LM INFO Special

LASER MEASUREMENT SYSTEMS ISSUE 1/2006

100 % QUALITY CONTROL IN INDUSTRIAL PRODUCTION

Polytec Provides Optical Sensors for Non-contact Measurement of Surface Vibration, Length, Speed and Topography

The optimization of products and processes plays an important role in a company's economic success. While performance and quality requirements increase, there is pressure to manufacture at the highest throughput and at the least possible cost.

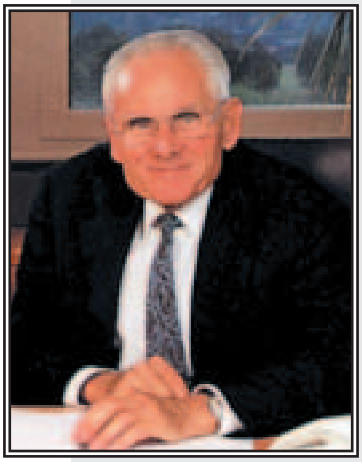
Statistical process control can't deliver optimized manufacturing with zero-failures. Instead, 100 % quality inspection of all manufactured products must be done either during production and assembly or immediately after. Therefore, quality control instrumentation must be fast, automated and rugged to avoid significantly reducing throughput. These scenarios are an ideal application for Polytec's non-contact optical measurement technologies.

In this issue, discover convincing solutions with the aid of Polytec sensors in the production of mechanical components (page 6, 10), of semi-finished goods (page 12, 24), in packaging technology (page 16), as well as in medical engineering (page 18, 20). Included in this issue is a tutorial to learn how appropriate test parameters are derived from vibration signals. Have fun reading!

Find more info on www.polytec.com/usa/industrial

CONTENT

In Memory of Heinz G. Lossau



1923 – 2005

On December 12, 2005, Heinz G. Lossau died at the age of 82. Mr Lossau was the founder of Polytec GmbH and longtime executive director of Polytec and Physik Instrumente (PI). The clever entrepreneur realized the potential of laser technology soon after it was invented and founded Polytec GmbH in 1967 as the first distributor of commercial laser technology in Germany. Only a few years later he began development and in-house manufacturing of products.

In the 80's, after attending a series of lectures about fiber-optical sensors at the University of Kent at Canterbury, he initiated the development of Polytec's first laser vibrometers. From this beginning, laser vibrometers have had substantial success and Polytec has become the global market leader in laser vibrometry. The "Optical Fiber Vibrometer" that was developed specifically for hard disk drive applications still remains as part of the "OFV" product line today.

Heinz G. Lossau directed both Polytec and PI successfully over many years with high personal commitment and creativity. Later, he chaired the advisory board of the company group where he assured the long-term success of the group with his visions and experience.

We will miss a manager who knew how to start and build an innovative group of companies counting about 600 employees worldwide and achieving an annual 90 million € turnover. Partners, management and staff will continue the pioneering work in the spirit of Heinz Lossau.

Dr. Helmut Selbach
Managing Director
Polytec GmbH

One of the first commercial Polytec vibrometers

New Polytec Offices and Representatives Worldwide

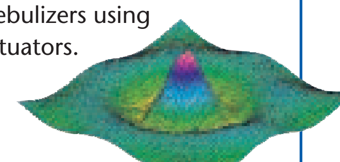
Our US subsidiary has strengthened its operation by expanding and relocating its East Coast Office to Hopkinton, Massachusetts and by setting up a fourth office in Wayzata, Minnesota. These offices compliment the headquarters in Tustin, California and the Detroit, Michigan office. In the ASEAN states, we welcome our additional representative, Logicom Instruments, who will focus on the automotive and environmental testing markets. This helps our existing representative, Millice, to have an even stronger focus on data storage, ultrasonic and microstructure applications. New representatives for the Laser Surface Velocimeter product line have been signed up in Austria and South Africa.

You will find all up-to-date addresses at **www.polytec.com**.

Watch & Win with Polytec

This was the title of our competition in the second LM Info Special edition in 2005. Nearly 100 entries reached us from Europe, the USA, Asia and Africa. Most of them were sent in with the right answer – the maximum vibrational velocity that can be measured with Polytec vibrometers is 30 m/s.

The first prize, an Apple iPod with 30 GB, was won by Mr. Holger Schürle of Pfeiffer GmbH. This company makes dosage systems for pharmaceutical and cosmetic applications and is successfully using the Polytec PSV-400 Scanning Vibrometer to develop micro-nebulizers using piezo actuators.

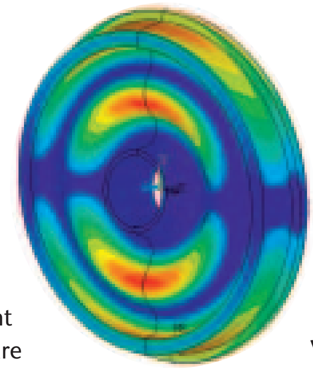


New Online Newsletter

The new, complementary, online newsletter will provide news, interesting applications and current events concerning non-contact metrology with laser vibrometers, surface velocimeters and white-light interferometers from Polytec. Register now on our website to be among the first to receive this new resource: **www.polytec.com/usa/newsletter**

Simulation Specialists:

CADFEM GmbH



CADFEM GmbH specializes in the numeric simulation of products in design and development. With its headquarters in Grafing near Munich, CADFEM begins 2006 with a total of 95 employees worldwide. Apart from selling the programs ANSYS, LS-DYNA and other complementary solutions, including all services accompanying the products, the name CADFEM also stands for consulting on a wide range of simulation projects commissioned by customers.

In the early stages of development, for both time and cost reasons, simulations are far superior to testing with real prototypes. Simulations and experimental measurement techniques are not in competition.

Quite the opposite is true. Developers are working towards a sensible combination that optimizes the product development process: Simulation supports the metrology by providing valuable information for assembling the model or supplementing data determined though numeric calculations for places that are difficult to access. On the other hand, validated findings from real measurements can flow into the calculation and update the FE model.

In the area of vibration technology, the ANSYS/SBSOUND solution developed by CADFEM allows structure-borne noise to be calculated. These surface velocities are perpendicular to the surface and correspond to those measured by a Laser Scanning Vibrometer, making a direct comparison possible. In the image above, the result of a simulation with SBSOUND is shown, demonstrating the distribution of the surface for sound radiation at a discrete frequency.

CADFEM is a founding member of TechNet Alliance, a global network of CAE experts. Through TechNet Alliance, companies have worldwide access to the unique range of CAE products and services.

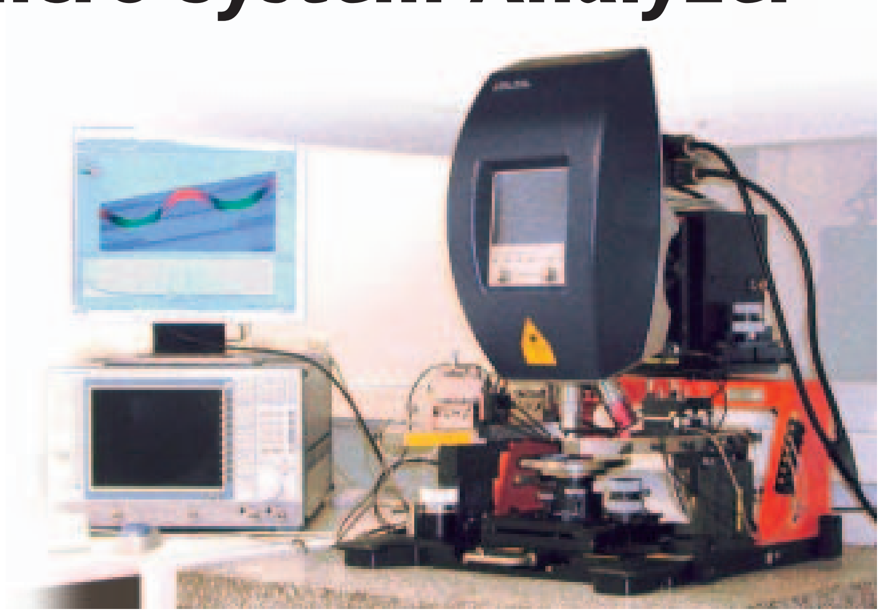
For more information visit
www.CAEworld.com

CADFEM

Great Success Worldwide

MSA-400 Micro System Analyzer

Polytec's new MSA-400 Micro System Analyzer, which last year won the Sensor Innovation Prize, is finding an ever increasing number of enthusiastic users in Europe, the United States and Asia.



For 12 years, Dr. Steffen Kurth of the Fraunhofer IZM (Institute for Reliability and Micro-integration) in Chemnitz, Germany has been using Laser Doppler Vibrometers to analyze vibrations in MEMS components to verify simulation models on the basis of the measured resonant frequencies and attenuation or to monitor the manufacturing processes (see his article in issue 1/2005, www.polytec.com/usa/LM-INFO). Experimental modal analysis, used to detect the deflection shapes of mechanical structures, took too much time when manual measurement of 100 sample points or more was needed. By using the new MSA-400 Micro System Analyzer, information on resonant frequencies and deflection shapes is now available in a matter of minutes. This information accelerates the development of laser scanners, MEMS sensors and MEMS components for high frequency and microwave technology which are the subject of current research projects.

More information about the MSA-400 on page 14 and on
www.polytec.com/usa/microsystems

New *Polytec Vibrometers*

The Right Instrument for every Measurement Application:

OFV-2500 Vibrometer Controller Series

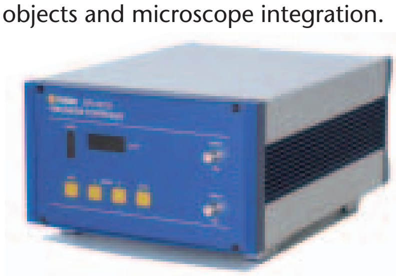
Polytec is offering a new range of specialized vibrometer controllers that complement the tried and trusted high-end OFV-5000 Vibrometer Controller. The OFV-5000 is the best solution for a wide range of challenging vibration measurement tasks with regards to versatility and extendibility. In addition, it is the centerpiece of the Polytec Scanning Vibrometer. The new 2500 Series Controllers are each specially designed for challenging measurement tasks in the area of industrial product and component testing, as well as for measurement tasks which require a very high frequency bandwidth.

