Issue 01 | 2012

Polytec

InFocus

Optical Measurement Solutions

Measuring by Light

Optical Sensors for Industrial Quality and Process Control

MORE INFO:
www.industrial-test.net

Eric Winkler

Dr. Hans-Lothar Pasch

Dear Reader,

As consumers of technical products, we constantly expect improved functionality and reliability. However, they are frequently manufactured inexpensively using fully automated mass-production. Customer satisfaction can therefore only be achieved with 100% process-integrated quality control.

Optical measurement processes, from among the wide range of instrumentation available for inline testing at the component and product level, are particularly well suited for measuring the characteristic properties of test pieces that are "moved" within the flow of the manufacturing process. Where acoustic quality checking is concerned, Polytec has developed special vibrometers for inline noise and functional testing that can be directly integrated into the production line.

In this issue you can read how engineers at Vorwerk, Loccioni and SKF are making efficient use of Polytec vibrometers to ensure the quality of vacuum cleaners, washing machines and roller bearings. Likewise, how scrap is effectively avoided in steel or corrugated board production with the help of Polytec laser surface velocimeters so that manufacturing costs can be minimized.

Industrial production is an important application area for our optical sensors, but there is also a very wide range of applications in research and high technology. Did you know that NASA's new Mars Discovery robot was tested using a Polytec 3-D Scanning Vibrometer before its launch last November? Or that a sound recording of Thomas Edison could be made audible for the first time with the aid of optical metrology, after more than 120 years?

You can find out about this and lots more in our new issue - enjoy!

Eric Winkler
Optical Measurement Systems

Dr. Hans-Lothar Pasch
Managing Director Polytec GmbH

Polytec

Polytec's New Building is Progressing Quickly

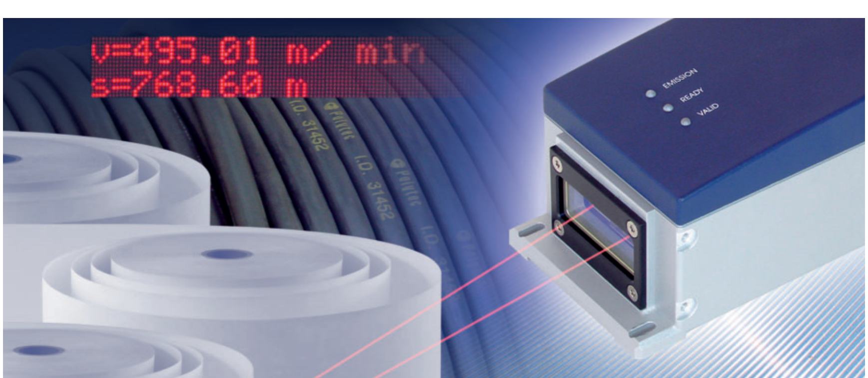
Construction of the 8000 square meter extension to Polytec's headquarters has made good progress since the groundbreaking ceremony that took place at the end of October. The warm weather towards the end of the year meant that prefabrication work could advance quickly. The framing for the new structure can be seen below with the existing building in the background.

New Worldwide Representatives for Length, Speed and Surface Metrology

Polytec's Laser Surface Velocimeters (LSVs) are a globally successful product line in industrial speed and length measurement. To enhance our worldwide presence, the sales network has been expanded with new agencies. In Scandinavia we are now cooperating with Begner Agenturer AB (**www.begneragenturer.se**), in Spain and Portugal with EUROSIDER (**www.eurosider.es**) and in Turkey with Arkun Metalurji Ltd. (**www.arkunmetalurji.com**).

In addition, Polytec is expanding its distribution network for surface metrology measurement systems in Turkey with MEGA Danışmanlık, Temsilcilik ve Dış Ticaret Ltd. (**www.mega-danismanlik.com.tr**), in China and Taiwan with ZSM Co., Ltd. (**www.dr-zhaoschneider.com**) and in Israel with Spectro Israel Ltd. (**www.spectro.co.il**).

More Info:
www.polytec.com/worldwide



Standard-compliant Surface Measurement

Polytec is working actively together with the national and international standards authorities to arrive at an application-appropriate standardization for optical surface metrology. Dr. Wilfried Bauer of Polytec has, since the beginning of the year, been an official German Representative in Work Group 16 (Areal and profile surface texture) of the ISO's Technical Committee TC 213 on dimensional and geometrical product specifications and verification (http://isotc213.ds.dk).

The TC 213 is involved with standardization in the area of "Geometric product specifications and testing (GPS)". The macro- and micro-geometric specification includes the nature and role of dimensional and geometric tolerances and surface properties. Also being addressed are corresponding test methods, dimensional and geometric measurement methods and system calibration, as well as uncertainties in dimensional and geometric measurement.

10th International AIVELA Conference on Vibration Measurements

The International Conference on Vibration Measurements by Laser and Non-Contact Techniques will take place at Ancona University, Ancona, Italy from June 26th to June 29th. The event is organized by A.I.VE.LA (Italian Association of LAser VElocimetry and non-invasive diagnostics). This conference is one of the very rare international events focused especially on the field of laser Doppler vibrometry. Experts in vibration and acoustics as well as manufacturers and authorities in the field of optical and non-invasive instrumentation, and industrial users of such measurement devices, will come from all over the world to present their activities and innovative approaches to vibration measurements. An exhibition is planned to enable participating organizations such as manufacturers of laser vibrometer systems, non-contact instrumentation and systems for vibro-acoustic testing, to bring their products directly to the attention of the participants.

More Info:
www.aivela.org/index10th.html

New Robot for Automated Structural Dynamics Testing

Polytec's application laboratory in Waldbronn was recently equipped with an even more powerful RoboVib® modal testing robot. The new RoboVib® Structural Test Station performs complete 3-D modal testing of structures large or small, for example on whole vehicles, within extremely short overall test times.

In comparison with a classical modal test using accelerometers, time savings of up to 90 % can be achieved with considerably increased measurement point density. The non-intrusive optical 3-D vibration measurement can also be carried out at the node points of a previously imported FE (Finite Element) grid. The new system offers options ideal for validation and updating of FE simulation models.

As part of its Engineering Services package, Polytec offers the following when a modal test is commissioned

- the design of the test rig,
- execution of the measurement and
- mode extraction from the recorded measurement data.

This system is of course equally well suited for operating deflection shape analysis. Together with the new RoboVib® applications lab in the Michigan office at Polytec USA, Polytec provides the most advanced, automated, full-field 3-D vibration measurements available.

Get in touch with us. We'll solve your measurement problem!

info@polytec.com (North America)
service@polytec.de (Europe)

More Info about RoboVib®:
www.robovib.us

"Each New Plant Will Again Include Lasers from Polytec"

Interview with Peter Marpe (B. Eng.), team leader of the automated manufacturing section at TRW Automotive in Gelsenkirchen

■ Mr. Marpe, what is your area of responsibility at TRW?

My duties, together with a small specialized department, encompass the electrical and data processing planning of new production plants, troubleshooting when complex plant problems occur, the implementation of contact-free noise measurements on motor-pump assemblies – MPAs – and power steering systems, as well as general production plant analyses. The vehicle correlations are made in collaboration with our engineering department in Düsseldorf.

■ How long have you been using Polytec's industrial vibration sensors and for which particular tasks?

Since about 2003. The vibration sensors are used exclusively for the contact-free noise measurement of motor-pump assemblies and complete power steering systems. They have also been used for two years on our belt drive power steering, which is a purely electrical steering system. For those interested, more information is available on the TRW website (http://www.trw.com/sub_system/electrically_powered_steering).

■ How was the decision in favor of the vibration sensor made? Were there any alternatives and what was ultimately the convincing factor?

The decision in favor of Polytec was made because the products were virtually free of speckle noise and smaller in size.

■ What is your assessment of their use up until now; if you've had any technical difficulties, how were these overcome?

The use of Polytec vibration sensors has proven to be relatively trouble-free. Indeed, there are 25 lasers running with our 24 hour operation. Regarding the belt drive system, the non-cooperative surface and the curvature had posed a challenge.

With the aid of specially developed software filters we were able to achieve reliable measurements even under those adverse conditions.

■ How are the vibration sensors incorporated into quality surveillance?

For 100 % checking of all motor-pump assemblies and all new steering production plants. If a part exceeds a set limit, even if it is only with regard to one parameter, then this part is rejected as a "FAIL" part and subjected to a fixed rework process. To check the noise measurement chain (including the lasers), master parts are processed during each shift, and these must always produce the known values for this part. If a master part measurement fails, then the test bed is automatically blocked.

■ In the meantime, the number of vibration sensors used along the testing track for MPAs has grown to 25. Are you planning further expansion or use in other manufacturing areas?

Each new production plant will again be equipped with more lasers from Polytec. All new production installations at the factory in Schalke will have noise measurement.

■ How do you see the potential for contact-free measuring techniques in industrial testing or in the automotive industry?

I think there's a lot of potential here. When using contact-free measuring technology there's no risk of wear to feelers, as is the case with conventional measuring systems; it is quick, low-maintenance and has no effect on the component being measured.

Thank you Mr. Marpe. It was nice to talk to you.

The LSV Irons It Out

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

Existing tactile 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 on continuous casters. In practice, these measurement techniques deliver cut length tolerances in the range of ±2 inches. Without constant attention, 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 inches 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. In addition to cut length, cast speed serves as an important input for process and quality control.

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 inches). Future phases will address issues related to the torch home position, clamping time, torch track motion and more.

Initial Investigations

An initial study by Anna Overdorf, Sr. Process Engineer, indicated that, although the cut length repeatability for short time periods could approach ±2 inches 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 over the existing contact wheel, which from experience provided cut length tolerances with variation up to ±4 inches over time.

Successful Installation

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 1500 mm, a depth of field of 150 mm and include a water-cooled housing with air wipe (fig. 1 and 2). 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.

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. Fig. 3 illustrates 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 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.

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.

Author · Acknowledgements

Peter Nawfel, Polytec Inc.
info@polytec.com

The author would like to thank TMK-Ipsco Koppel as well as Anna Overdorf and Guy Gazda of TMK Ipsco for their efforts and input.

This article is based on the same-titled paper presented at the AIST Iron & Steel Technology Conference and Exposition, 2–5 May 2010, Indianapolis, Indiana, USA.

The full paper is available on our homepage **www.velocimeter.us.**

Fig. 1: Laser Velocimeters on TMK-Ipsco 4 strand caster.

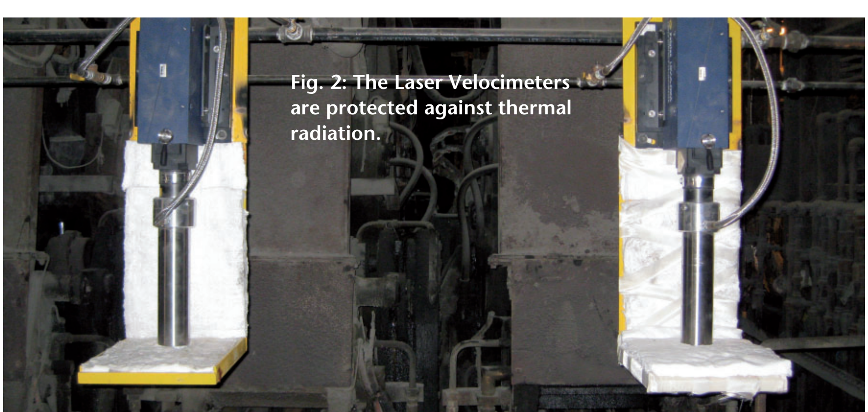


Fig. 2: The Laser Velocimeters are protected against thermal radiation.

