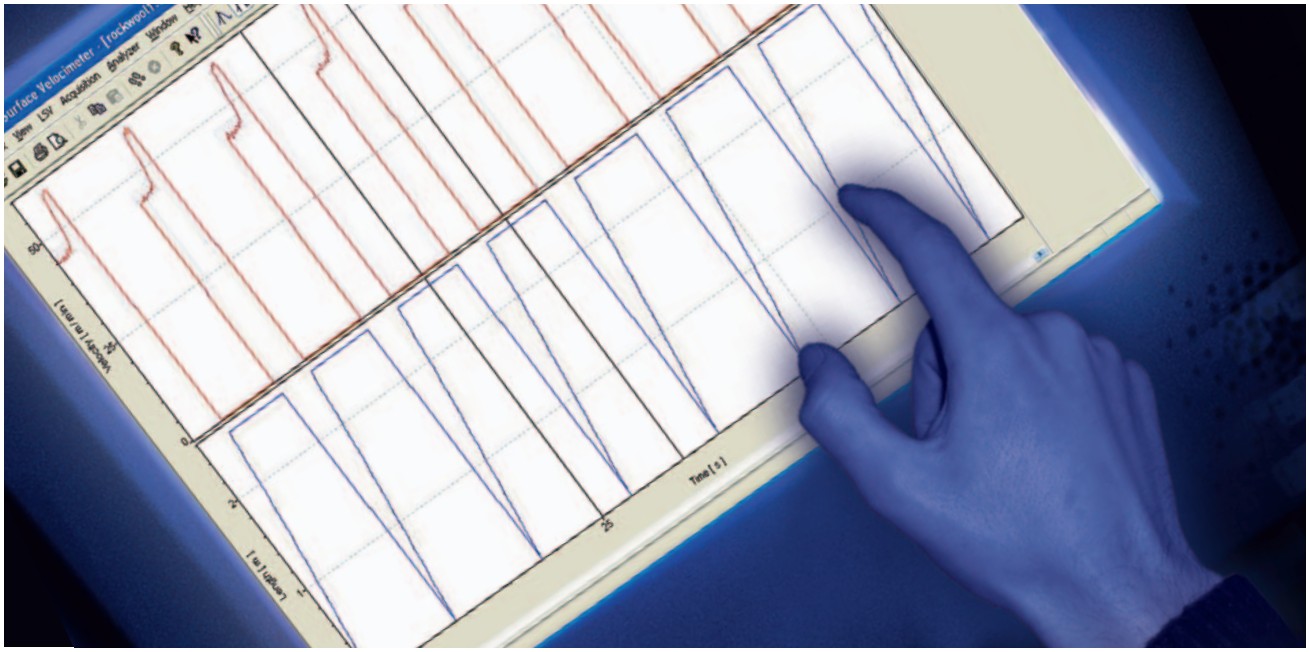
Various oil- and heat-resistant sensor head cables are available for the different mill process environments, with cable lengths of up to 110 m between sensor head and controller. The section of cable near the sensor is exposed to the harshest ambient conditions and is therefore designed to be a “break-away cable” which can be quickly exchanged.

LSV-029 Adapter Box

The universal adapter box enables you to exchange the breakaway cable quickly and contains connections for the laser warning lamp, an additional on/off switch for the laser and a beam shutter.

Please contact Polytec’s sales or application engineers for more information about other recommended accessories.

LSV PC Software

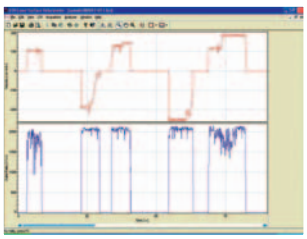


User-friendly Software as an Integral Part

This user-friendly software is an integral part of every LSV measurement system. The LSV PC software runs under Windows® 2000 and XP. It not only simplifies configuring the LSV system, but also offers excellent process, observation and analysis options.

For example, via the serial interface of a notebook, all LSV configuration parameters can be set and velocity, length and signal quality can be transmitted. Up to 1024 measurement values can be recorded and displayed per second.

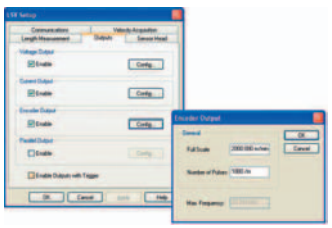
By selecting suitable parameters, processes taking from milliseconds up to several days can be saved and analyzed via the zoom function and the click of a mouse. It is also possible to export the measurement data as an ASCII file and use other software programs to process the data.



Trend of velocity and data rate as measured at the reversing stand of a hot rolling mill.

Diagnostics – Temperature of Sensor Head

The diagnostics provides the user with comprehensive information on the status of the sensor head. The temperature of the sensor head and the laser diode are displayed and respectively checked to ensure they are within the permissible range.



LSV Setup

The clear and simple structure of the setup menu makes it possible to quickly adapt the LSV settings to the measurement task. For example, various signal outputs can simply be activated and configured via the “Output Setup” menu. These outputs are used for data acquisition and process control (roller table, flying saws...).

All setup parameters are saved in a flash memory in the LSV-6200 controller so that they are not lost, even during a power outage.