The new controller series offers the following instruments:

- OFV-2500-1 Vibrometer Controller with velocity demodulation up to 10 m/s, frequency range up to 1.5 MHz, displacement signal up to 250 kHz using an optional integrator module.
- OFV-2502 Vibrometer Controller with velocity demodulation to connect and simultaneously operate 2 sensor heads, frequency range up to 1.5 MHz.
- OFV-2510 Vibrometer Controller with displacement demodulation for specialized industrial test and inspection setups, frequency range up to 250 kHz.
- OFV-2570 Ultrasonic Controller with 2 demodulators to measure velocity (up to 10 MHz) and displacement (up to 20 MHz) simultaneously.

The new controllers can be used with the following sensor heads:

- OFV-503 and OFV-505 Single Point Sensor Heads, particularly suitable for large measurement distances.
- OFV-551 and OFV-552 Fiber-optic Sensor Heads, preferred for short measurement distances, small objects and microscope integration.



- OFV-534 Compact Sensor Head with optional integrated color video camera and microscope lens. Excellent for measurements which are difficult to access, production applications and small objects.

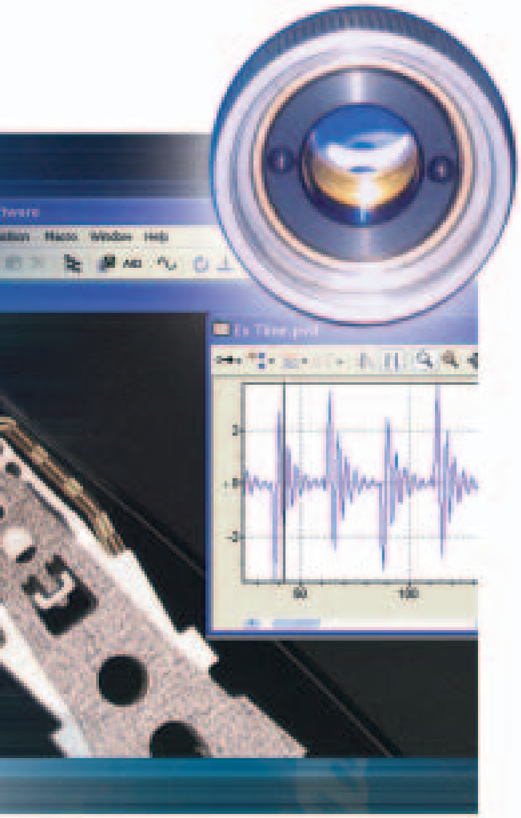
Handy Item with Sharp Eyes

OFV-534: The Compact Sensor That's Big on Measurements!

Perhaps you have been faced with making precise vibration measurements in confined spaces under difficult positioning conditions. Or it could be that you were working under conditions which would not allow satisfactory direct visual control of the measurement.

An optimal solution for such conditions was the design goal when the new OFV-534 Compact Vibrometer Head was initiated.

The excellent optical sensitivity Polytec vibrometers are known to have has been packed into an extremely compact, very versatile sensor head housing. Despite the amazingly small size of its housing, the sensor head is both



a high performance vibrometer, and a video camera for online monitoring of the measurement. In addition, a microscope lens can be fitted directly onto the sensor head which makes it possible to measure vibration on microstructures.

Thus, with the new OFV-534 Compact Sensor Head, the user can cover a wide range of challenging applications: from integration into a test stand, via camera-supported position regulation, to measuring vibrations on tiny components.

The new sensor head can be operated with the modular OFV-5000 Vibrometer Controller as well as with controllers from the new OFV-2500 Controller family.

You will find more information at **www.polytec.com/usa/vibrometers**

Polytec *at Your Service*

Polytec is well known for precise and sophisticated instruments that measure vibration, length and topography measurements. In addition, Polytec also offers paid measurements, system rentals and training classes as special services to support customers in solving their measaurement challenges.

Paid Measurements and System Rentals

Paid measurements are performed by Polytec's team of experienced application engineers and enable customers to make use of the latest, specialized measurement equipment and help to better understand and assess the impact of vibration phenomena. Likewise, temporary shortages in measurement capability can be overcome by renting Polytec's measurement equipment. Call your local application engineers in Waldbronn and Berlin (Germany), Hopkinton (MA), Detroit (MI), Tustin (CA) and Yokohama (Japan), discuss your measurement requirements and find out how innovative vibration, velocity and topography measurement can help.

Customer Training Classes and Seminars

To increase our customers' knowledge and capability to apply Polytec measurement technology, Polytec's application engineers conduct training classes – at private, customer determined locations or within the framework of the regular training classes open to all customers at Waldbronn (Germany) or at selected locations inside the USA. Whereas the first option exhibits the highest degree of flexibility to adjust the schedule to the users' needs, the latter one provides the invaluable opportunity to meet and exchange experiences with other users of Polytec equipment.

Though the main sources of these services lie in Germany and the US, users worldwide can utilize these services through Polytec's subsidiaries and representatives.

If you are interested in any of these please do not hesitate to contact **info@polytec.com** (for North America) or **LM@polytec.de** (all other regions).

The Searching *Look*

Industrial Quality and Process Control with Remote, Non-contact Optical Sensors

Polytec's interferometric sensors optically measure vibration, velocity, length and surface integrity. In addition, they offer many specific advantages for industrial production applications such as precise results without contact, a flexible retrofitting and continuous operation under industrial conditions with low maintenance and few repairs. Several applications are outlined within this article.

A company's profitability and success often depend on the optimization of a product's performance. This optimization depends on design as well as the manufacturing process, key to keeping costs low and quality high. A poorly manufactured product can ruin the best design and the company depending on it. Today's products are smaller and more complicated than before. Structures are continuously decreasing in size, and incorporate more semi-finished materials. Inspection of these small structures is a big challenge to test engineers managing the quality and process control. At the same time, the number of products being inspected is increasing enormously driven by the current push towards zero-manufacturing failures leading to 100 % inspection of all manufactured products instead of traditional statistical process control.

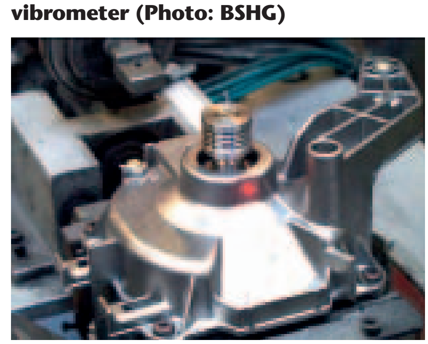
Optical technologies are ideally suited to current and future quality control measurement challenges. Polytec has developed a series of compact and rugged interferometric sensors for production testing that cope with the special conditions of an industrial environment. The test parameters measured are not affected by the measurement since contact with the test item is avoided. High resolution along with a large measurement range ensures highly precise measurements with a high level of reproducibility and thus allows an unrivaled test depth. Through flexible stand-off distances the sensors can be integrated into the test environment almost without limitation. The stand-off distance combined with simple integration and static fixturing suggests low maintenance requirements, as no wear and tear on mechanical components is to be expected.

Household and Medical Appliances

Vibration measurement on a dentist drill (Photo: Myonic)

Household appliances and medical equipment can have unplanned vibrations and noises when assembled in manufacturing. These anomalies are detected in production using laser vibrometers and are removed from the process. Examples of products inspected in this way are washing machines, vacuum cleaners, electric toothbrushes, dental instruments or drive systems for medical equipment. For critical medical devices such as membrane inhalation systems, 100 %-inspection is required to assure that the products work properly (page 18).

Quality measurements made on a washing machine motor using laser vibrometer (Photo: BSHG)



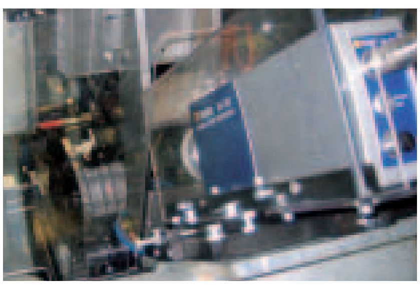
Automotive Industry

In the automobile and automobile supply industry, laser vibrometers are a familiar sight in production testing.

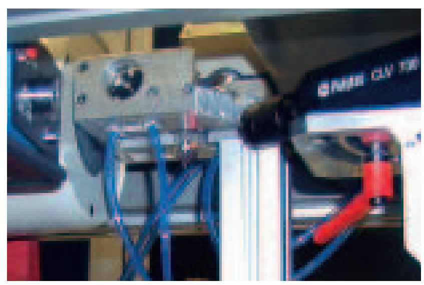
They are used for noise and fault analysis in components with moving parts, such as combustion engines, gearboxes, steering systems, climate control systems, injection valves, actuators and small drives, but also for material testing, for example on cam shafts or light bulbs. The images show a facility for 100 % quality assurance on vehicle components using the IVS-300 Digital Laser Vibrometer (left), and a test stand for material testing on light bulbs using the CLV Compact Laser Vibrometer (right).

More info: **Issue 2/2004**.

(Photo: P. Marpe, TRW Automotive)



(Photo: Philips)



You will find further information and example applications on our industry portal page www.polytec.com/usa/industrial.

Please download previous issues of the LM INFO Special from www.polytec.com/usa/LM-INFO.