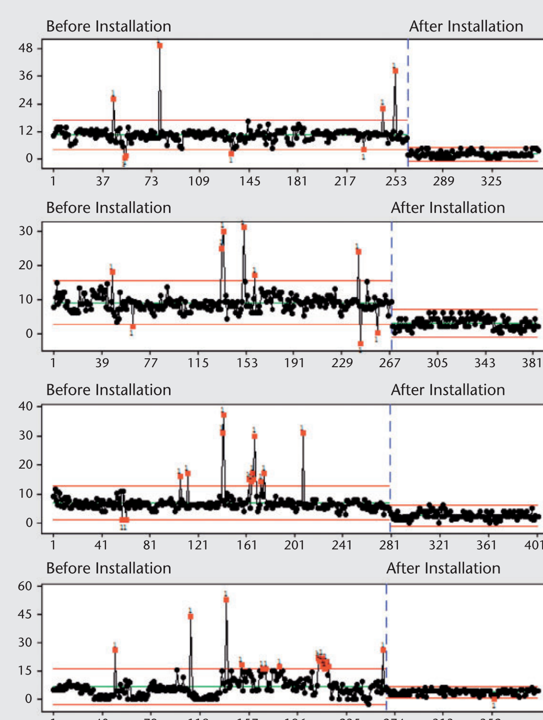
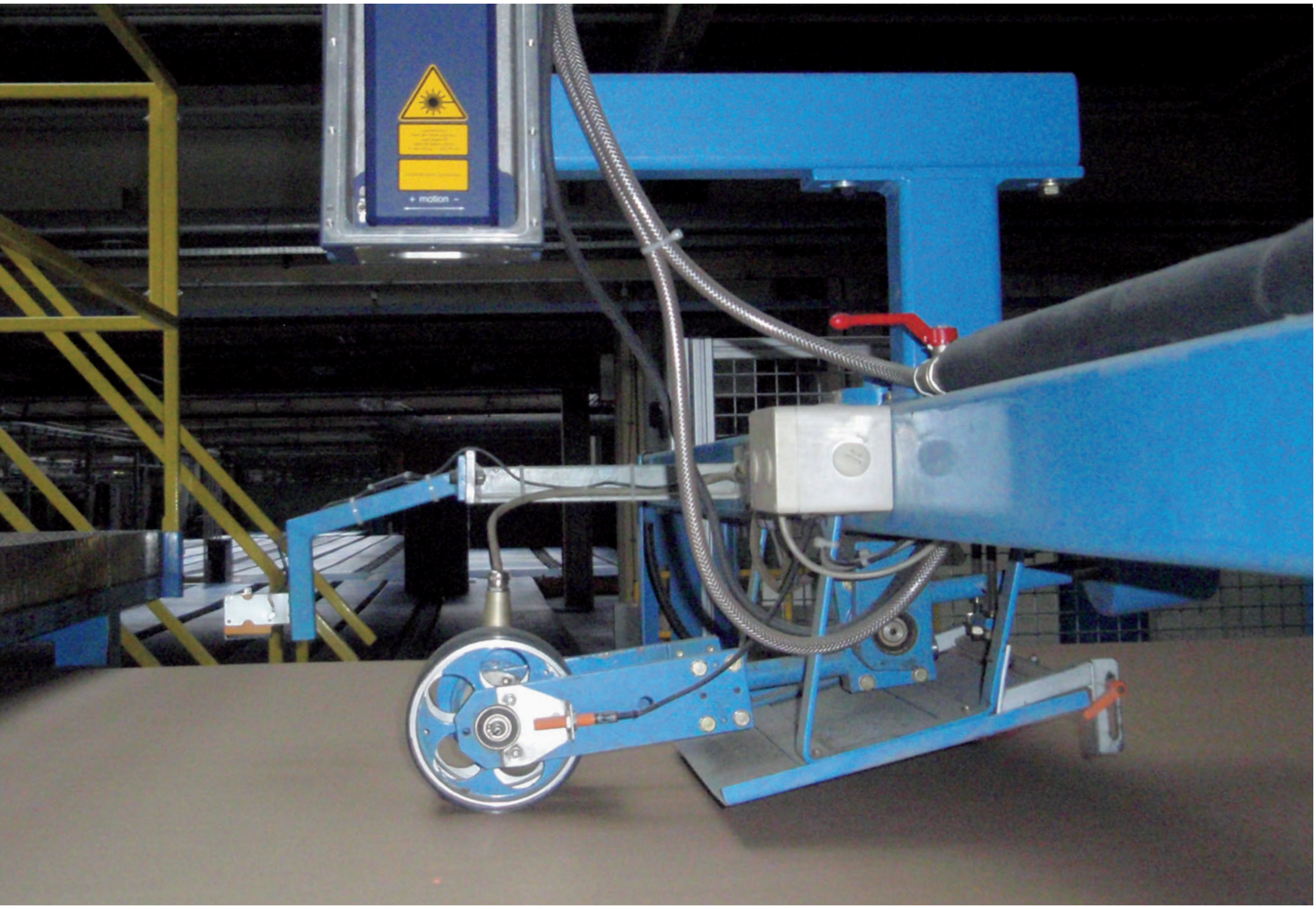


Fig. 3: Billet scrap (in inches) before and after LSV installation for strand 1, 2, 3, and 4 (from top).

The LSV Cuts It

Contact-free Velocity Measurement in the Corrugated Board Industry in Comparison with Conventional Measurement Methods



Increasing Accuracy Requirements in Corrugated Board Production

In addition to triggering at the correct length, knowledge of web speed is required to synchronize the motion of the cross cutter. In practice there are two solutions for measuring the line reference: a classic measuring wheel during normal production, and a feed roller encoder which is selected during a size change, the so-called order change (fig. 1). To achieve better accuracy, a non-contact laser surface velocimeter was implemented.

Comparison Between Laser Measuring System and Existing Measuring Methods

As part of the investigation, the laser measuring system was used instead of an encoder wheel for cross-cutter control of the corrugator (large image). The cut sheets, approximately 200 different sizes in a wide quality spectrum were then re-measured manually. The behavior was also investigated using various plant operating speeds. Continuously changing plant velocities represent the greatest challenge for the measuring systems. The instrument from Polytec achieved the best results – no deviations of greater than ±1 mm were measured under all operating conditions.

Results of the Idler/Laser/Encoder Comparison

To give an indication of the size of the cut length error relative to the sheet length for the three measuring systems, fig. 2 shows all three curves in the same diagram. The analysis is based on a range of 3 x 1500 measurements of different sizes, velocities and corrugated board qualities. The laser provides very good results, cut length deviations of more than 3 mm do not occur, and the largest portion of the measurements, approximately 45%, show no deviation from the actual cut length.

Conclusions

The high absolute accuracy and repeatability of the laser measuring system cannot be achieved with the conventional idler encoder and feed roller encoder. Also, a significant performance difference exists between the laser measuring systems and idler systems and contact wheels. Laser measuring systems offer a measureable improvement over these traditional methods. And, for those customers having difficulties maintaining specified cut length tolerances due to slippage, changing

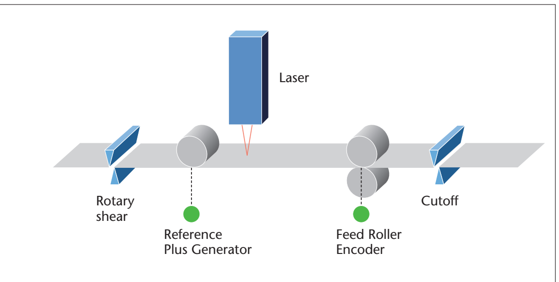


Fig. 1: Process flow at a cross-cutter.

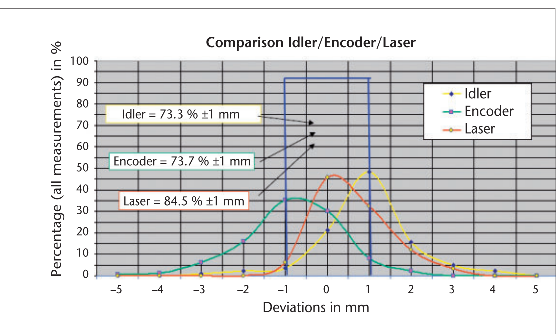


Fig. 2: Measurement deviations for all measurement systems.

wheel diameter and general wear & tear, the LSV provides greater accuracy and improved repeatability, with long term stability – three factors necessary for long term quality, consistent process control and improved yield. The higher investment cost for the laser compared to traditional tactile methods is why the area of deployment for the laser measuring system should be differentiated. For example, the investment pays off quickly for customers who operate with varying (especially very large) cut lengths and high quality spectra, and where accuracy is important.

Author · Contact
Stanisław K. Musielak
SMusielak@bhs-corrugated.de
BHS Corrugated Maschinen- und Anlagenbau GmbH
D-92729 Weiherhammer, Germany
www.bhs-world.com

Source: S.K. Musielak, Velocity measurement in the corrugated board industry – contact-free velocity measurement in comparison with conventional measurement methods. Sensor Magazin 2/2011, p. 8-11 (in German).

"The Laser is Actually Unbeatable"

Interview with Stanisław K. Musielak (B. Eng.), instrumentation expert with BHS Corrugated Maschinen- und Anlagenbau GmbH

■ Mr. Musielak, you are a development engineer with BHS Corrugated, the world's largest solution provider in the corrugated board industry. What area do you work in?

I'm highly involved with rotary cutters, including the drive technology, instrumentation, service, and generally anything to do with vibration on the corrugated board installations.

■ Since when have you and/or BHS Corrugated been involved with Polytec's laser surface velocimeters and what triggered your interest?

It all started 8 years ago. At that time, a German customer was having significant problems with cutting accuracy. The decision was then made to install the LSV-6000 measuring system from Polytec. And of course that was successful!

■ How do you view the use of LSVs up until now? What do you consider are the essential advantages of optical measurements when compared with the alternatives?

The laser is actually unbeatable! The technology has always proven successful over a number of years. Even when you are comparing advantages and disadvantages, the laser always wins.

■ How are the velocimeters incorporated into process control, is there a direct data transfer into quality control?

The LSV controller simulates a classical encoder that is coupled to the PC control of the cross cutter. The cut length differences are determined in the PC and visualized in the WinCC system.

■ What is the reaction of your customers. What proportion of orders has corrugators with LSVs as the velocity measurement technology?

The customers who have implemented the laser system rate the modern instrumentation positively. Unfortunately the number of applications has remained low until now, because for many companies the technology appears expensive at first glance. Very often though it pays for itself, for example with machines producing a large range of different qualities, or when the measuring wheel or parts of them require frequent replacement. Also with special products, for example for certain surfaces where the slip cannot be controlled, or with narrow tolerances - because when a whole batch goes out of tolerance, that's when it gets expensive!

■ How do you see the potential for laser measuring technology in the corrugated board industry and in other areas of the paper and non-metal manufacturing and packaging sector?

This technology has a future, not only in the corrugated board industry. In this day and age when companies are looking to save money, it's a must. Anybody can run the numbers for themselves and reach their own conclusions; if just 1 mm per sheet is saved and in addition the cutting process is improved.

Thank you very much for the interview, Mr. Musielak!

A Clean Solution

Automated Quality Control and Testing Systems for Washers

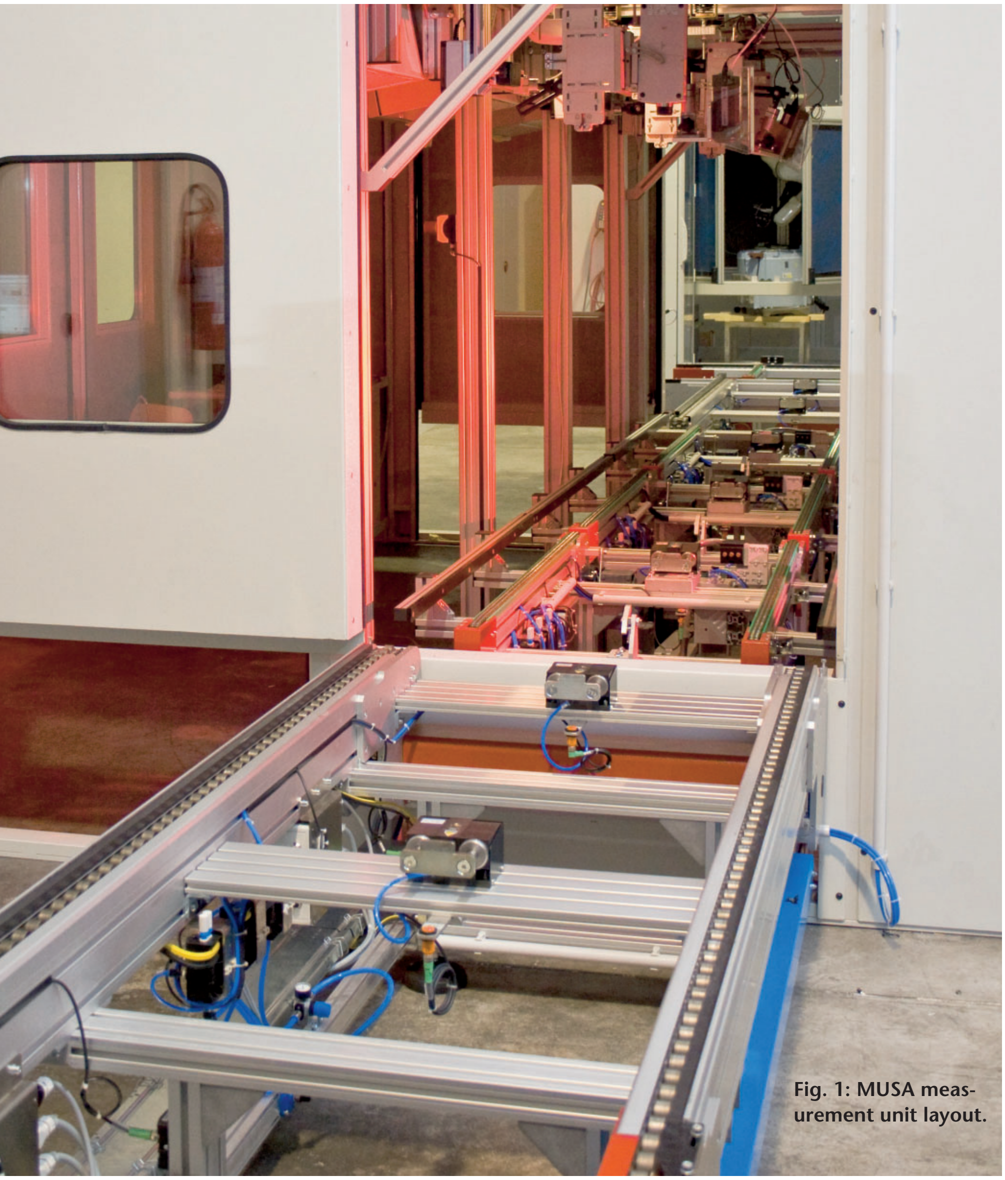


Fig. 1: MUSA measurement unit layout.