Technical Specifications

LSV Series 6000 System	
Sensor Heads	LSV-065, LSV-026
Measurement range - velocity - length	 0 ... ± 7200 m/min (23,600 ft/min) 0 ... 99 km (99,999 ft)
Accuracy	< 0.05 % of the measurement value at |v| > 60 mm/s
Reproducibility	< 0.02 % of the measurement value
Max. acceleration	< 20 m/s²
Signal delay	< 5 ms (measured at the analog output)
Signal acquisition time	typically 20 ms, depending on the signal quality
Measurement value output rate	speed (all outputs) 1024/s; length (RS-232) 512/s

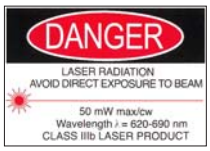
LSV-6200 Controller	
Power consumption	100 VAC ... 240 VAC, 50/60 Hz, max. 100 W
Operating temperature	10 °C ... 40 °C (41 °F ... 104 °F)
Dimensions (L x W x H)	450 mm x 360 mm x 145 mm (17.7 in x 14.2 in x 5.7 in)
Weight	8 kg
VFD display	velocity, length, status information
Units	m/s, mm/s, m/min, m, ft/s, ft/min, ft
Protection class	IP 51 (NEMA 2)
Standard interfaces - Serial, front - Serial, back - Analog voltage output - TTL interfaces	 RS-232, max. 115 kBit/s RS-232 or RS-422, max. 230 kBit/s ± 10 V, scalable, 16 bit D/A 4 TTL outputs/ 3 TTL inputs
Optional interfaces - Encoder signal output - Parallel data interface - Analog current output - Process coupling module - Ethernet interface - Interface for external display	 LSV-I-001: Opto-insulated encoder output, pulse output frequency can be configured freely max. 125 kHz, 5 V up to 24 V level LSV-I-002: Opto-insulated data interface, 18 data bits, 1 sign bit LSV-I-010: 0 (4) ... 20 mA current output can be scaled, active or passive operating mode, 16 bit D/A LSV-I-020: Process coupling module, 4 opto-insulated outputs 24 V / 400 mA (ext. supply necessary), 3 opto-insulated inputs, 24 V standard LSV-I-100: Interface for direct LAN connection LSV-I-040: RS-422 Interface for external large display
Material detect (optional)	LSV-I-004: Signal for presence of an object in the measurement volume

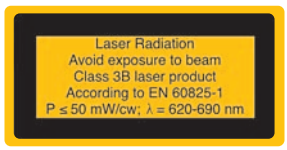
LSV-065 and LSV-026 Sensor Heads		
Light source	visible laser diode, laser protection class 3B 670 nm / < 10 mW 690 nm / < 30 mW for stand-off distances ≥ 1000 mm	
Standoff distances	300 mm, 500 mm, 1000 mm, 1500 mm, 2000 mm, 2500 mm	
Depth-of-field	60 mm ... 200 mm	
Max. cable length	110 m (360 ft)	
Specifications	LSV-065	LSV-026
Protection class	IP 65 (with connector)	IP 66
Ambient temperature	0 °C ... 45 °C (32 °F ... 113 °F) without cooling	–20 °C ... 200 °C (–4 °F ... 392 °F) with suitable cooling
Dimensions [L x W x H]	240 mm x 120 mm x 64 mm (9.45 in x 4.72 in x 2.52 in)	418 mm x 160 mm x 125 mm [1] 418 mm x 240 mm x 184 mm [1] [2]
Weight	2 kg (4.4 lb)	20 kg (44 lb)

[1] without air wipe unit (16.46 in x 6.3 in x 4.92 in)
[2] with LSV-027 mounting plate (16.14 in x 9.45 in x 7.05 in)

Sensor Head Configurations for LSV-065-XXX and LSV-026-XXX				
Model Suffix	**Stand-off distance [mm]**	**Max. depth-of-field [mm]**	**0.1 % Error depth-of-field [mm]**	**Max. velocity [m/min]**
-306	300	±20	±20	1150
-506	500	±30	±30	1800
-1004	1000	±75	±60	4800
-1006	1000	±50	±40	3300
-1504	1500	±100	±70	7200
-1506	1500	±75	±60	4800
-2006	2000	±100	±60	6600
-2506	2500	±100	±60	6600

LSV-026 Utilities	
Processed compressed air	- Dust- and oil-free (8 µm filter is recommended) - Pressure: 0.5 bar to 1.5 bar - Flow rate: up to 120 l/min
Processed industrial water	- Temperature: +15 °C to +35 °C - Flow rate: 1 to 3 l/min - Solid particles content: < 15 ppm - Degree of hardness: < 18 °dH
Oil cooling	- Mill oil - Paraffin oil (aluminum mills)





Uncompromising Accuracy
Built Mill Tough

For over 30 years, Polytec has supplied high-technology measurement solutions to researchers and engineers in the steel, automotive, aviation, aerospace, semiconductor and hard disk drive industries.

Polytec has set the gold-standard in the design and manufacture of optical instruments for non contact vibration, velocity and length measurement. Our subsidiaries in Europe, the USA and Japan ensure that our customers are well served.

Our market leading position is built on innovative technology, high-quality products, qualified and customer-oriented service, expert technical advice and thousands of satisfied customers worldwide. By continuously developing new, trend-setting, non contact sensors and instruments, we embrace our philosophy:

"Advancing Measurements by Light"

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