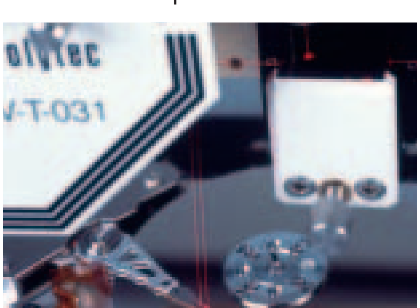
Data Storage and Microsystems Technology

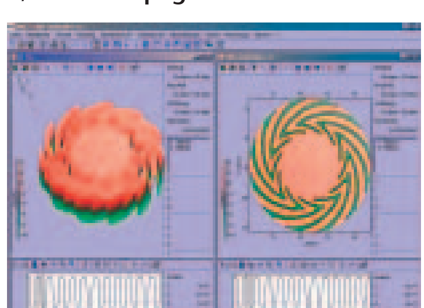
Single point and scanning vibrometers are used in manufacturing data storage media, in particular hard disks. They are used as highly sensitive detectors for undesirable deviations in the dynamic behavior of filigree components, but also in testing DVD players or bubble jet printers.

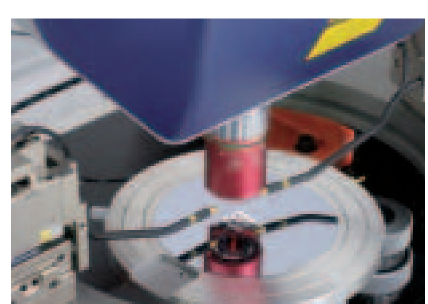
Left image: non-destructive quality control on hard disk components using the OFV-552 fiber-optic interferometer.

Center: Surface quality of a hard disk bearing part measured by the TopMap White-Light Interferometer. Right image: The static and dynamic properties of micro-sensors, actuators and other MEMS components can be tested in production even at wafer level using the MSA-400 Micro System Analyzer combined with a Wafer Probe Station.

More info: **Issue 2/2004, Issue 1/2005 and page 20**.







Semi-Finishing Industry and Production Technology

Polytec Laser Surface Velocimeters (LSVs) monitor the length and speed of strip goods in the production process. The LSV can be used on most surfaces, including metal sheeting, film, paper or red-hot steel (see image on page 6). High frequency vibrometers can monitor the quality of ultrasonic-based joining techniques, such as welding plastics together (page 16) or wire bonding between pads.

More info on page 24 and on **www.polytec.com/usa/lsv**.

Polytec LSV measures section lengths in corrugated cardboard production

New Applications *in the United States*

Laser Surface Velocimeters for Mill Automation and Process Control

Steel mills require operational efficiencies to survive in today's competitive environment. Polytec's Industrial Laser Surface Velocimeter (LSV) is specifically designed for on-line, hot and cold process measurement and control of the velocity and length of billets, slabs, plates, tubes and profiles. The LSV replaces traditional, high-maintenance contact measurement techniques with accurate, non-contact, low-maintenance. Due to the significant advantages it provides, many mills in Europe, Asia and the USA have purchased Polytec's Laser Surface Velocimeters. The photos show some current applications in the aluminum, tube and steel industry.

In the last year, LSV installations in North America have been particularly strong as these manufacturers increase their competitive advantage through advanced automation and control.

New installations in North America include:

- Nucor Steel (Darlington, SC) ordered four LSV's for application on a continuous billet caster.
- Nucor Steel (Decatur, AL) ordered LSV's for two separate projects, three for a hot mill application and two for a cold mill application. Both installations were completed in 2005 and are operating as planned.
- Dofasco Copperweld (Shelby, OH) has ordered two LSV's for a tube and pipe cut-to-length application. Installation will occur in the first quarter of 2006.

Increased Sales of Production Vibrometers Means Better Products in the Future

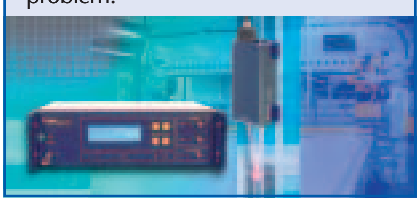
The benefits of using laser vibrometry for quality control and inspection is being utilized by a growing number of system integrators and OEM's.

- Comau Pico (Southfield, MI), an innovative leader in industrial automation, has ordered Polytec IVS Industrial Vibration Sensors for cold engine test stands.
- Veri-Tek (Wixon, MI), a specialist in dynamic testing and signature analysis, has ordered the first of four Polytec In-plane Vibrometers to be used on engine test stands. The In-Plane Vibrometer will be used to characterize engine torsional behavior by analyzing motion at the fly wheel.
- ATW (Assembly & Test – Worldwide) is a global company providing automation systems and solutions, where B+K Precision Corporation is specializing in the design and manufacture of high quality test and measurement products. Both B+K and ATW have ordered multiple Polytec IVS Industrial Vibration Sensor systems for installation on gear box test stands for a plant in New York state.

A Powerful Tool for Diagnosing Slippage and In-Plane Vibration

Polytec In-Plane Vibrometer

Polytec's In-Plane Vibrometer is a proven technology designed to measure the velocity of a surface moving in a plane perpendicular to the laser probes. It is a powerful tool for diagnosing slippage and vibration problems, measuring continuous in-plane velocities – including stopping and reversals – from –40 to +50 m/s, and in-plane vibrations up to 100 m/s. Several versions of the In-Plane Vibrometer cover a vibration frequency range from 0 to 250 kHz. Non contact, load-free velocity measurement is essential to study and develop tape drives, ultrasonic knives and scalpels, photocopiers, printers, belt drives and other moving parts where slippage, vibration and mass-loading can be a problem.



Non-Contact Surface and Speed Measurement

LSV-6000/LSV-300 Laser Surface Velocimeters

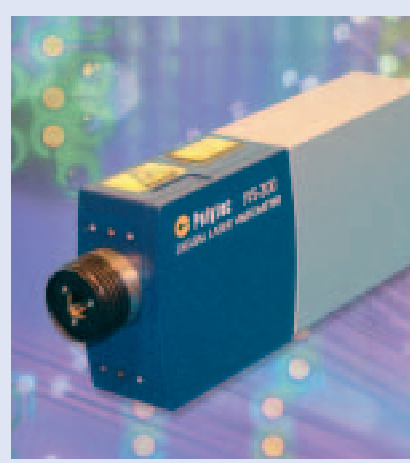
Laser Surface Velocimeters can measure surface speed and length on all types of materials and, in addition to paper, have been used in a variety of industries including steel and metals, plastics, high-grade films, glass, textile, paper and rubber. The velocimeters are typically used when contact devices such as encoder wheels or tachometers do not provide an accurate measurement due to slippage, poor contact, thermal expansion/contraction, or would damage the product. Polytec's LSV systems combine a sensor head, a controller and software into a rugged industrial package that makes precision velocity measurements from standstill to speeds of more than ± 23,000 ft min^{-1} in either direction.

www.polytec.com/usa/lsv

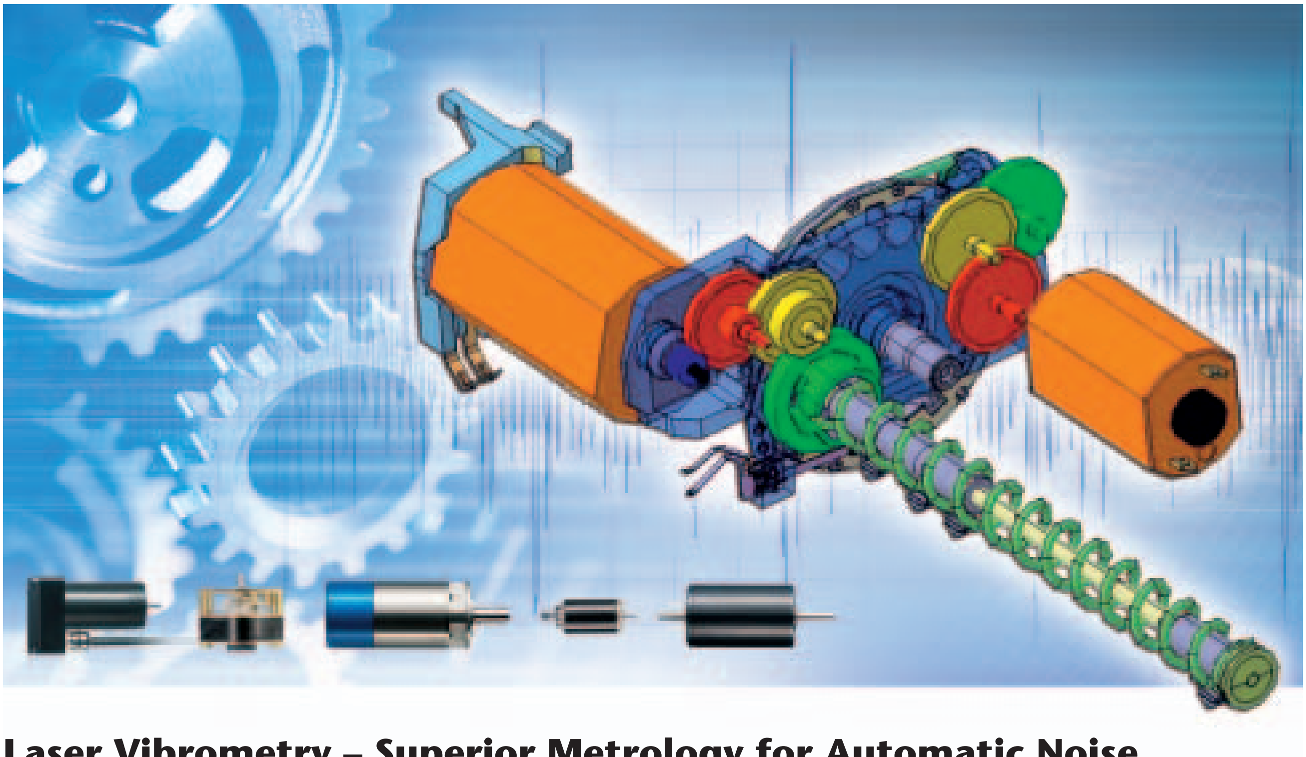
On-line Vibration Testing

IVS-200 and IVS-300 Industrial Vibration Sensors

These ruggedized laser Doppler vibrometers are perfect for non-contact, on-line vibration testing up to 22 kHz. Laser interferometer optics and electronics are all contained within a single, compact and robust industrial housing (IP 64) to cope with the challenges of harsh industrial areas. The IVS-300 exploits the latest digital signal processing techniques to ensure accurate and repeatable measurement even from un-cooperative surfaces. More info: **www.polytec.com/usa/vibrometers**



Silent Running *is Real Power*



Laser Vibrometry – Superior Metrology for Automatic Noise Measurement and Quality Control in Micro Drive Systems

Drive systems which contain damaged or warped components – for example cogs – generate unwanted operating noises and therefore need to be detected and rejected in production. Laser vibrometry has proven to be the optimal measurement technique for this selection process, as it allows non-contact, automatic and reliable quality control.