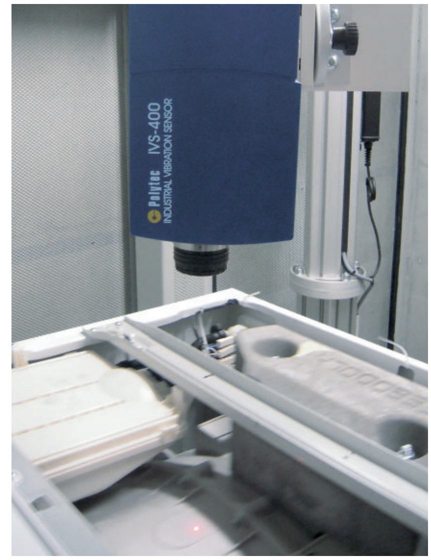


Fig. 2: LDV pointing at the washing machine tub.

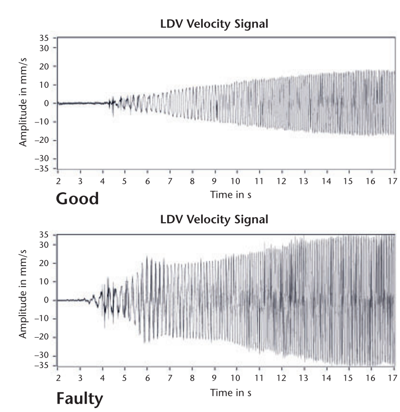


Fig. 3: Velocity time signals for a good (above) and faulty (below) washing machine.

Thanks to a close collaboration with the world's largest manufacturing companies over more than 40 years, the Loccioni Group has gained a widely-recognized leadership in the implementation of automated quality control and testing systems in laboratories and production lines.

MUSA (Measurement Unit in Sound-proof Area) is a turn-key, completely automated testing solution for washers, integrating noise & vibration tests that are usually performed in R&D laboratories. A complete (100%) test on the finished products is an appropriate method to assure a high standard of quality because statistical tests on a random selection of samples cannot guarantee the quality of the full production run. It is well known that vibration tests enable discrimination between good and faulty products and hence the analysis of the vibration signals can be used for quality control of household appliances. LDV (Laser Doppler Vibrometry) is widely used for in-line quality control where non-contact measurements are essential.

MUSA – the System

This paper presents an industrial solution for the in-line monitoring of washing machines, where the use of LDV and microphones allows an objective vibroacoustic characterization of the product in order to distinguish specific mechanical faults. The system mainly comprises:

- A sound-proof cabinet that is able to reduce the external noise by about 35dB, containing three stations running simultaneously (fig. 1)

- 3 IVS-400 industrial LDVs, one per station, pointing at the tub of the washing machine in a radial direction with respect to the axis of the motor (fig. 2)
- 3 microphones, one per station, positioned on the rear part of the washing machine, facing the motor.

When the three washing machines arrive in the sound-proof cabinet, they stop in front of each station and the cabinet doors are closed. Each washing machine is driven to the spinning phase and the signals coming from the LDV and the microphones are acquired simultaneously, both during the run-up and the steady state.

The core of the system is the signal processing software which:

1. Calculates the machine's RPM directly from the LDV signal (fig. 4).
2. De-noises the velocity signal (not described here in detail).
3. Analyzes the LDV and microphone signals during the transient state in the time-frequency-domain (STFT, fig. 5).
4. Analyzes the LDV and microphone signals during the steady state in the frequency domain (fig. 6).

Certain features are calculated both in the run-up and steady state phases. The selected features are compared with fixed thresholds in order to decide the status of the machine and these values are related to the specific model of the machine under test. In particular, the sum of the energy in specific frequency bands is extracted and correlated to the specific defect, e.g. the defect related to the electrical motor. As shown in fig. 7 (left), the main frequency peak in the spectrum is related to the RPM of the washing machine. In fact, it is around 20 Hz, which corresponds to the speed of the tub (1,200 RPM). The faulty machine shows additional frequencies around 280 Hz and 560 Hz (fig. 7, right). It can be easily demonstrated that these frequencies are related to the motor (the fundamental and the second order harmonic). It is known that the ratio between the RPM of the motor and washing machine RPM is 13.5. It therefore follows: RPM motor = 13.5 x 1,200 = 16,200, or 270 Hz.

Results

The software has been developed in the LabVIEW® programming language.

Using the LDV, the system is able to detect the following defects:

1. Unscrewed or damaged pulleys;
2. Unscrewed counterweight;
3. Defective belt (dirty, damaged or incorrectly positioned on the pulley);
4. Defective bearings;
5. Defective/missing spring connecting the drum to the cabinet;
6. Drum unbalance;
7. Defective motor.

The microphone mostly allows the operator to distinguish those defects that create noise but are not big enough to generate vibratory effects on the machine, such as a ground wire touching the pulley, missing material (e.g. a screw) inside the tub, etc.

Conclusion

The described solution shows how the developed data analysis system, composed of appropriate sensors, a data acquisition system and pattern recognition algorithms, can be successfully applied to mechanical defect diagnostics for washing machines in the production line. Particular features have been extracted in order to replace the subjectivity of human inspection testing with an objective assessment of product quality. In particular, laser Doppler vibrometers can be used to detect the vast majority of mechanical defects in washing machines.

Authors · Contact
Barbara Torcianti, Cristina Cristalli, Ph.D.,
Gianluca Agostinelli, Ph.D.,
Enrico Concettoni, Ph.D.
b.torcianti@loccioni.com

Loccioni Group
I-60030 Angeli di Rosora, Italy
www.loccioni.com

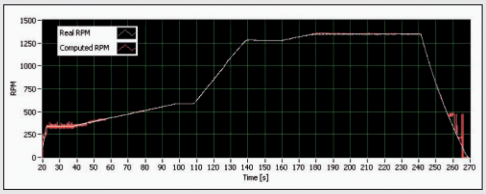


Fig. 4: Washing machine RPM computed from the LDV.

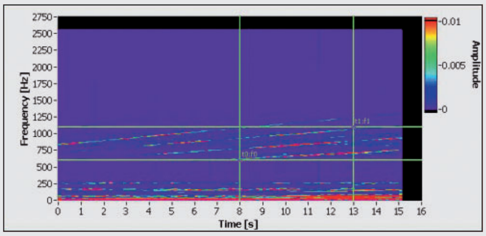


Fig. 5: Velocity signal STFT of a good washing machine during run-up.

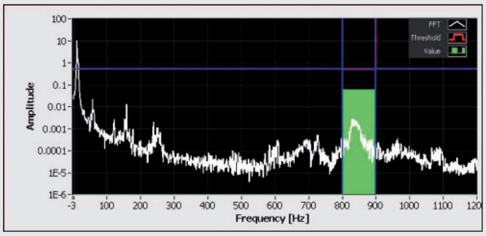


Fig. 6: Velocity signal FFT for a good washing machine during steady state phase.

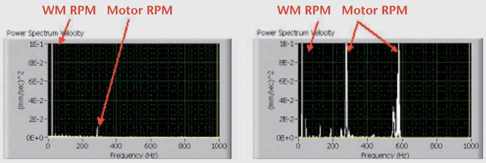


Fig. 7: Power spectrum of the velocity time signals for a good (left) and faulty (right) washing machine.

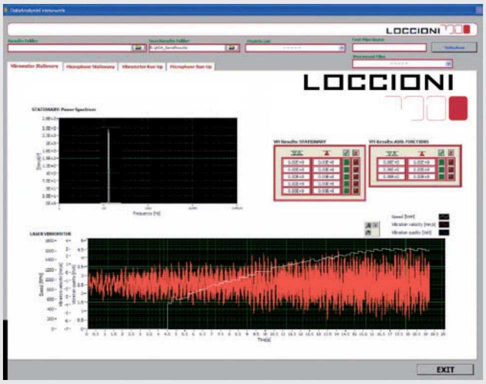


Fig. 8: Front panel of the vibration test system.

Keep On Optimizing!

Vibration Testing on Vacuum Cleaner Motors

Acoustics and long service life are quality criteria which consumers value particularly highly in household appliances that are in daily use.

For this reason 100% of the vacuum cleaner motors by Vorwerk (fig. 1) are subject to final testing during production. This test is carried out using three laser vibrometers, which measure the vibrations at three characteristic locations. A PASS/FAIL decision is made based on a comparison of measured spectra with reference spectra.

To achieve meaningful results in production and to minimize false rejects, it is important to find suitable measurement points. To optimize the testing process, the motors that have already been optimized during the development phase with respect to their vibration behavior are measured using a 3-D Scanning Vibrometer. The measuring system determines and visualizes the operational deflection shape (fig. 2), based on which the suitable test points can then be identified.

To take into account variations between motors, it was decided that a series of nine motors would be measured. Since the vibration profile was to be determined around the entire periphery as well as in the axial direction on the motor's front side, the RoboVib® Structural Test Station (fig. 3) appeared to be particularly well suited for this task. Because the motors are geometrically identical, the geometry, the robot program and the other settings need only be adjusted once; thereafter all of the motors can be tested with the same settings, resulting in low cost, and in particular, high reproducibility (fig. 4).

Measurement Sequence

A robot program is defined after the assembly and positioning of the motors that are inserted in a mounting. This program contains various robot positions, from which it is possible to reach all points or surfaces to be measured with the vibrometer lasers (fig. 5).

As several motors were going to be measured sequentially, the mounting was designed so that a quick changeover and identical positioning was possible. After defining the robot program, the geometry of the motor is measured at the designated measurement points. To do this the robot travels to each measuring position. The function "VideoTriangulation®" is used to achieve high accuracy with this relatively small measurement object (80 mm diameter).

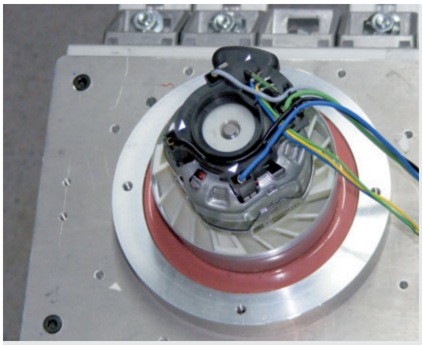


Fig. 1: Vacuum cleaner motor.

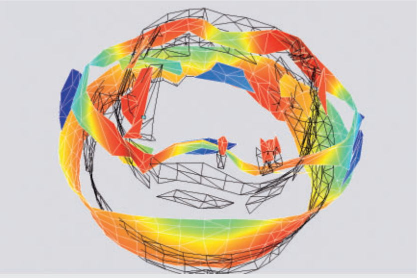


Fig. 2: Operational deflection shape.

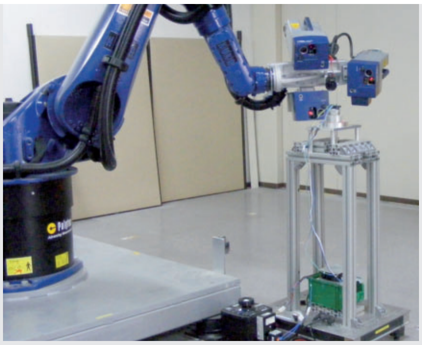


Fig. 3: RoboVib® Test Station.

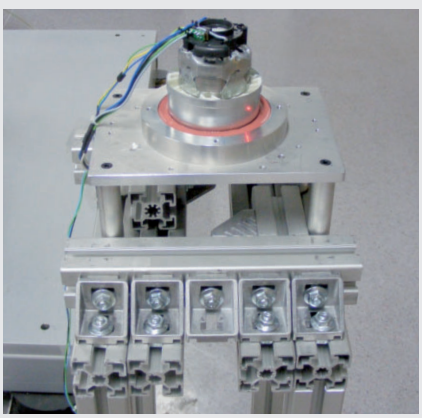


Fig. 5: Measurement beam of the laser vibrometer.

Fig. 4: Vibration measurement on a vacuum cleaner motor.

This function is used to optimize geometric measurement and beam superposition. Before the measurement starts at the first scanning point, the laser positions on the measurement object are optimized so that all three laser beams are perfectly superimposed. The 3-D coordinates are then determined by triangulation and updated in the geometry. After scanning the surface from each robot position, the vibration measurement results as well as the geometry are available for all measured points. The geometry data are then imported for all other motors.

Clear Increase in Efficiency

Because the measurement can be repeated so easily, it was possible to measure 12 motors completely within 3 days instead of the planned series of 9 motors. Without robot support the high-resolution measurement during the development phase would have lasted a full two days for one motor alone, including the preparation work. Here RoboVib® brought about a clear increase in efficiency. Using this measurement data, Vorwerk can now define suitable measurement points for the 100 % final testing of motors. As mentioned above, Vorwerk's quality control test stands also use laser vibrometers so that the motors can be inspected and classified in a contact-free manner.

Conclusion

To prepare a meaningful 100% check of vibration parameters, it is essential to have a precise understanding of the overall vibration behavior of a component and of course the error indicators in the vibration spectrum. The contact-free measurement approach described here is very efficient, both for the identification of measurement points and for the test stand. The qualification of a series of parts, taking into consideration scatter, is particularly time efficient using the automated RoboVib® method, and can be achieved with high reproducibility. The system needs to undergo only one learning procedure to deliver high-resolution operating vibration shapes for the entire series. The end result of the process is high quality vacuum cleaner motors and consequently many satisfied customers.

Authors · Contact
Dr. Roland Kraus
roland.kraus@vorwerk.de
Research + Development / Dept. TEP
Vorwerk Elektrowerke GmbH & Co. KG
D-42270 Wuppertal, Germany
Mélanie Gerard, Jörg Sauer
Polytec GmbH

Zero Defects

Noise Testing and Condition Monitoring of Roller Bearings at World Leading Manufacturer SKF

Roller bearings are high precision mechanical components produced in very high quantities. SKF is the world leader in the bearing industry and continues to extend its lead in process development and quality technology.

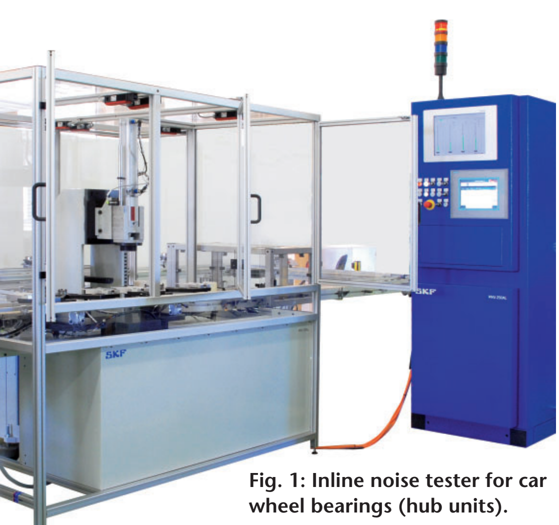


Fig. 1: Inline noise tester for car wheel bearings (hub units).

Dimensional tolerances of bearings are on the order of a few micrometers and special attention is paid to achieving low running noise. In addition, SKF is dedicated to a Zero Defect policy, despite making thousands of products every day. As a consequence, SKF applies 100% noise testing at the end of its production lines that requires highly sophisticated testing systems.

A Center of Excellence for Bearing Noise

SKF has established a Quality Technology Centre (QTC), which is located at SKF Österreich AG in Steyr, Austria. QTC develops, manufactures and sells high precision measuring equipment to support quality control and process improvements for the automotive-bearing and grease industry. QTC is the center of excellence for bearing noise, roundness and waviness as well as form measurement and non-destructive testing.

QTC has delivered more than 500 noise testing machines (fig. 1) worldwide for continuous operation. In 2010 QTC started a joint project with Polytec in order to replace commonly used inductive body vibration sensors by the IVS-400 laser vibrometer (fig. 2).
This new technology offers a number of advantages for SKF factories:

- Contactless measurement
- Flexible use
- Accurate and constant signal
- Lower operating expenses through quick resetting and simplified calibration
- Lower cost for sensor repair
- Easy upgrade for existing machinery

The use of laser vibrometers also allows the simplification of layout and equipment design. In addition it is possible that other machines such as life test rigs or run-in stations can be easily complemented with noise testing sensors and electronics.

Mobile Measurements for Many Different Applications

There was another strong synergy that could be achieved with SKF's "Condition Monitoring" business. SKF is the leading company for condition monitoring systems and offers a wide range of portable instruments and on-line systems using piezo vibration sensors. By continuing the active cooperation between SKF and Polytec, the IVS-400 was further developed in order to be used together with SKF condition monitoring products. The SKF Laser Vibrometer MSL-7000 can be combined for example with SKF Microlog (fig. 3), thus offering additional value to all our customers.

On the one hand this opens up more potential applications with SKF portable instruments or in-line systems. On the other hand it gives SKF service engineers an advanced and flexible tool for a large number of different applications in the field.

- Mobile use for many different applications
- Measuring over large distances
- Measurement on hot surfaces and rotating parts
- Consistent signal, no influence of force applied to the piezo
- Offers measurements in hazardous zones or areas that are difficult to reach
- Measurements through glass

Quality Control Technology for Customers

SKF is now also capable of supporting its customers in quality control. The new SKF MSL-7000 Laser Vibrometer can be connected with the QTC noise testing technology for advanced end-of-line testing installations for electric motors, pumps, compressors and many more. This means that SKF offers their own in-house noise testing standards to outside customers as well, for final quality inspection and continuous manufacturing process improvements, following SKF's vision "To equip the world with SKF knowledge".

Author · Contact
Werner Palmetshofer
Werner.Palmetshofer@skf.com
SKF Österreich AG
Quality Technology Centre
A-4400 Steyr, Austria
www.skf.com

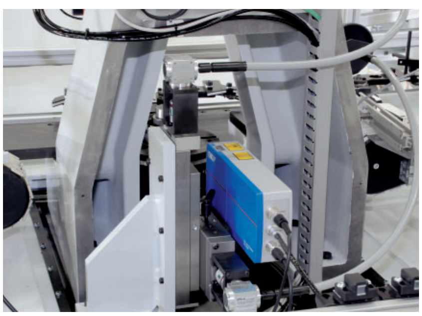


Fig. 2: SKF laser vibrometer applied in noise testing machine.

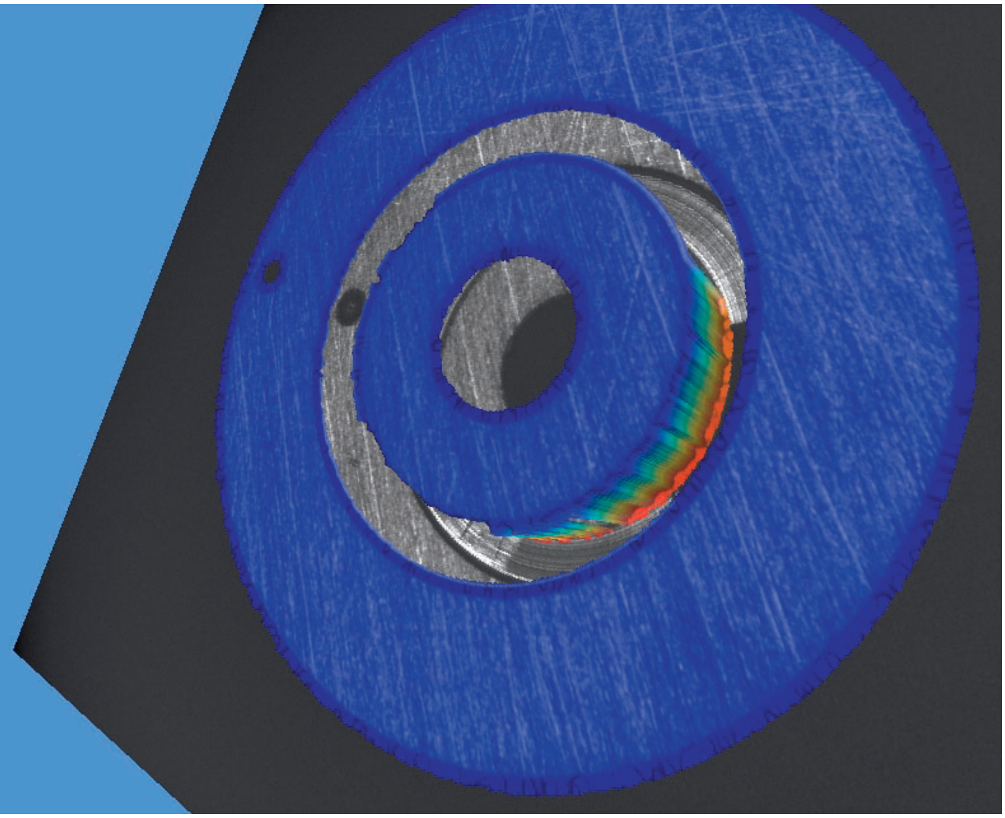
Fig. 3: Mobile vibration analysis kit with SKF laser vibrometer and SKF Microlog.

SKF – a Global Company

Year established:	1907
Revenues in 2011:	7.400 M €
No. of employees:	46,039
No. of manufacturing sites:	around 140 in 32 countries
SKF presence:	in more than 130 countries
No. of distributors:	15,000 worldwide

Where Quality Counts

Optical Surface Metrology in Manufacturing Using White-light Interferometry



The use of optical measuring techniques in quality assurance is becoming more and more popular, especially where fast and accurate results are required. 3-D topography of the entire surface is obtained resulting in considerably more information and indeed more meaningful information than from the linear profiles obtained using mechanical sampling methods.

Use of the latter tactile technique is very time consuming if an entire surface topography is to be determined, as surfaces must be assembled from individual lines of data. A clear example is the measurement of tool marks. Because they are spatially aligned, very different results are obtained depending on the direction of the line profiles. For example when determining smoothness, the measurement direction could be parallel or perpendicular to the machining direction. Mechanical sampling methods reach their limits, especially when short cycle times are required. These are the most important reasons why optical topography measuring methods are used ever more frequently in quality assurance.

Optical Measuring: Contact-free and Whole-surface

White-light interferometry (also called coherence scanning interferometry) is ideal for these tasks because it enables the measurement of large fields of view with interferometric accuracy in the vertical direction. With white-light interferometry, measurement accuracy is independent of the field of view and a parallel optical path can be used to avoid shadowing. This means that even low lying surfaces inside deep holes can be reached and characterized almost up to the edge. Large working distances can also be implemented and hence a large measuring volume achieved. As an example, Polytec's TMS-100 TopMap Metro.Lab has a vertical scan range of 70 mm for a field of view of 38 mm x 28 mm. This permits measurement of step heights of up to 70 mm with a measurement uncertainty of a few micrometers.

Example: Measuring Components for Piezo Injectors

Piezo injectors are critical components in automotive engines. In this example two separate surfaces of the component are to be recorded as a 3-D profile with a cycle time of approximately 5 s and evaluated for smoothness, parallelism and separation. Here, reproducibility of approximately 100 nm is required. The result can be seen in fig. 1. The two surfaces are acquired in a precisely separated manner to determine the parameters mentioned.

Example: Smoothness Measurements on Sealing Surfaces

For the smoothness measurement on a work piece with faces that seal (fig. 2) it turned out that values from the side walls (large image) were also recorded. They are removed using a suitable mask because they should not be included in the evaluation. A smoothness of 2.5 µm (fig. 3) was determined for both surfaces together, while the line profiles each gave smaller smoothness values (1.2 µm or 1.6 µm) because the highest and/or lowest point of the surfaces was not on the line profile (fig. 4). This indicates the necessity of considering the entire surface in the case of precision work pieces so that reject parts are reliably detected.

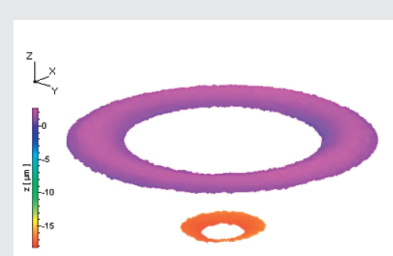


Fig. 1: The smoothness and parallelism of two annular surfaces of a component part in a piezo injector. The height is represented by colors.

Use in Quality Assurance – Practical Aspects

In practice, suitable programming of a test process sequence is easy and safe. For example, the surfaces of interest are automatically selected and evaluated with software. An appropriate user interface means that even inexperienced users can carry out a good/bad analysis and export the relevant data to the quality assurance software, for example to create quality assurance cards. For this purpose Polytec makes an extensive library of subroutines available for C# programs, however most users leave it to the measurement instrument manufacturer to develop such add-ins. This also ensures that the evaluation algorithm for the work pieces is stable and comparable in terms of accuracy and repeatability, and that no additional errors occur.

Intensive cooperation between supplier and user is of course also necessary if a measurement instrument is to be integrated into a production line. Here, interfaces must be precisely defined, as well as environmental influences on the measurements in the production shop. For example fig. 5 shows the vibrations that occur when the measuring station is loaded. Although they attenuate after less than one second, vibrations must be considered during the measurement sequence.