Introduction

The FAULHABER Group specializes in the design, manufacture and application of high precision, miniature and micro electromechanical drive systems, components, and controls. This includes everything from high precision customized DC motion control systems to versatile, standardized, off-the-shelf products.

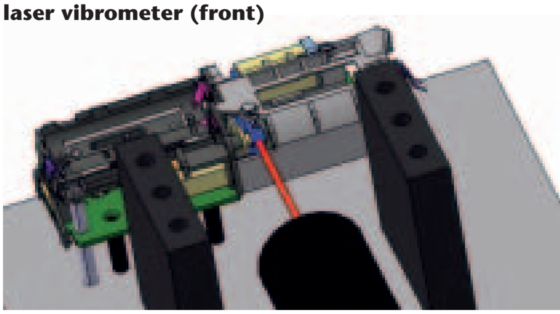
A program was initiated to ascertain whether automated quality control could be realized for a customer-specific drive system composed of two motors coupled to two gear boxes with three internal cogs each (Figure 1).

Small deviations in cog geometry were known to generate several typical noise patterns subjectively characterized as "rattling", "whining", "clicking" or "chirping."

Figure 1: Micro drive system and typical damage of cogs

A successful program must be able to distinguish these patterns automatically on a test bench. The goal was to automatically analyze the noise characteristics at a throughput rate of 10,000 to 16,000 parts per day and to cost-effectively obtain a reliable measurement in less than 50 seconds per test item. The manual noise test benches constructed in an initial phase of development were to be set up in such a way that it would be possible to integrate them into the automatic production line.

Figure 2: Noise test bench with laser vibrometer (front)



Selection of the Optimal Sensors

To select the optimal sensors for noise measurement, comparison tests were made using microphones, accelerometers and a Polytec laser vibrometer. These technologies were tested in their own test rig (see info box). The laser vibrometer proved to be the best measurement technique.

Construction of the Noise Test Bench

The noise test bench permits the measurement of the test item undisturbed by ambient vibration. Typically, the vibrometer sensor head and the test item holder are mounted on the same base plate. The vibration measurement is made at an empirically determined point on the drive at the optimal stand-off distance (Figure 2).

The evaluation software uses the measurement and the evaluation of the vibrometer data as well as the engine power to calculate the rotational speed of the system. The energy bands from the two signals are analyzed in the range of the 1st and 2nd rotational order using frequency analysis. The test item classification is then carried out using a threshold comparison.

The system reliably identifies all noise characteristics and it was possible to attain a test time of 17 seconds, including handling. The required throughput is 16,000 drive systems/day and can be done with 8 test benches.

Prospects

The manual noise test bench was a success. The new goal is to retrofit the vibrometer into an existing assembly line. A test as part of an automatic production line is now being prepared.

This system allows micro drive systems to be automatically and reliably sorted out according to the acoustic measurements. Also, early planning is underway to use a PSV-400-3D Scanning Vibrometer for additional or more complex noise characteristics.

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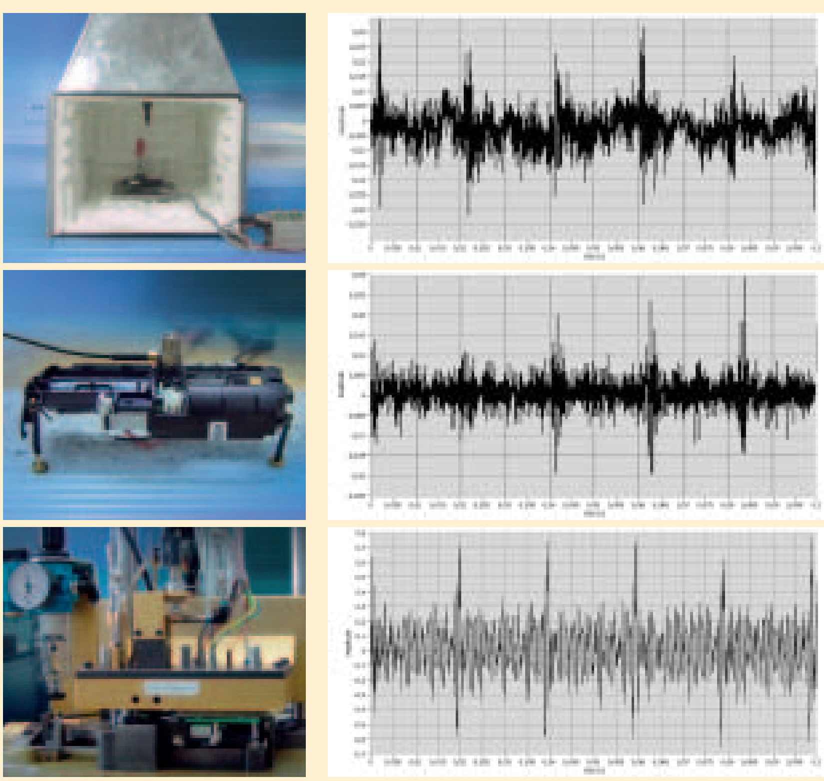
A Comparison: Microphone Vs. Accelerometer Vs. Laser Vibrometer



Test rig and time signals of the measurement with microphone (top), accelerometer (middle) and laser vibrometer (bottom)

A phonometer equipped with a microphone was used for the airborne sound measurement. Inspite of the sound screening, significant disturbances from the surroundings were measured. Furthermore, integration into an automatic production line could not be efficiently realized.

It is also difficult to automate the measurement using contact accelerometers. Several sources of noise such as the mechanical release of the test item, the electrical contacts and making contact to the sensor can cause problems.

The laser vibrometer was installed into an existing test bench. Despite the complex test item holder, it proved to be the best measurement technique because it provided good measurement results without screening airborne noise and without contacting the test item.

The difference in quality between the processes becomes very clear if you compare the time signals with each other. The laser vibrometer offers substantially better resolution.

Exciting *Paper Quality*

Laser Ultrasonic Measurement of Bending Stiffness on Moving Paper: A Mill Demonstration

A laser-based ultrasonic system for non-contact, in-process measurement of the elastic properties of paper was successfully tested at an operating paper mill with web speeds exceeding 20 m/s. The paper's flexural rigidity and out-of-plane shear rigidity were calculated from the frequency dependence of the phase velocity of ultrasonic waves generated in the moving paper by a pulsed Nd:YAG laser and detected with a Polytec Laser Vibrometer.

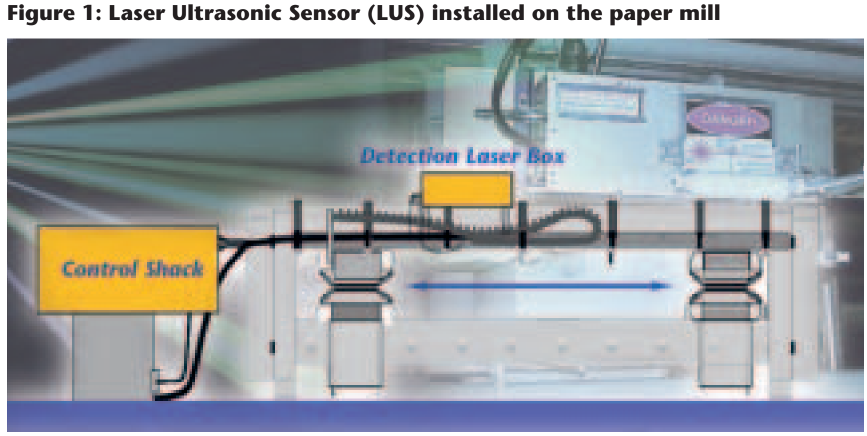
Introduction

When a 15 to 30-ton paper roll is manufactured, a few samples are obtained from the end of the roll and analyzed for their mechanical properties to determine the paper's quality. In the case of copy paper, bending stiffness and flexural rigidity are very important. If the samples don't meet certain specifications, the entire roll is recycled into pulp or sold as an inferior grade. To avoid making a costly mistake, manufacturers often over-engineer the paper and use more pulp than necessary to ensure the final product isn't substandard.

To minimize the consumption of excess raw material and energy, a team of scientists from the U.S. Department of Energy's Lawrence Berkeley National Laboratory and the Institute of Paper Science and Technology at the Georgia Institute of Technology developed a sensor that tracks paper flexibility on the fly, in real time. Specifically, the sensor measures the time it takes ultrasonic Lamb waves to propagate from a laser-induced excitation point on the moving paper to a detection point several millimeters away. The velocity of the ultrasonic waves is related to two elastic properties of the paper: bending stiffness and out-of-plane shear rigidity.

The Laser Ultrasonic Sensor (LUS) has been successfully used to measure mechanical properties of paper in the laboratory. With the recent, successful testing at an operating paper mill

Figure 1: Laser Ultrasonic Sensor (LUS) installed on the paper mill



(Figure 1), the paper industry is one step closer to saving millions of dollars each year. When feedback control is fully implemented, the sensor can ensure that the optimum amount of raw material is used to make the paper, reducing the consumption of trees and chemicals and saving the U.S. industry as much as $200 million in energy costs and up to $300 million in fiber costs each year.