Cycle Time Precise to the Second

There are different time sequences depending on the work piece and measurement task. For piezo injectors it was possible to verify the following testing times:

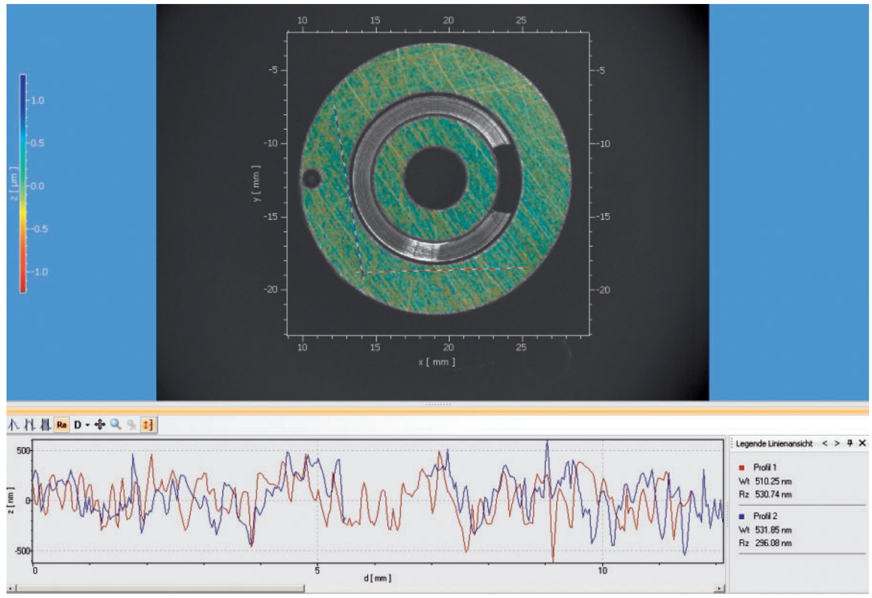


Fig. 4: Line profiles along two sections over the work piece.

- 1–2 s Loading and vibration attenuation
- 1–2 s Quick measurement to find the height of the surfaces
- 2–3 s Precise measurement of surfaces of interest
- 2–3 s Calculation and unloading

When the height differences are greater, the times may well be longer. Often the cycle times are not critical down to the second because only occasional samples are measured. If the test pieces cannot be brought into a different measurement area, then a protected measurement station can also be deployed in the vicinity of the production process. With this approach work pieces can be sequentially characterized on pallets.

Summary

These examples show that optical surface metrology used in quality control provides a high measurement accuracy while simultaneously measurement times can be significantly decreased in comparison to traditional methods.

Author · More information

Dr. Wilfried Bauer, Polytec GmbH
oms@polytec.de

Parts of this article are based on the paper "W. Bauer: Special Properties of Coherence Scanning Interferometers for large Measurement Volumes", Journal of Physics: Conf. Ser. Vol. 311 (2011) 1, 012030. Full text available on http://iopscience.iop.org/1742-6596/311/1/012030

More Info: **www.topmap.info**

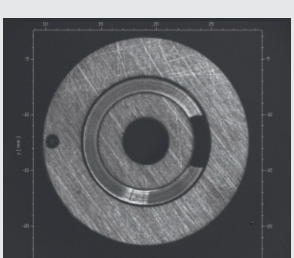


Fig. 2: Photograph of a work piece with sealing surfaces.

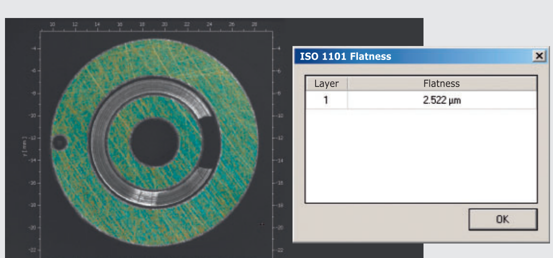


Fig. 3: Smoothness measurement on the work piece (ISO 1101).

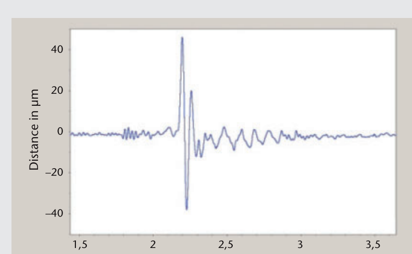


Fig. 5: Vibration attenuation behavior after loading with a work piece.

All Along the Line

Real Time Analytics in the Production Process

Besides physical parameters such as pressure or temperature, chemical characteristics are also increasingly used for automated process control in industrial production. In-line determination of relevant parameters such as ingredient concentration, applied quantity, or moisture content enables direct monitoring of significant product properties. Thus the production processes can be controlled to yield pre-defined qualities.

100% Control in the Process

Chemical ingredient analysis of both intermediate and end products has been a fixed part of quality control in many manufacturing plants for decades. Also indispensable is the incoming analysis of raw materials. All of these control measures are taken in order to provide a smooth process and of course a consistent product quality.

There are a broad range of testing methods available for the analysis. However, optical spectroscopy has proven to be particularly suited for most applications. Based on the direct interaction between light and the matter under test, it is a versatile method for the qualitative and quantitative determination of material properties.

Process analytics is a rather recent discipline that is committed to transfer proven analytical procedures from laboratory into the process. There are many immense advantages to the user, e.g. no more sampling and sample preparation due to the measurement being in-line. Moreover, the results are available in real time and can be fed into the automated process control exact to the second. This makes it possible to determine rejects not only at the end of the line, but they can be avoided already during production.

The development of process analytical instrumentation is a great challenge. First, automated systems have to be rugged, reliable and as precise as a laboratory method even under the harsh environmental conditions that can be found in production plants. Furthermore, the data processing and complete evaluation must be accomplished in real time and thus fully computer based. This will require sophisticated and proven hardware as well as advanced methods of data processing.

Individual Solutions using Standard Components

Depending on the product and its properties that are to be monitored for process control, various spectral ranges can be selected, from visible light to the near infrared (NIR) range. For dedicated measurement tasks, Raman spectrometer systems are available that are also ruggedized to meet the requirements of challenging production environments.

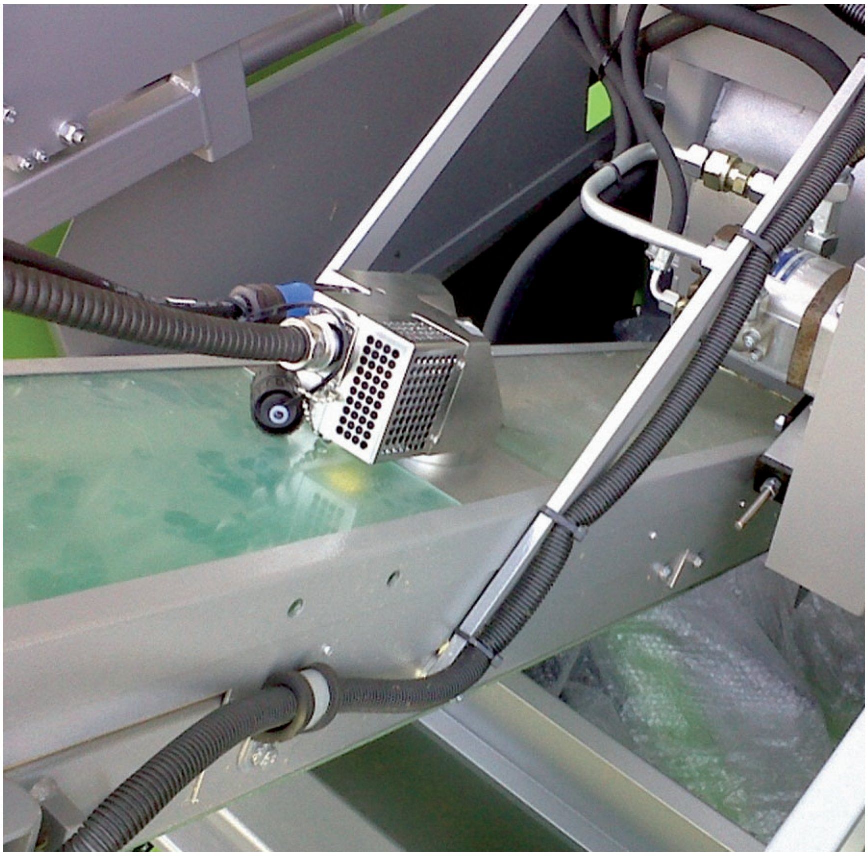


Fig. 1: Reflection sensor head installed in a continuous production line.

Fig. 2: Contact sensor head in potentially explosive environment.

Adequate sample presentation is always the key to successful system operation. Polytec is committed to the idea that its process analytical systems should be perfectly adapted to the customer's production facilities and products, and not vice versa. A variety of specialized sensor heads are available to answer this claim in the best possible way and to accommodate different sample properties and installation situations.

For measurements over large distances, e.g. for goods placed on conveyor belts or for web applications, reflection sensor heads are the best solution (fig. 1).

On the other hand, contact sensor heads are the best choice for measurements over short distances or in direct contact with the sample (tubes, chutes, funnels, etc.), see fig. 2 and large image above. Recently, the product range has been extended with ATEX-compliant components enabling the process analytical solutions to also be used in potentially explosive atmospheres, e.g. when working with inflammable dust (fig. 2).

Modular Spectrometer Systems: Designed for Flexibility and Precision

Polytec Spectrometer Systems (PSS) are designed for flexibility and provide optimal solutions for various applications. This is achieved by combining the best suited sensor heads with spectrometers and process software packages. The components are highly standardized in order to ensure uncompromised high precision and ease of use during process integration. The PSS systems are based on well-proven technology and offer application-specific solutions that are nevertheless safe and easy to integrate.

Author · More information
Dr. Linas Urbonas, Polytec GmbH
analytics@polytec.com
More Info: **www.analytics-online.com**

Science Lab on Mars

Space System Component Design Validation Using Scanning Laser Vibrometry

Scientists at NASA's Jet Propulsion Laboratory (JPL) have validated the dynamic response of spectrometer inlet funnels on the Mars Science Laboratory rover utilizing the Polytec PSV-400-3D Scanning Laser Vibrometer.

NASA JPL's latest mission to Mars in November 2011, sent the Mars Science Laboratory rover named "Curiosity" to assess whether Mars ever had, or still has today, an environment able to support life. Curiosity will act as a robot geologist on the surface of the red planet to acquire information about the geology, atmosphere, environmental conditions and potential biosignatures on Mars.

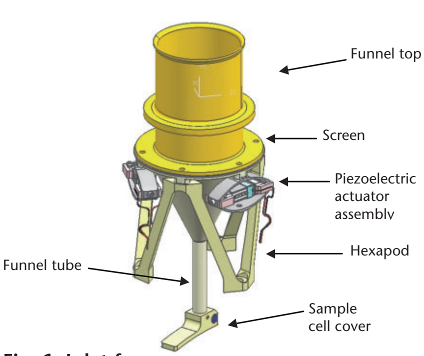


Fig. 1: Inlet for soil samples.

While on Mars' surface, Curiosity will collect soil and environmental samples, and utilize cameras, spectrometers, radiation detectors, environmental sensors and atmospheric sensors to analyze the samples on location. The resulting data will be sent to NASA scientists for analysis and interpretation.

Preventing contamination of the rover is critical to ensure that Curiosity's data collection and analysis yields accurate results. Thus engineering models and flight models are tested separately to validate design requirements of the various systems aboard the rover.

The inlets (fig. 1) for the Chemistry and Mineralogy X-Ray Diffraction/X-Ray Fluorescence Instrument (CheMin) and

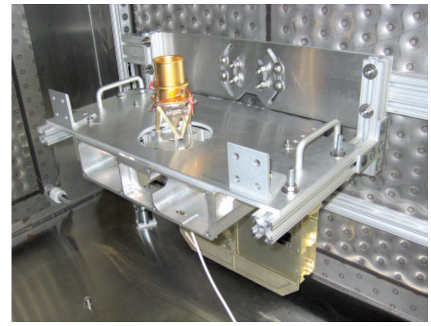


Fig. 2: Engineering model of the sample funnel.

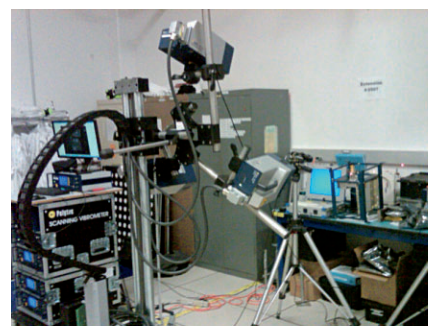


Fig. 3: Vibration analysis of the engineering model.

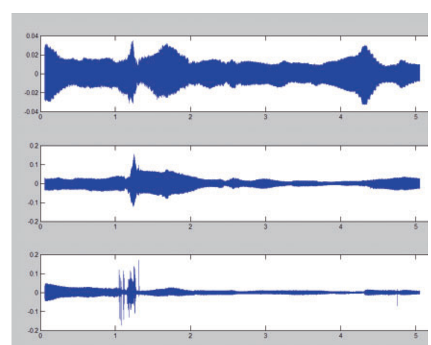


Fig. 4: Frequency response of the model in X, Y, and Z directions.

Sample Analysis on Mars Instrument Suite (SAM) utilize piezo driven actuators at the base of the funnels to shake and sift soil from Mars' surface into the spectrometers for analysis.