LUS Sensor

The system (Figure 2) consists of a Nd:YAG laser which delivers a 5 nanosecond pulse at 1.06 µm for ultrasound generation, a Polytec laser vibrometer with a continuous helium-neon (HeNe) laser source for detection, a scanning mirror to track paper motion and to position the HeNe laser beam, and a timing system to fire the generation laser. Regarding the Polytec vibrometer, the prototype laboratory system was based on an OFV-303 Vibrometer Sensor Head (current model is OFV-503) while the online system used at the paper mill was a CLV Compact Laser Vibrometer. Through the use of the scanning mirror, the detection beam and the paper are moving at the same speed, leaving the detection beam fixed on the same point on the paper. An optical encoder determines when the detection beam is perpendicular to the paper, at which time a circuit fires the YAG laser. This pulse causes a microscopic thermal ablation of the paper, which is too small to visibly mar the paper but strong enough to send an ultrasonic shock wave through the sheet. The wave propagates until it reaches the detection beam. Because the laser is synchronized to fire only when the detection beam is perpendicular to the paper, the distance between the excitation point and detection point is known, and the wave's speed is calculated from which bending stiffness and shear rigidity are computed.

Calculation of Elastic Properties

In paper, the energy from the laser-generated Lamb wave goes predominantly into the zero-order anti-symmetric mode plate wave, A_o, and is characterized by relatively large (hundreds of nanometers) out-of plane displacements, which are easily detected with the vibrometer. A Fourier transform, "phase unwrapping" computational method is used to calculate two important elastic properties from a phase velocity versus frequency dispersion curve: flexural rigidity (D) and out-of-plane shear rigidity, SR. Flexural rigidity differs slightly (it is about 9% larger) from bending stiffness (BS) through a term that depends on the in-plane Poisson ratios, ν_{xy} and ν_{yx}:

$$D = BS / (1 - \nu_{xy}\,\nu_{yx})$$

Summary

On-line laser ultrasonic measurement of flexural rigidity of paper has been demonstrated using a new, innovative sensor in a real mill environment. The laser ultrasonic sensor measures without contact, an important advantage when the paper moves at approximately 20 m/s and the slightest disturbance can mar the paper or break the sheet causing costly machine downtime. The resulting savings to the paper industry may exceed several hundred million dollars annually.

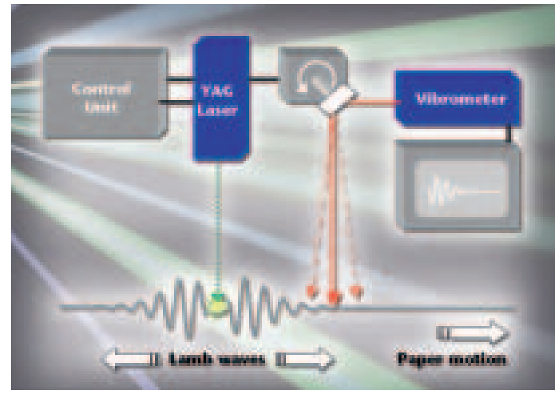


Figure 2: Working principle of the LUS Sensor system for laser-based ultrasonic analysis of paper

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For Efficient Measurements *on MEMS*

MSA-400 MICRO SYSTEM ANALYZER ADD-ONS

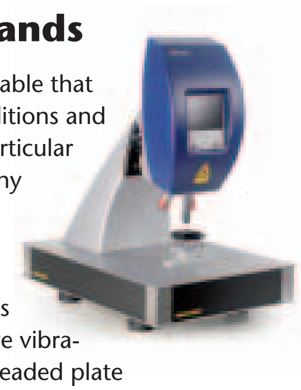
Polytec's MSA-400 Micro System Analyzer supports three measurement techniques that characterize dynamic and static properties of micro systems: Laser Doppler vibrometry, stroboscopic video microscopy and white-light interferometry. The award-winning design unifies these techniques in one instrument allowing measurement of out-of-plane and in-plane dynamics as well as static topography. MSA software can calculate and display many characteristic MEMS parameters such as frequency response functions, deflection shapes, Fourier transforms and surface profiles.

For each application or laboratory measurement requirement, Polytec offers the user a range of important accessories.

Optics

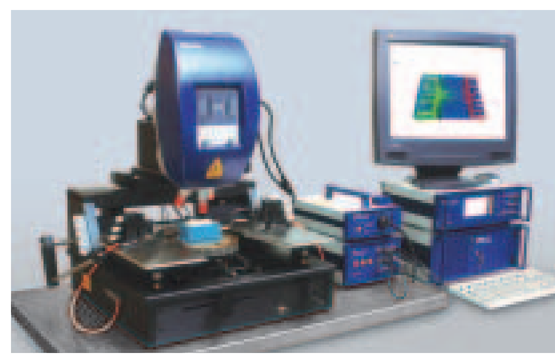
- Microscope objectives with magnifications of 5x, 20x and 50x for dynamic and interference objectives with magnifications of 2.5x, 5x, 20x and 50x for topographical measurements cover a wide range of device sizes.
- An attenuator option allows you to regulate the beam intensity of the laser vibrometer for measurements on highly reflective surfaces or light-sensitive structures.
- A Mitutoyo compatible focus block allows Z-translation of the measurement microscope of 50 mm.

Mounting Stands



Several stands are available that help adapt to the conditions and requirements of the particular measurement. The many possibilities run from a simple support to an optical table based platform with variations such as passive or active vibration-isolation and a threaded plate for mounting positioning stages.

Adaptation to MEMS Probe Stations



The Micro System Analyzer was developed right from the start as a probe station compatible measurement system. Consequently it can be used for measurements with both electrical and non-electrical stimuli as well as on die or wafer level devices. The MSA measurement microscope can be mounted directly to MEMS probe stations by SUSS MicroTec or MicroManipulator (other systems on request).

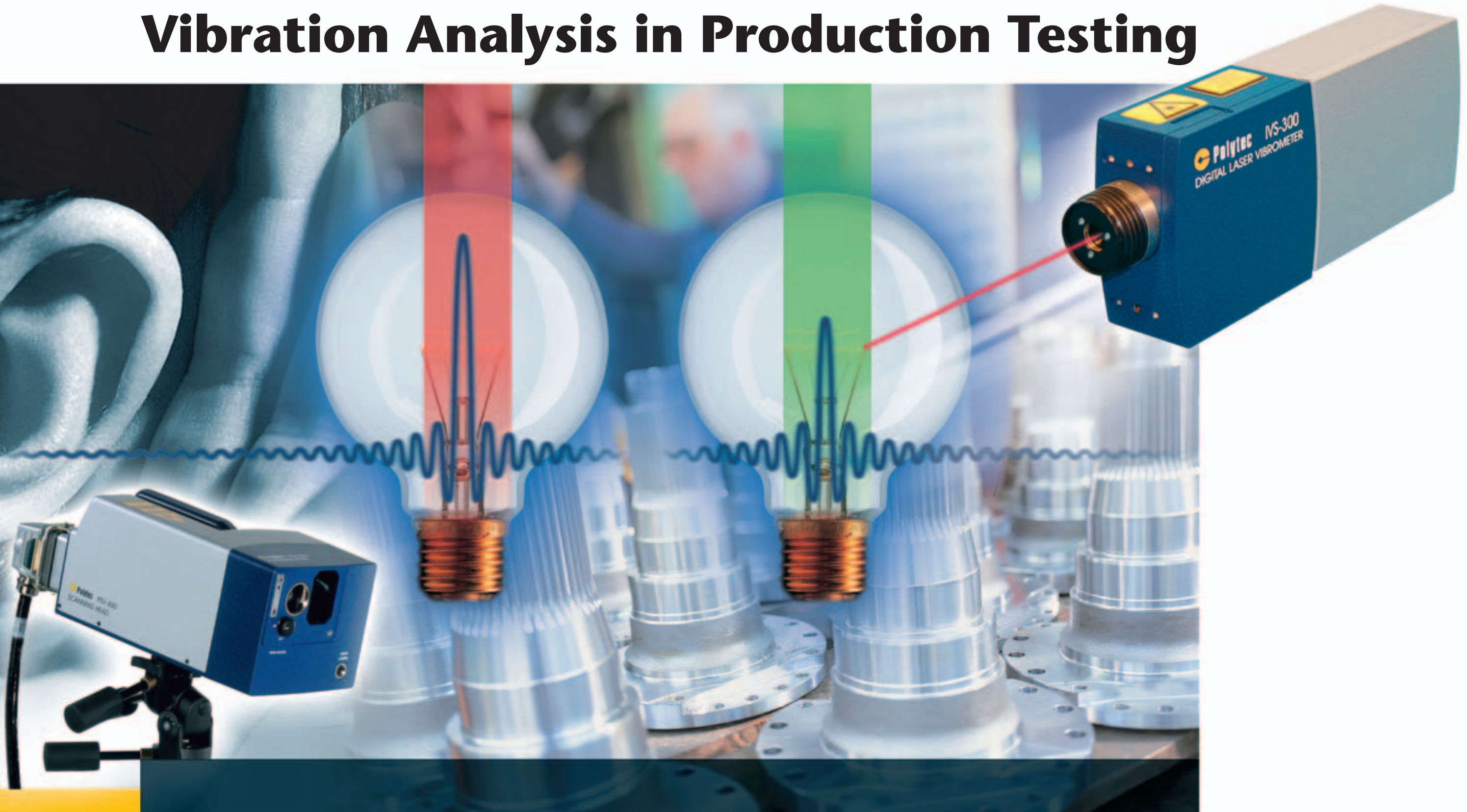
Software Tools and Options

The MSA Software launches and controls the following programs for data acquisition and data processing: PSV Scanning Vibrometer Software, PMA Planar Motion Analyzer Software (page 15) and TMS Topography Measurement Software.

- When making scanning measurements, special software options allow you to analyze time domain data, zoom-FFT or high resolution-FFT, data export to ME'scope or special preparation of the topography measurement data.
- Desktop versions of the MSA software components allow analysis and further processing of the measurement data at any work station of your choice.
- Polytec Scan Viewer is a free and easy-to-use tool that enables the user of PSV, VibSoft or PMA Software to display vibration measurement data in MS Office applications or web pages without a Polytec software license (page 15).