Previously tested models using accelerometers produced inaccurate data due to the mass loading effects of attaching the transducers to the test article and limiting the amount of measurement locations possible. Scientists at JPL have developed a method of non-contact dynamic performance testing to measure the vibration levels of the spectrometer inlet funnels for design validation.

Experimental Setup

The first step in the validation process was to dynamically characterize the engineering models (fig. 2) that have proven to effectively move soil through the funnel. By characterizing vibration levels at various locations on the inlet funnel, this data can be compared to the predicted results from the Finite Element Model (FEM) and provides a benchmark to be later compared with measurements on the flight model which cannot be tested with soil.

The engineering model testing was performed (fig. 3) with excitation to the actuators, using a 100 Hz – 500 Hz sweep over 15 seconds for the SAM and a 10.5 kHz – 12.5 kHz sweep over 5 seconds for the CheMin. The plan called for testing each of the three actuators separately, then together in groups of two actuators exciting and all three actuators exciting. The Polytec PSV-400-3D was used to measure vibrations in 3D on the engineering model. The engineering model was oriented in several positions to allow line of sight access from the Polytec sensor heads to the CheMin inlet (inside and outside), the CheMin funnel, the CheMin collection screen, and the SAM inlets. The measurement locations consisted of approximately 20 to 30 measurement points on the inlets as well as a few locations on the collection screen and funnel. Time history data of the response to the sweep input was acquired in X, Y and Z directions at each measurement location (fig. 4).

To validate its functionality, the flight hardware had to be compared to the engineering models tested. The flight hardware is the CheMin and SAM instruments that are installed on the rover being sent to Mars. The rover is assembled in the Spacecraft Assembly Facility (SAF), which is clean room. To prevent damage to the rover and its components, access was limited to one meter away from the rover. The Polytec PSV-400-3D was thoroughly cleaned and brought into the SAF to a distance of one and a half meters away in front of the rover with a direct line of sight to the CheMin and SAM inlets (fig. 5). Only the inlets of the CheMin and SAM were visible above the rover's top surface. Measurements were taken with the same excitation and acquisition settings from the engineering model tests on the outside and inside rim of the CheMin and SAM inlets.

Results and Conclusion

The data was analyzed by JPL, low pass filtering the time history data and computing the RMS velocity over one chirp for each measurement location. The resulting data was compared between the engineering models and the flight hardware. The results of this testing showed that the dynamic behavior of the flight model matched that of the engineering model, giving JPL scientists confidence in the functional performance characteristics of the inlet actuation system.

Authors · Contact
Toby Ban, Anthony Brock
t.ban@polytec.com
Polytec Inc.

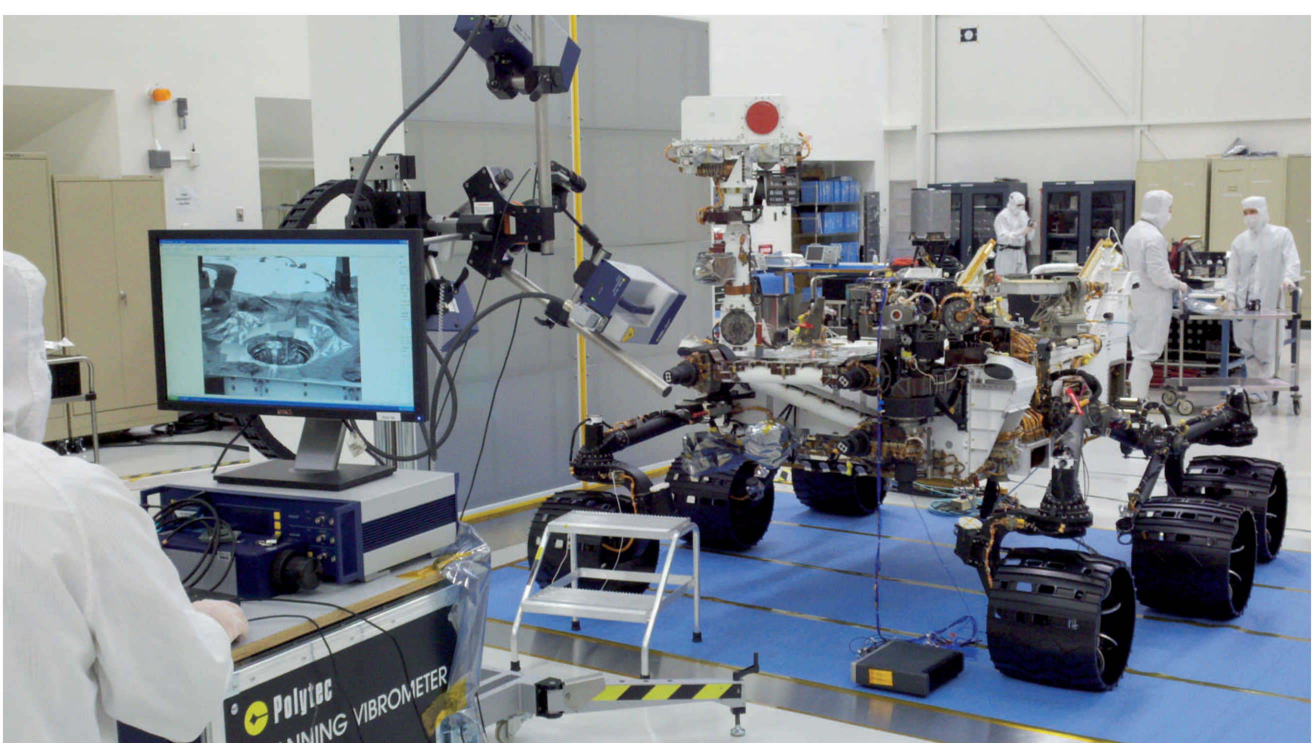
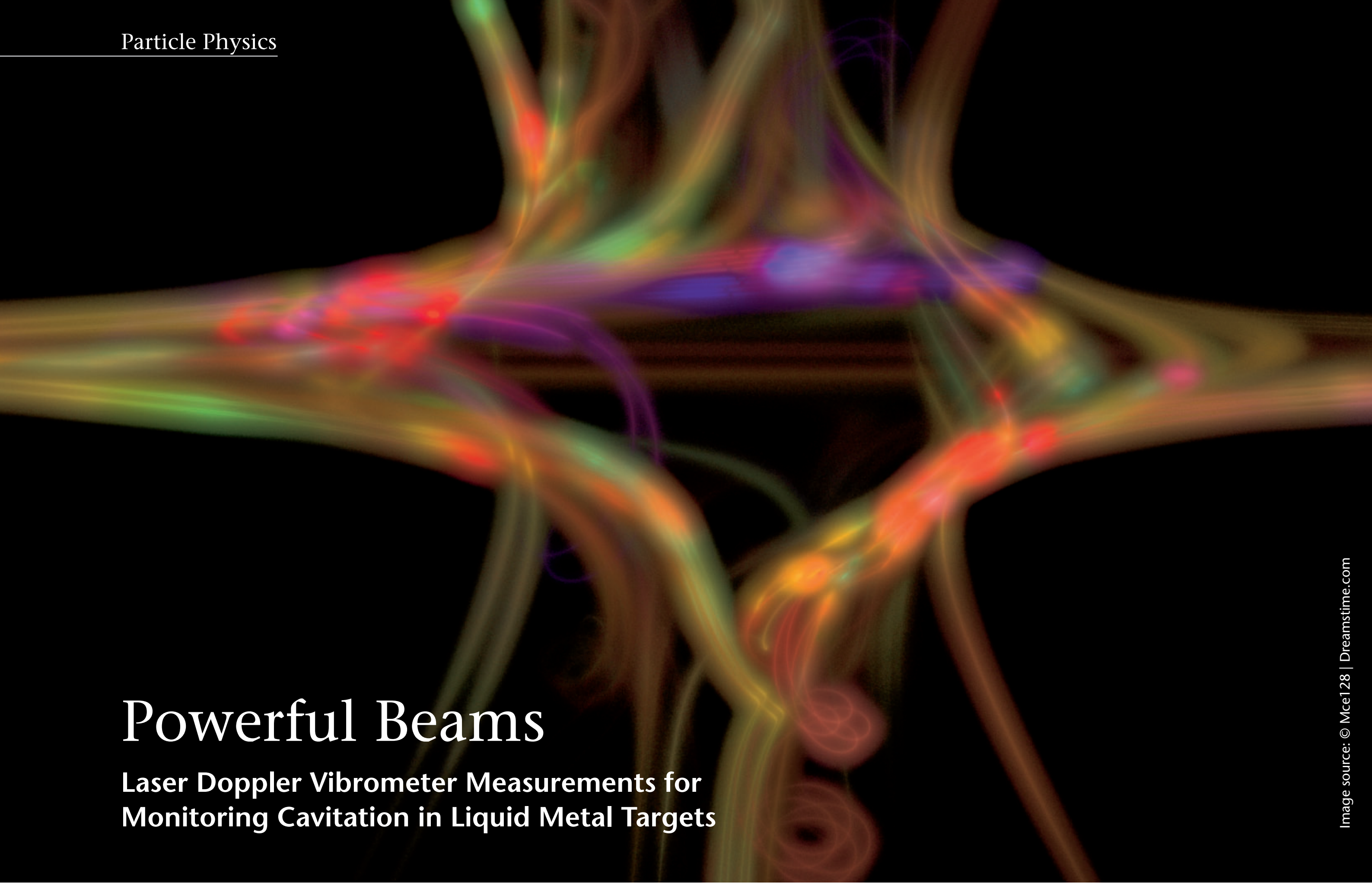


Fig. 5: Vibration measurement on the inlets installed on the rover.



Powerful Beams

Laser Doppler Vibrometer Measurements for Monitoring Cavitation in Liquid Metal Targets

Image source: © Mce128 | Dreamstime.com

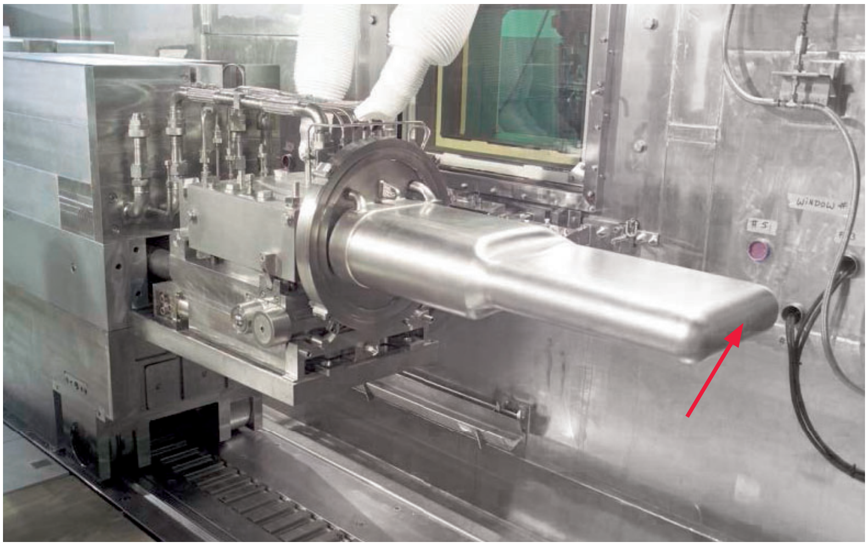


Fig. 1: SNS target installed in the SNS service bay. The location from which the disk specimen of fig. 2 was extracted is shown in red.

The Spallation Neutron Source (SNS) is an accelerator-based neutron source at the Oak Ridge National Laboratory (ORNL), Tennessee, providing the most intense pulsed neutron beams in the world for material research and life science by academia and industry. To detect cavitation damage by liquid mercury on stainless steel targets for the SNS, a Polytec Remote Sensing Vibrometer (RSV) was used by engineers from Oak Ridge National Laboratory. An experimental mercury-filled target was bombarded by a pulsed proton beam while vibrations of the stainless steel target test plates were monitored with the RSV laser. The high frequency vibration was recorded for post-analysis of cavitation damage. Using these data should be helpful in determining whether certain mitigation techniques were successful in the experiment. The results were collected for 19 targets and evaluated for comparison against direct measurements of the physical damage to the test plates.

Introduction

The Spallation Neutron Source (SNS, neutrons.ornl.gov) in Oak Ridge uses a high-power pulsed proton beam directed to a liquid-filled mercury target (fig. 1) to provide neutrons for scientific research.

Pressure waves in the mercury created by the proton pulses lead to cavitation damage on the target container (fig. 2) which limits the target's lifetime. An R&D program at ORNL seeking to improve understanding of the damage mechanisms and develop mitigation technologies has a need for data that characterize the intensity and dynamics of cavitation events within mercury spallation targets.

One method is to measure the vibration of the container's exterior surface and quantify the emitted energy in the frequency band expected for cavitation. Correlations between laser Doppler

Polytec

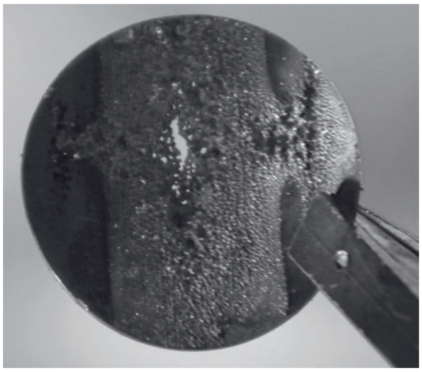


Fig. 2: Disk specimen cut from SNS spent target showing cavitation damage on a vessel wall.