Find more info on www.polytec.com/usa/microsystems

Vibration Analysis in Production Testing



FOR BEGINNERS AND EXPERIENCED USERS

The dynamic properties of structures can be described with the aid of eigenfrequencies, attenuation and eigenshapes. Suitably measured, analyzed and classified, these properties can quickly determine quality for pass/fail selection of manufactured components.

For many production inspection applications, Laser-Doppler vibrometers offer significant advantages over conventional, structure-born noise sensors, such as contact accelerometers. Apart from the high dynamic range, wide bandwidth and small spatial measurement spot, it is the non-contact, non-reactive measurement of a laser vibrometer that plays a decisive role.

There are many high performance methods available to analyze vibration signals (see table on page E24). In this tutorial, the basic principles of frequency analysis are introduced including two versions of frequency band analysis: short-term Fourier analysis and order analysis.

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Frequency Analysis

Automatic digital analysis of vibration signatures for product final inspection is most commonly done using frequency analysis.

With a discrete Fourier transformation,

$$S(f_n) = \frac{1}{Nf_\Delta} \sum_{k=0}^{N-1} s(t_k) e^{-j2\pi nk/N}$$

a signal $s(t_k) = s(kT_\Delta)$ with N samples is mapped onto N discrete frequencies $f_n = nf_\Delta$ (Fig. 1). The frequency resolution $f_\Delta = f_A / N = 1/T = 1/NT_\Delta$ solely depends on the sample frequency f_A and the number of data points N and thus on the duration of the measurement, T. If the measurement time selected is too short, then individual frequencies close to each other will no longer be resolved, but will be seen as a single, broad frequency line (Fig. 2).

For real signals, only the Fourier spectrum $S(f_n)$ for $n = 0, 1, 2, \dots, N$ needs to be calculated for symmetry reasons. Usually in frequency analysis, the power density spectrum $|S(f_n)|^2$ is analyzed; the phase of the individual frequencies nf_0 is of no importance. Because of the periodicity of the discrete Fourier spectrum in N, $e^{\pm j2\pi kn/N}$ $= e^{\pm j2\pi kn(k+\alpha N)/N}$, $\alpha \in N$ there can be an overlap of individual spectra, leading to an effect known as Aliasing (Fig. 3, 4). This can be avoided by selecting the sample frequency f_A according to Shannon's sample theory: to be at least twice as big as the highest frequency occurring in the signal f_{max}.

To prevent aliasing for real signals, the analog signal must be band-limited with a low-pass filter prior to digitalization. Since all real filters have a transitional area between the pass band and the stop band, frequency parts outside the cutoff frequency, f_C, of the filter are not fully attenuated and can lead to aliasing artifacts. To prevent this, a factor of 2.56 is usually selected in the digital signal processing and applied to the cutoff frequency of the selected low pass filter to determine an appropriate sampling frequency, $f_A = 2.56 \cdot f_C$.

Another effect in calculating the Fourier spectrum of a discrete signal is the so-called *Leakage*. Discret frequency variables $f_n = nf_\Delta$ with $f_\Delta = 1/T$ are the only way to display frequencies that are an integer multiple of the frequency resolution without error. Leakage must be expected if the product of the observation period T and the frequencies to be displayed f_n is not an integer. Leakage is noticed by additional frequencies in the spectrum. It can be reduced if the discrete time signal is weighted with a suitable window function (e.g. Hanning, Hamming) before the Fourier transformation.

In *material testing*, the position of the spectral frequency lines is usually evaluated directly by the frequency analysis. Independent of whether the components are excited in a pulse shape or continuously with a shaker, only the characteristic resonant frequencies of the component are ascertained. From these characteristic frequencies, the status of the test item is determined.

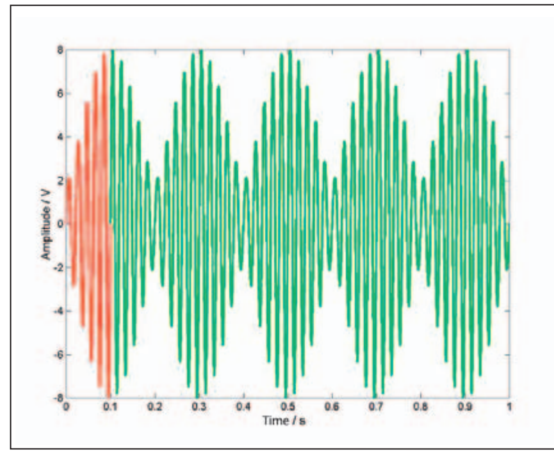


Figure 1: The increased resolution of a long measurement versus a short measure-ment time; red: 0.1 s measurement duration; green: 1 s measurement duration

Frequency Band Analysis

In contrast to material testing, *operational vibration analysis* is not entirely concerned with the structural resonances; but, also, the forced vibrations generated through the interaction of assembled components. This vibration content depends on both the resonant frequencies of the components and the driven movement velocity that often corresponds to an RPM value.

In simple applications, such as testing

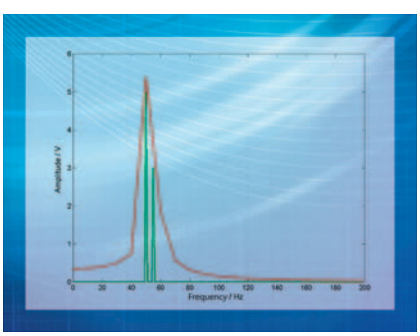


Figure 2: Results of both signals from fig. 1; green: $f_\Delta = 1$ Hz, red: $f_\Delta = 10$ Hz

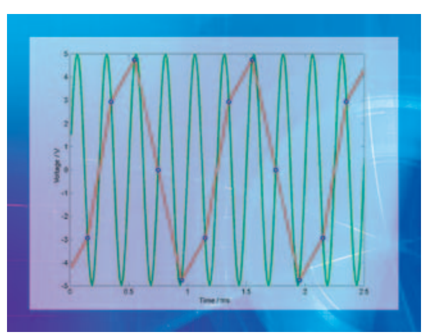


Figure 3: Digitalization of a 4 kHz signal; green: sample frequency 10 kHz, red: sam-ple frequency 5 kHz

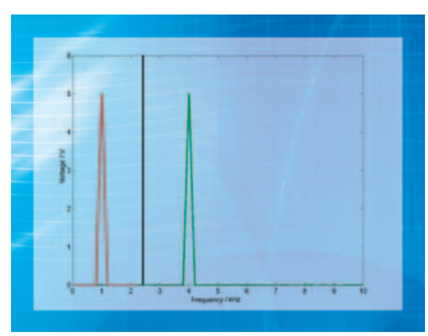


Figure 4: Results of frequency analysis of both signals from fig. 3; green: real fre-quency, red: pseudo-frequency through Aliasing

electric motors or cooling fans, the individual frequency lines are not analyzed; instead, groups of frequencies , called *frequency bands*, are examined. Identical products with similar behavior are analyzed at a constant RPM and can be reliably qualified, even with a slight deviation in the RPM value.

In the case of *narrow band analysis*, the signal spectra are divided up into frequency intervals which are seamlessly strung together, whereby the average frequencies of the bands are arranged equidistantly. The power density is determined for every frequency band and the so-called narrow-band spectrum is used for analysis.

In contrast to narrow band analysis, *proportional band analysis* uses spectra that are divided into joined frequency intervals, where the bandwidth of the frequency intervals increases with increasing average band frequency. In this case, the proportion, q_B, of the respective neighboring frequency bands, B_i, B_{i+1} is constant and equal to the proportion q_f of the corresponding band average frequencies, $f_{m,\,i}$, $f_{m,\,i+1}$. If $q_B = q_f = 2^{1/3}$ applies, the calculated frequency bands are designated as 1/3 octave bands, and the analysis as *one-third octave band analysis*. The partitioning of the frequency bands for one-third octave band analysis is oriented towards the subjective perception of the human ear, in which doubling the physical frequency is seen as a proportional frequency increase (Figure 5/6).

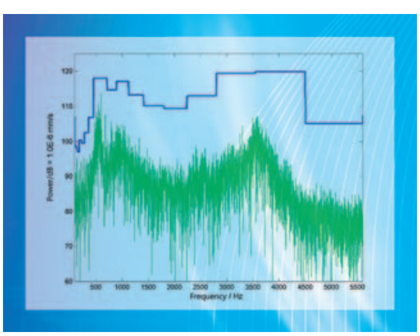


Figure 5: Green: spectrum of a signal, blue: one-third octave band level of the spectrum

Modulation Analysis is used to evaluate the spectral composition of the envelopes of signals caused by amplitude modulation. In principal, modulation analysis is based on frequency analysis of the rectified signal. Since carrier frequencies with a different frequency can be modulated differently, in modulation analysis the frequency analysis is usually applied to several carrier frequency bands. Apart from the spectral analysis of the envelopes, in modulation analysis, the degree of modulation, i.e. the ratio between the carrier frequency amplitude and the modulation amplitude is also determined.

Short-time Fourier Analysis

For certain applications, such as testing gearboxes, actuators or attenuators, the mechanical construction has no stationary condition that can be attained which means that the test sample is in different operating modes at different points in the process. This means that during operation, the vibration characteristics continually change. An initial impression of the change in the vibration characteristics at different operating modes allows analysis of the *level progression*. In doing so, the average performance is not determined for the whole signal, but continuously for joined time periods. How-ever, to be able to carry out detailed analysis of the vibration characteristics at certain points in time, *short-time Fourier analysis is often used* (Fig. 7).

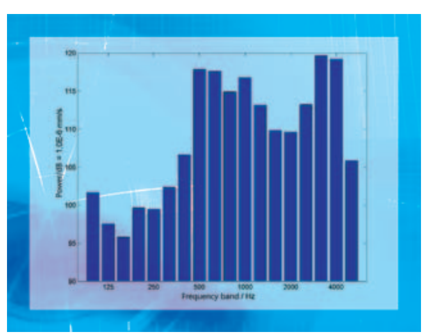


Figure 6: One-third octave band level spectrum from fig. 5 (frequency axis is llogarithmic)

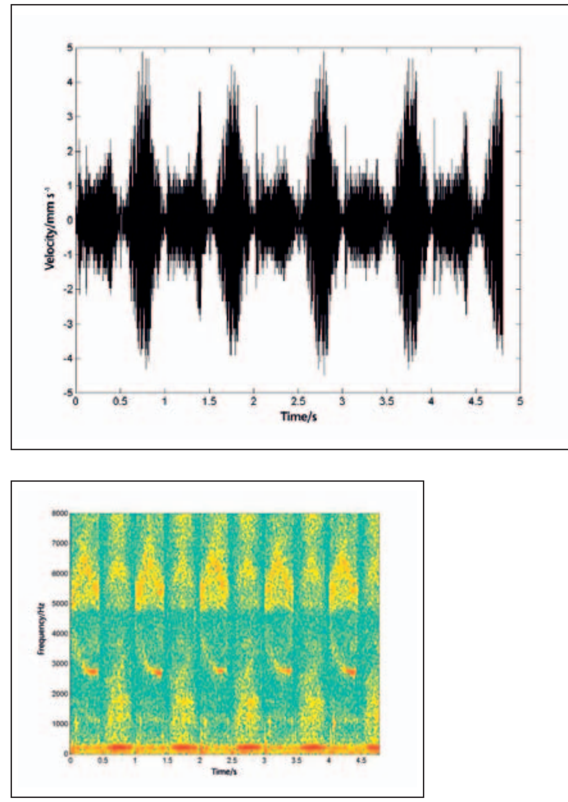


Figure 7: Fourier transformation; on the left: output signal; on the right: spectrogram (short-time FFT)

In short-time Fourier analysis, the discrete time signal is weighted in a window function $w(k - m)$ which depends on a translation parameter and subsequently the Fourier transformation is applied to it.

$$S^{ST}(f_{m,n}) = \frac{1}{Nf_{\Delta}} \sum_{k=0}^{N-1} s(t_k) w^*(t_k - t_m) e^{-j2\pi nk/N}$$

$$m = 0, 1, \ldots, M-1, M \leq N$$

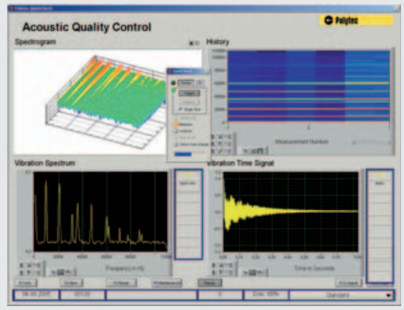
The window function $w(k - m)$ then ensures that just one time section of the signal $s(k)$ is transformed at a time. The time period of the signal section observed is defined by the width of the window function and determines the spectral bandwidth. Therefore, the resolution of the time period/bandwidth product is equal for all values n and m. The short-time Fourier transformation provides a constant time-frequency resolution.

Order Tracking

For high performance machines, such as car engines or gearboxes, which are tested and operated over a long period, frequency analysis does not provide meaningful results. Such machines are usually tested in one or more cycles with continuous run-up. Due to the permanently changing operating mode, it is not possible to analyze events which occur briefly using short-time Fourier transforms.
In such cases, order analysis is used in which the vibration amplitude instead of the short-time Fourier transform is applied to the RPM value in place of the time, and also to the order (multiple of the RPM) in place of the frequency.

Conclusion

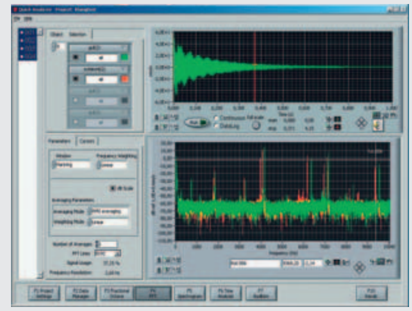
High-performance, non-contact vibrometers, combined with appropriate signal analysis, enable in-line 100% quality inspection and control of components and products.
Polytec's ruggedized laser-Doppler vibrometers and easy-to-use Quality Control Software offer optimal solutions for more efficient inspection, enhancing process throughput, lowering product cost and increasing customer perception of product quality.



QuickCheck – Hardware and Software Package for Acoustic Quality Control

QuickCheck is a multi-channel, PC-based software for semi or fully automatic process monitoring and control using the vibration behavior of the product.. Typical applications include noise and vibration testing, 100% in-line quality inspection, material testing, flaw (crack) testing, solidity testing, operational vibration analysis and process control.

The range limits for each product test are assigned a priori during quality examinations of good and bad products, entered into the software and stored in a database. During the test process, a pass/fail decision is calculated by comparing the vibration response of each test sample with the limits corresponding to that product test. The pass/fail decision is indicated on the display, transferred to the production controller and stored in a log file for future statistical evaluation.



QuickAnalyzer – Efficient Analysis of Vibration Signals

QuickAnalyzer is a PC-based, single-channel signal analyzer that is designed for pass-fail evaluation of acoustic signatures emanating from a product or machine under test. It is designed for research and development of process and quality control applications.

The software has various modeling techniques that are available for analyzing measurement data. By simply selecting a new analysis window, the user can quickly and efficiently differentiate between unique signal criteria. The software can then group measurement data into fault classes which are clearly arranged and displayed in the analysis window.
Many methods, including Fourier transformation and octave analysis, are included as standard software for analyzing vibration signals. In addition, an "audition" module enables digital filtering and audio playback of the saved signal.

To learn more visit: **www.polytec.com/usa/industrial**

Application	Type of excitation	Excitation	Function	Analysis
Material testing	external	pulse-shaped (e.g. pulse hammer)	– crack detection – resonance testing	– frequency analysis
		continuous, periodic (e.g. with shakers)	– resonance testing	– frequency analysis
Noise testing Operational vibration analysis	self-excitation, continuous, constant	at a constant velocity	– engines – cooling fans – bearings	– total level – narrowband analysis – 1/3 octave band analysis – modulation analysis
	self-excitation, continuous, not constant	subject to changing operating modes	– drives – actuators – attenuators	– level progression – short-time Fourier analysis
		run-up or run-down	– combustion engines – gearboxes	– order analysis

The complete Polytec Tutorial Series can be found as downloadable PDF files on www.polytec.com/usa/vib-university

Straight to the Point

A New Stand Unifies PSV-400-3D Scanning Vibrometer Heads

Before you had to have three heavy-duty tripods and a lot of patience to make the alignment, now a single support stand makes 3-D scanning vibrometer measurements simpler and faster. The new motorized PSV-A-T31 support stand allows you to quickly and easily position three PSV-I-400 Scanning Heads to make measurements with the PSV-400-3D Scanning Vibrometer.

The castors on the frame make the system mobile. By folding in the arms, it is easily maneuvered in tight places and transported through normal doors.

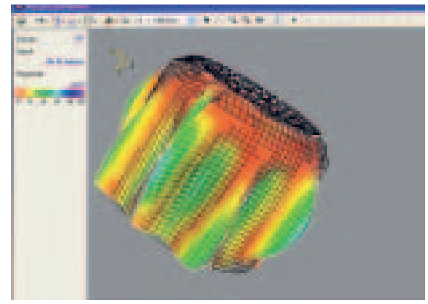
With adjustable feet, the support system can be set up safely and positioned on location. The height of the trio of sensor heads can be set between 600 mm and 1,700 mm by a motorized lift. The star-shaped arrangement of the assembly arms positions the top scanning head at heights of up to 2,500 mm.

The modular design allows quick adaptation to a wide range of measurement tasks with alignment in almost any measurement direction.

More Information:
www.polytec.us/psv3d

Visualize Vibrations Everywhere

Polytec Scan Viewer



We listened to our users and developed a free viewer that can display, visualize and manipulate Scanning Vibrometer data graphically in Microsoft Office applications. Now any number of colleagues can see the outstanding data taken on Polytec systems as quickly as possible, on web pages, in PowerPoint presentations or any other office documents.

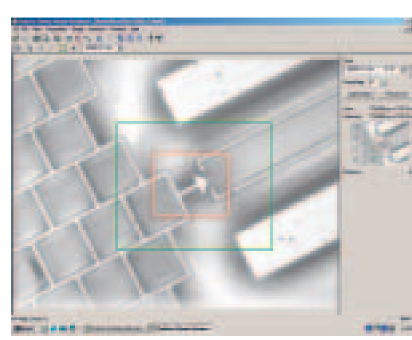
Polytec Scan Viewer is an ActiveX-Control which can be embedded into Microsoft Office applications and Internet Explorer; the Scan Viewer is also available as an independent application. The Scan Viewer offers you the same high performance presentation and animation options that come standard with the Polytec Scanning Vibrometer software. Make a measurement, analyze and present – all with the same data file! Download the Polytec Scan Viewer from the Polytec Website today:
www.polytec.com/usa/scanviewer

Improved In-Plane Motion Detection on MEMS

Planar Motion Analysis Software Release 2.3

The performance of the newest version of Planar Motion Analyzer Software – Version 2.3 – incorporates numerous new functions and improvements that will facilitate measurement and analysis of in-plane MEMS dynamics.
The following features are available:

- Analysis and visualization of complex MEMS motions such as the differential motion between two parts of the structure
- Measurement geometries of out-of-plane analyses can now be imported and displayed
- Advanced frequency band import and automatic separation of frequency bands
- Substantially reduced size of data files due to limited regions of interest
- Various enhancements/extensions of the user interface



Find more details on:
www.polytec.com/usa/microsystems

Optimal Welding *With Ultrasound*

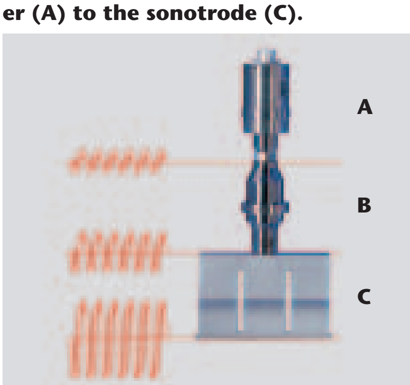
Laser Vibrometers Help Optimize Production of Ultrasonic Welding Tools for Joining Thermoplastic Materials

Ultrasonic welding is well established in the plastics processing industry. This technology allows high process speeds with constant, reproducible weld quality and low energy requirements. For this reason, it is preferred for high volume production applications in the automobile, electrical, medical, packaging, semiconductor and textile industries. Polytec single point and scanning vibrometers help develop optimal ultrasonic welding tools.