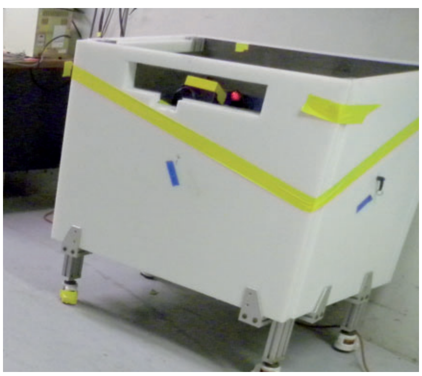


Fig. 3: RSV laser enclosure without lid for shielding of equipment from radiation.

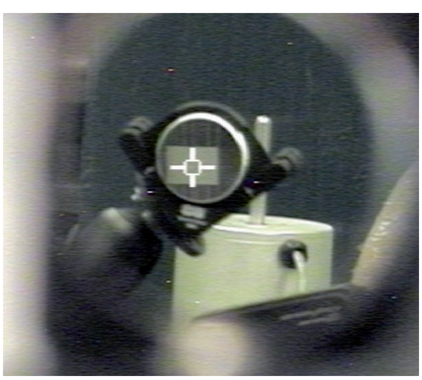


Fig. 4: View from RSV laser through three mirrors to rectangular reflective tape on target.

vibrometer (LDV) measurements and actual observed cavitation damage are being developed by engineers who recently performed tests at the Los Alamos National Laboratory's LANSCE user facility (lansce.lanl.gov). These tests were designed to investigate various mitigation options that might prolong the lifetime of SNS targets, and the LDV diagnostic enhances their understanding of the physics.

At the LANSCE WNR test room, high-energy proton beam pulses with comparable intensity to those in SNS were directed to mercury-filled experimental test targets. Also similar to the SNS was the release of high levels of neutron and gamma radiation caused by the proton-target impact.

Experimental Setup

The RSV laser head (fig. 3) was placed at a distance of 70 ft from the test target and behind substantial concrete, steel, and polymer shielding in order to protect the sensors from exposure to neutron and gamma radiation while monitoring the vibration of the stainless steel target wall. Three intermediate mirrors were used to direct the laser beam to the target and back again to the sensor. The controller was pulled back even further behind another layer of steel and lead. A snapshot from the RSV video view to the target with reflective tape attached is shown in fig. 4.

Results and Conclusions

The arriving proton pulse was used to trigger the RSV, and the subsequent vibration measurement was collected for 200 ms, although the cavitation apparently occurs within the first few milliseconds. Typical traces showing raw signal, filtered signal, and the calculated cavitation damage potential (CDP) are shown in fig. 5. Rankings of expected damage between test cases based on CDP are correlating well with direct post-irradiation observations.

One interesting result that has been discovered in the LDV data are the different transient features in the damage deposition. Some test conditions seemed to experience cavitation beginning as early as 100 microseconds after the beam pulse arrives, whereas for others, the cavitation occurs later – and suddenly – at 700 microseconds. Such an observation could not be made simply by examining the damage after the test. These observations provide an insight to the cavitation phenomenon and aid in the development of mitigation technologies for the SNS target.

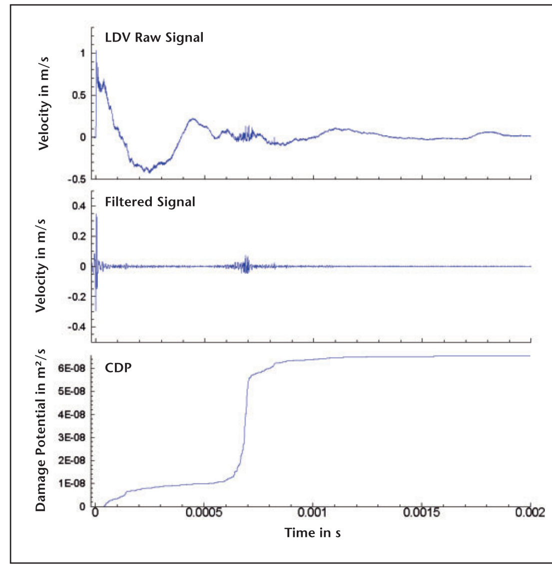


Fig. 5: Laser Doppler vibrometer velocity (top) with bandpass filtered data and integrated cavitation damage potential.

Authors · Contact
Mark Wendel, Bernie Riemer
wendelmw@ornl.gov
Oak Ridge National Laboratory
Oak Ridge, TN 37831, Tennessee, USA
Michael Stone, Polytec Inc.
More Info: **http://neutrons.ornl.gov**

Sounds Good

The Edison Tinfoil Phonograph – A Tool for Teaching Acoustics

In 1877 Thomas Edison invented the phonograph, which was the first device capable of both recording and reproducing sound. The first phonograph was a purely mechanical device (no electrical components were used) and the transparency of its operation makes the phonograph an effective tool for teaching acoustics to students of all ages. For this purpose, a replica of Edison's phonograph was constructed and the mechanical drawings and bill of materials were made available.[1]

The phonograph can be used to teach advanced acoustics topics, such as mathematical modeling of multiple-energy-domain systems. A common modeling technique taught to graduate students in acoustics is analogous circuit modeling, where physical components in various domains are represented by "analogous" electrical circuit elements. This technique employs certain assumptions about the physical device (e.g. components vibrate with uniform motion). When comparing model predictions with measured data, it is important for students to understand the range of validity of the model resulting from these assumptions.

An analogous circuit model of the replica phonograph was created and compared to laboratory measurements.[2] A PSV-I-400LR scanning laser Doppler vibrometer (SLDV) (1) provided auxiliary measurements that give insight into the validity of model assumptions and (2) collected the primary data to which the model is compared. The remainder of this article discusses these two topics.

Horn Measurement

The phonograph utilizes an acoustic horn (not shown in the title image) to amplify the sound as it travels into and out of the mouthpiece. The model assumes that the horn walls are rigid and do not vibrate in response to an acoustic field. To demonstrate the impact of this assumption on the transmission of an acoustic wave through the horn, the SLDV was used to measure the surface velocity of the horn wall while a microphone measured acoustic pressure at the horn throat, as shown in fig. 1. This measurement was made for two horn constructions, one made from ½" thick medium density fiberboard (MDF) and the other from poster paper. A loudspeaker broadcasting white noise was used to acoustically excite each horn.

Fig. 2a shows that the spatially-averaged surface velocity of the paper horn is approximately an order of magnitude larger than for the MDF horn. This sound-structure interaction has an important effect on the acoustic measurement, shown in Fig. 2b. For the first three axial resonances of the horn, the acoustic pressure measured at the microphone when using the paper horn is approximately half of the acoustic pressure when using the MDF horn. Since the non-rigidity of the paper horn could affect the model comparison to the measured data, the MDF horn was chosen for the remainder of the measurements.

Phonograph Diaphragm Measurement

Another model assumption is that the phonograph diaphragm vibrates with uniform motion. To test the validity of this model assumption, the phonograph mouthpiece was positioned at the horn throat, as shown in fig. 3. The SLDV measured the surface velocity of the phonograph diaphragm while the loud-

Fig. 1: Photograph of the measurement apparatus to measure the rigidity of the horn wall. The paper horn is visible in the photograph.

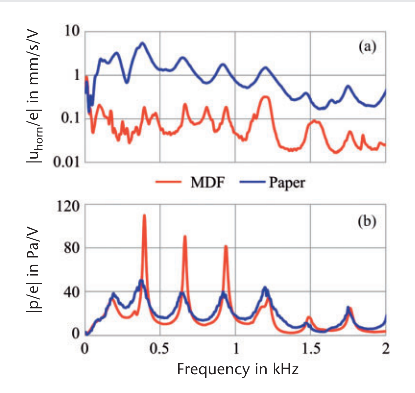


Fig. 2: (a) Surface-averaged horn wall velocity and (b) horn throat pressure for MDF (red) and paper (blue) horns. Both quantities are normalized by the drive voltage. Note in (b) that in addition to the amplitude differences, the resonance frequencies (the frequencies of the local maxima) of the system are also affected.

speaker acoustically excited the system. A photograph of the measurement apparatus is shown in fig. 4.

SLDV measurements revealed that the diaphragm vibrates with uniform motion below 1.5 kHz, and exhibits modal wave motion above 1.5 kHz. Fig. 5 shows the surface velocity of the diaphragm for several excitation frequencies.

Measurement/Model Comparison

The pressure measurement shown in Fig. 2b and the diaphragm measurement described in the previous section comprised the primary data to which the model was compared. Fig. 6a shows the modeled and measured acoustic pressure at the throat of the MDF horn and fig. 6b shows the velocity of the diaphragm. In Fig. 6b, the measured data is the coherent average of the five scan points closest to the center of the diaphragm.

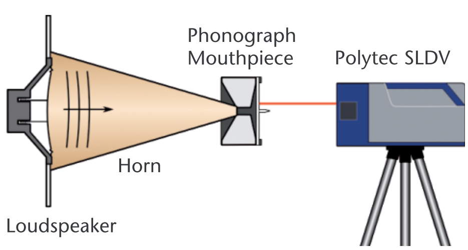


Fig. 3: Schematic of the measurement apparatus for diaphragm velocity.

The model is in good agreement with the measured data up to about 1.2 kHz. The largest disagreement occurs in the velocity transfer function above 1.5 kHz, after the onset of modal vibration was observed (fig. 5). Uniform motion of the mechanical elements is one of the assumptions built into the analogous circuit model, and hence once uniform motion ceases, one can no longer expect agreement between the measurement and the model predictions.

Conclusion

In this article, a replica of Edison's original phonograph was used to illustrate concepts related to analogous circuit modeling of multiple-energy-domain systems. The replica, along with the measurement capabilities of the SLDV, allows students to gain an understanding of the impact of model assumptions. SLDV measurements both illuminated the limitation of model assumptions and provided the primary data to which the model was compared. As shown, the acoustic response of a paper horn is difficult to model due to lack of rigidity and the modal vibration of the diaphragm is not captured by the model. Despite these limitations, the analogous circuit model provided a good fit to the measured data below 1.2 kHz.

Authors · Contact
Jason D. Sagers, Andrew R. McNeese, Richard D. Lenhart, Preston S. Wilson, Ph.D.
jdsagers@utexas.edu

Applied Research Laboratories,
The University of Texas at Austin,
Austin, Texas 78758, USA

For a video demonstration of the phonograph, see www.texasacoustics.org/edisonphonograph.

References

1. A.R. McNeese, J.D. Sagers, R.D. Lenhart, and P.S. Wilson. "A homemade Edison tinfoil phonograph." Proc. Meet. Acoust. 12, (1), 025001, (2011).
2. J.D. Sagers, A.R. McNeese, R.D. Lenhart, and P.S. Wilson, "Analysis of a homemade Edison tinfoil phonograph," J. Acoust. Soc., in press (2012).

Image Citations

Title image (left): Unknown photographer, "Prof. Edison, Phonograph," Brady-Handy Photograph Collection (ca. 1878). URL http://www.loc.gov/pictures/item/brh2003000454/PP/.

Title image (right): Andrea Duensing, "McNeese with Phonograph", 2011

Acknowledgments

This work was supported by the Applied Research Laboratories at the University of Texas at Austin. The authors would also like to thank Dr. Jonathan Blotter and the Brigham Young University Acoustics Research Group for the use of the SLDV.

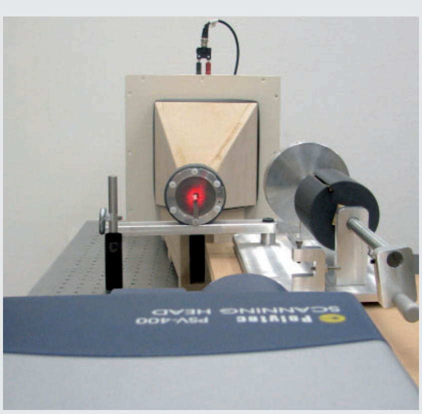


Fig. 4: Photograph of the measurement apparatus for diaphragm velocity.

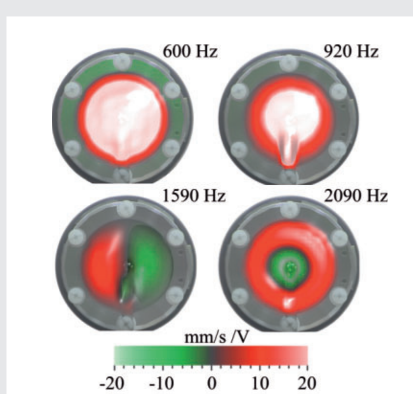


Fig. 5: Surface velocity of the phonograph diaphragm at four excitation frequencies. The surface velocity is normalized by the drive voltage. The upper left frame exhibits the most uniform motion. Modal patterns are seen in the lower two frames.

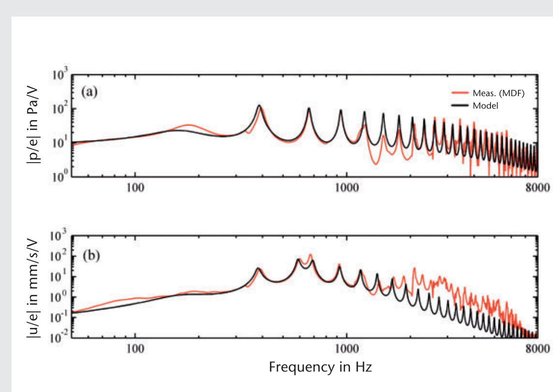


Fig. 6: Measurement (red) and model (black) for (a) |p/e|, the cone throat pressure and (b) |u/e| the diaphragm velocity, both normalized by the drive voltage.

His Master's Voice

Optical Surface Sensors Bring Old Audio Records Back to Life

In 2000, an American physicist named Carl Haber heard a radio program reporting on the fragility of some audio archives at the US Library of Congress. Wax cylinders and recorded tapes were broken or too damaged to be listened to, or played. So he decided to apply his experience in optical metrology to this rather unique application.

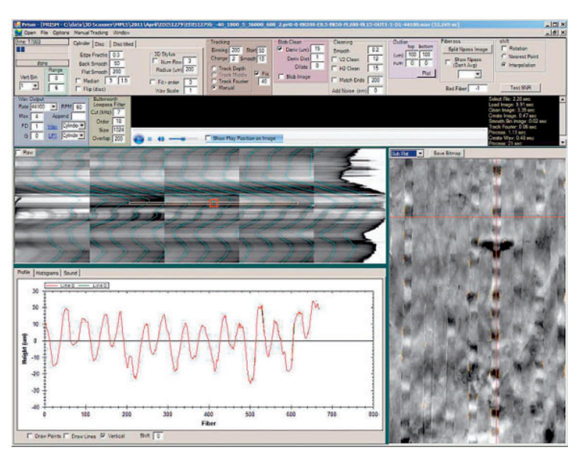
There are several teams of researchers worldwide that are working on this audio restoration issue. The core of the American team collaborating with the Library of Congress is from the Lawrence Berkeley National Laboratory and the University of California, Berkeley. The project (IRENE), started in 2002, used a system which enabled them to digitize those objects with a vision system. Their first article was published in 2003. The 2-D images only showed modulations of the groove in the lateral direction. In order to quantify the complete shape from which the audio information can be extracted, the team then set out to look for the best 3-D optical measurement method. Soon afterwards, they selected the confocal chromatic imaging technology invented by STIL.

From 2003 to 2005 the studies performed with the CHR controller – part of STIL point sensors product line – demonstrated excellent results. However the digitization took too much time, up to several days for an Edison cylinder. So in 2007 a new generation line sensor (MPLS) could be delivered to the American team, which allowed them to perform every measurement far more quickly. The MPLS sensor works nearly 200 times faster than the CHR sensor. The technical collaboration between STIL and the Library of Congress continues today with STIL delivering a second optimized MPLS sensor in 2009.

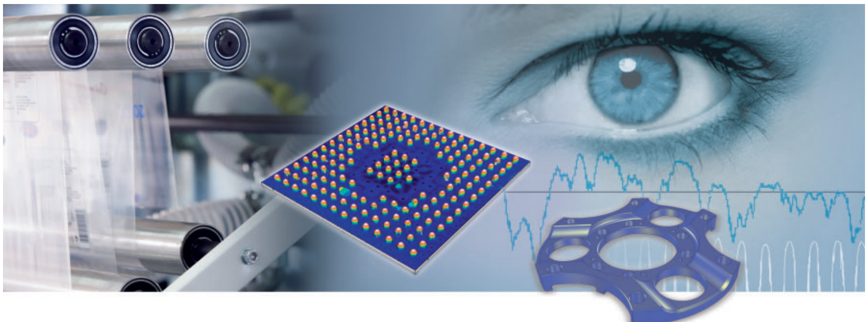
There have been numerous publications dealing with these studies. One of the most recent was published by American newspapers and television in July 2011, reporting on the recovery of the audio from what is believed to be the oldest (123 years) commercial recording in the world, a woman's voice reciting "twinkle, twinkle little star" recorded by an Edison device and integrated into a talking toy doll (www.nps.gov/edis).

The cooperation shown here with the Lawrence Berkeley National Laboratory projects is continuously inspiring STIL to develop new products. STIL has been a privileged partner for 18 years now with institutions working on documents related to France's cultural heritage (C2RMF, The National Library of France, LRMH, and RMN). Optical non-contact methods (with no risk of damage) are perfectly suited to the study of thickness, topography and spectroscopy of fragile works in order to perform archiving, assist in the restoration process or study materials. The chromatic-confocal sensor solutions described here are distributed by Polytec within the TopSens product line.

More Info: **www.topmap.info**



New Software and Accessories



Surface Parameters now Conform to ISO Standard 25178:

New TMS Software Release

With version 3.2 TMS Software, Polytec's optical 3-D profilometers for measuring and analyzing surface data now provide the following new features and advantages.

- Application-specific add-ins can now be designed so that they are even more user-friendly thanks to new access options on the user interface.
- The processing of large-area measurement data records that are compiled from several individual measurements (stitched) now takes place more efficiently.
- Control of the TMS program has been made even easier through optimization of the GUI (fewer clicks).
- Filters can be configured to be applied automatically after the measurement.
- A high depth-of-focus background image can now be calculated from the measurement data.
- The reporting options have been expanded with customer, load and part-specific information.
- If desired, the exposure time can now be automatically set by the system.
- Other features include: geometric evaluation options for sphere matching; and determinations of step heights and layer thicknesses have been expanded.
- Surface parameters conform to ISO standard 25178.

New Version of TMS Report Software

In the latest version of Polytec's TMS software, powerful additional analysis features are available for measuring and analyzing surface measurement data, through the optional packages TMS Report, TMS Report+ and TMS Report Premium. Here Polytec draws upon the proven software technology of its partner, Digital Surf. Likewise, a special programming package is available for analysis of the linear measurement data from the new Polytec TopSens Point Sensors in the form of TMS Report Profile.

More Info: **www.topmap.info**

Speed and Length Measurement for Calibrated Machines:

MID Conformity for Polytec LSV

Wherever goods are sold by length in the EU, they must be cut using calibrated machinery. The requirements for the corresponding instrumentation and data storage are summarized in the somewhat cumbersome European "Measurement Instrument Directive 2004/22EC" – abbreviated to MID. The particular focus of this standard is data security, protection against manipulation, and access control. Thus all values must remain stored for at least 90 days and it must be clearly apparent if someone has modified the values.

In the second quarter, Polytec will bring a system to market that fulfills the requirements of MID and has its own certificate attesting suitability for calibration in the PTB, Germany's national metrology institute. Initially, the system consists of an LSV-1000-200 and the junction box with an integrated panel PC in which the data is stored and from which they can be called up by other systems over a network, for further processing.

For all OFV-551/552 Fiber-optic Sensor Heads:

OFV-C-103 Deflection Head

Vibration measurement on complex parts is frequently made more difficult by the limited optical accessibility of the measurement point. With tailor-made vibrometer accessories, Polytec offers practical solutions for even these tricky applications. The OFV-C-103 deflection head for all OFV-551/552 fiber-optic sensor heads provides a 90° deflection of the laser beam and thus enables measurements at right angles to the original beam path. The miniaturized deflecting optical probe is now directly integrated into the tip of the OFV-C-103 head, so that the laser beam is deflected only approximately 1 mm in front of the tip. Vibration measurements that were almost impossible, on surfaces that are nearly obscured, can now be carried out more easily, such as the analysis of the lower read/write head of a hard disk drive.

www.vibrometry.com

Trade Shows and Conferences

Date		Event	Location
Mar	26 – 30, 2012	Tube 2012	Düsseldorf, Germany
Apr	18 – 19, 2012	Converting Packaging and Printing Expo	Cleveland, OH, USA
Apr	11 – 13, 2012	FilmTech Japan 2012	Tokyo Big Sight, Japan
Apr	16 – 18, 2012	EuroBrake 2012	Dresden, Germany
Apr	17 – 20, 2012	Analytica	Munich, Germany
Apr	23 – 27, 2012	Hannover Messe	Hannover, Germany
Apr	25 – 27, 2012	APACT 12 Advances in Process Analytics and Control Technology	Gateshead, Newcastle
May	07 – 10, 2012	AISTech Iron & Steel Technology Conference	Altanta, GA, USA
May	08 – 10, 2012	Spacecraft Technology Expo 2012	Los Angeles, CA, USA
May	16 – 18, 2012	Japan Automotive Engineering Exposition	Yokohama, Japan
May	21 – 24, 2012	IEEE International Frequency Control Symposium	Baltimore, MD, USA
May	22 – 23, 2012	WAI Operations Summit & Wire Expo 2012	Dallas, TX, USA
May	22 – 24, 2012	SENSOR+TEST 2012	Nuremberg, Germany
May	22 – 24, 2012	The 15th International Conference on Low Frequency Noise and Vibration and its Control	Stratford-upon-Avon, UK
May	22 – 24, 2012	Swiss NanoConvention 2012	Lausanne, Swizerland
June	04 – 05, 2012	Nondestructive Evaluation of Aerospace Materials and Structures III	St. Louis, MO, USA
June	10 – 13, 2012	Euronoise	Prague, Czech Republic
June	13 – 14, 2012	Automotive Testing Expo Europe	Stuttgart, Germany
June	18 – 22, 2012	ACHEMA	Frankfurt, Germany
June	26 – 29, 2012	AIVELA 10th Intl. Conference on Vibration Measurements by Laser and Non-Contact Techniques	Ancona, Italy
June	26 – 06, 2012	Pipe & Tube	Nashville, TN, USA
Jul	03 – 06, 2012	6th European Workshop an Structural Health Monitoring	Dresden, Germany
Jul	08 – 12, 2012	ICSV 19th International Congress on Sound and Vibration	Vilnius, Lithuania
Jul	11 – 13, 2012	Micromachine/MEMS Robotech	Tokyo Big Sight, Japan
Jul	22 – 27, 2012	ICEM15 International Conference on Experimental Mechanics	Porto, Portugal
Sept	11 – 13, 2012	10th International Conference on Vibrations in Rotating Machinery	London, UK
Sept	17 – 19, 2012	ISMA 2012 Conference on Noise and Vibration Engineering	Leuven, Belgium

Polytec Web Academy

Are you interested in special topics such as brake testing, experimental modal analysis, measuring rotational vibration, characterizing ultrasonic devices and biological/medical applications of laser vibrometry?

Polytec Web Academy

Just register and attend one or many of our free webinars at the Polytec Web Academy. For more information visit: **http://polytec.webex.com**

Cordial Invitation

10th International AIVELA Conference on Vibration Measurements

The 10th International Conference on Vibration Measurements by Laser and Non-Contact Techniques will take place at Ancona University, Ancona, Italy from June 26th to June 29th. For more information please see page 4 and **www.aivela.org/index10th.html**.

Imprint
Polytec InFocus · Optical Measurement Solutions
Issue 1/2012 – ISSN 1864-9203 · Copyright © Polytec GmbH, 2012
Polytec GmbH · Polytec-Platz 1-7 · D-76337 Waldbronn, Germany

CEO/Publisher: Dr. Hans-Lothar Pasch
Editorial Staff: Dr. Arno Maurer, David E. Oliver
Production: Regelmann Kommunikation
Images courtesy of the authors unless otherwise specified.

Polytec GmbH (Germany)
Polytec-Platz 1-7
76337 Waldbronn
Tel. +49 7243 604-0
Fax +49 7243 69944
info@polytec.de

Polytec France S.A.S.
Bâtiment Orion – 1er étage
39, rue Louveau
92320 Châtillon
Tel. +33 1 496569-00
Fax +33 1 57214068
info@polytec.fr

Polytec Ltd.
(Great Britain)
Lambda House, Batford Mill
Harpenden, Herts AL5 5BZ
Tel. +44 1582 711670
Fax +44 1582 712084
info@polytec-ltd.co.uk

Polytec Japan
Arena Tower, 13th floor
3-1-9, Shinyokohama,
Kohoku-ku, Yokohama-shi,
Kanagawa, 222-0033
Tel. +81 45 478-6980
Fax +81 45 478-6981
info@polytec.co.jp

Polytec, Inc. (USA)
North American Headquarters
16400 Bake Parkway
Suites 150 & 200
Irvine, CA 92618
Tel. +1 949 943-3033
Fax +1 949 679-0463
info@polytec.com

Central Office
1046 Baker Road
Dexter, MI 48130
Tel. +1 734 253-9428
Fax +1 734 424-9304

East Coast Office
25 South Street, Suite A
Hopkinton, MA 01748
Tel. +1 508 417-1040
Fax +1 508 544-1225

www.polytec.com