Introduction

In contrast to alternative technologies, such as gluing or thermal welding, ultrasonic welding does not have any impact on the material properties. In addition, ultrasonic technology allows multilayer welding or laminating and several process steps can be carried out in a single step, such as welding, cutting and perforating.

Figure 1: Design of the stack. The vibration amplitude (red) is being boosted on its way from the converter (A) to the sonotrode (C).



Herrmann Ultrasonics in Karlsbad, Germany, is a specialist in joining thermoplastic materials using ultrasound. Within the Plastics, Packaging and Nonwovens business units, customer-specific solutions are found for a wide range of ultrasonic welding applications.

This is How it Works

During ultrasonic welding, mechanical vibrations are transferred to the plastic parts under pressure. Warmth is generated through molecular and interfacial friction which increases the attenuation coefficient of the material. Locally, the plastic begins to soften. This reaction is self-accelerating due to the increase in the attenuation of the plasticized material, and a large share of the vibration energy is converted into heat. After welding and while maintaining joint pressure, a short cool-off phase is necessary to homogeneously solidify the formerly plasticized material. Subsequently the parts or rolls of material now joined together with the aid of the ultrasonic energy can be further processed.

The ultrasonic welding process is started with a stack. The stack is made up of a piezoelectric converter A, the amplitude transformation piece B and the actual sonotrode C (Figure 1).

High Quality Requirements

A prerequisite for good welding results with regards to stability, density and optical quality of joints is joint tools designed to suit both the process and the material. The vibrational properties of the individual components are of particular importance here, in particular the vibration amplitudes. All components of the ultrasonic stack are tested as individual units at Herrmann Ultrasonics. The amplitude measurement is of utmost importance.

Measuring the Vibration Amplitudes

Depending on which individual component is at issue, its vibration amplitudes are verified using a Polytec single point or a Scanning Vibrometer.

Converter and transformation pieces are commercially available, standard components with fixed, tightly specified output vibration amplitudes. The vibration amplitudes are tested by making measurements with a Polytec CLV Compact Laser Vibrometer, thus ensuring that they are within the specified range.

Sonotrodes are individual components adapted to match the work piece to be welded. These components must fit the work piece geometrically and provide critical ultrasonic amplitude levels sufficiently high to produce good welds. A 3-D CAD model (Figure 2) is used to develop and design the sonotrodes by prototyping them on the work piece. The vibrational properties are then optimized with the aid of Finite Element Model (FEM) analysis until they fulfill the given parameters. Only then does the sonotrode go into production.

The properties of the finished sonotrode are measured with the aid of a PSV-400 Scanning Vibrometer. In Figure 3 the measurement layout is shown; on the left is the PSV-400 Sensor Head, on the right the sonotrode in a suitable holder and in the middle the measurement screen with the video image of the sonotrode surface in the PSV Software.

The amplitudes occurring at a certain frequency are measured using the PSV-400 Scanning Vibrometer on selected points of the sonotrode surface (Figure 4). Specially configured software for this measurement saves time, allows safe operation and provides documentation. The amplitude distribution thus defined is compared with the value calculated from the FE model. So if necessary, the sonotrode can be further optimized.

CONTACT

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Schaumburg IL 60193
www.herrmannultrasonics.com

Figure 2: Modeling the dynamic behavior of a sonotrode

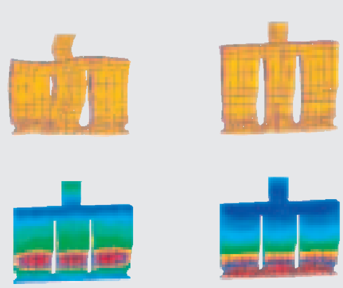
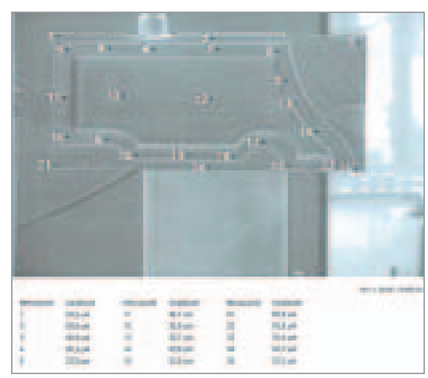


Figure 3: Measurement layout to characterize the sonotrodes

Figure 4: Amplitude distribution on the surface of the sonotrode



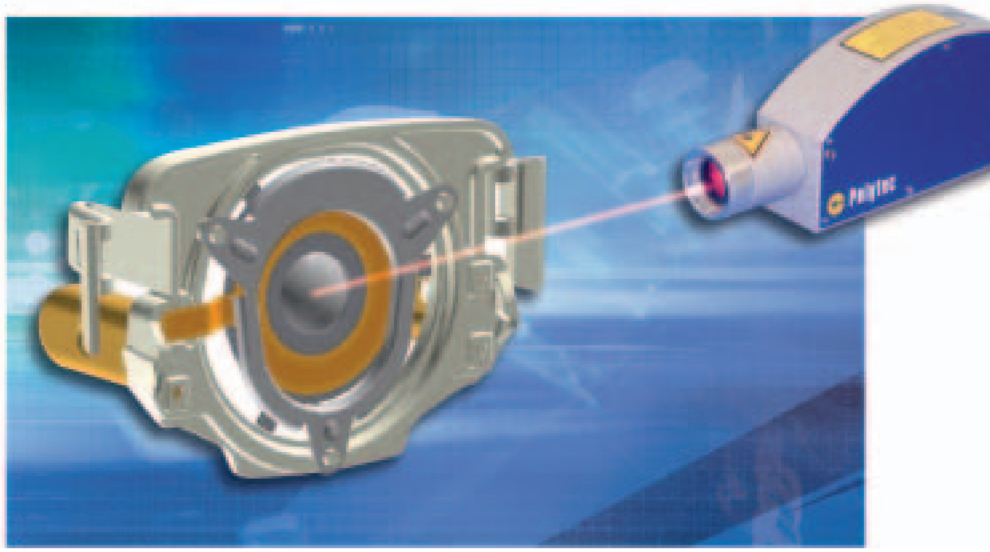
PSV-400 Scanning Vibrometer

The PSV-400 Scanning Vibrometer is a full-field vibration measurement and imaging system for the analysis of structural vibrations that is fast and easy to use. It simplifies complex noise and vibration characterization for R&D, commercial and industrial applications, but is also an universal instrument for various measurement tasks in production testing and quality control.

A complete PSV Software package provides detailed vibration data analysis including graphing, animation of 2-D and 3-D color maps and data export. Thus, the PSV-400 helps to find appropriate locations on the test object for a subsequent quality control by industrial vibration sensors.

For more info see:
www.polytec.com/usa/psv400

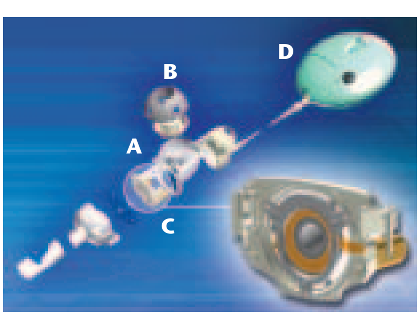
Inhaling Efficiently *with 100% Quality*



In-line Quality Control with a Laser Vibrometer during Production of Membrane Inhalation Systems to Optimize Treatment of Respiratory Illnesses

Inhaling medication plays an important role in treating respiratory illnesses. To be effective, the liquid drugs must be transformed into an aerosol with well-defined drop size distribution. The nebulizer system creates the aerosol to meet the extremely demanding properties. At Pari GmbH, one of the leading manufacturers of aerosol generation systems in Germany, the quality of the systems is 100% tested using a Compact Laser Vibrometer. By measuring the vibration characteristics of the aerosol generation membrane, the quality of the aerosol generator – the key element of the nebulizer system – is ensured.

Figure 1: Design of an aerosol generation system. A, Medication reservoir; B, Medication cap; C, Nebulizer; D, Control unit



Performance of a Nebulizer System

In Figure 1 the components of the aerosol generation system are shown. The dose of the liquid drug intended for inhalation is fed into the reservoir via the medication cap. In the nebulizer, the aerosol is generated from the liquid in the medication reservoir with the aid of a perforated membrane. Piezo elements actuate the membrane at ultrasonic frequencies. The resulting change in pressure behind the membrane forces the fluid through the perforations in the membrane; thus, nebulizing it (Figure 2).

Vibration Test on Aerosol Generators

During product development at Pari GmbH, extensive tests were carried out on the vibration characteristics of the nebulizer membrane. The deflection shapes of the nebulizer membrane were precisely analyzed using a Polytec Scanning Vibrometer. On the basis of these results and others, the optimal membrane structure and the most suitable resonant frequencies for optimal inhalation were defined.

A semiautomatic test station was developed and installed in production for quality control (Figure 3). It uses a Polytec Noise Analysis software-driven subsystem based on the CLV Compact Laser Vibrometer. The CLV is made up of a control unit and a compact vibrometer head connected by a flexible fiber-optic cable.

In the production process, the vibration characteristics of each aerosol generating membrane is measured without contact using the CLV with a bandwidth of 350 kHz, and the frequency spectrum is calculated (Figure 4).

Using Polytec's QuickCheck* test software, certain frequency ranges are

Figure 2: Nebulizer with medication reservoir and medication cap as well as magnified view of the nebulizer membrane showing micromachined perforations.

Figure 3: Station constructed for 100 % quality control of nebulizer membranes.

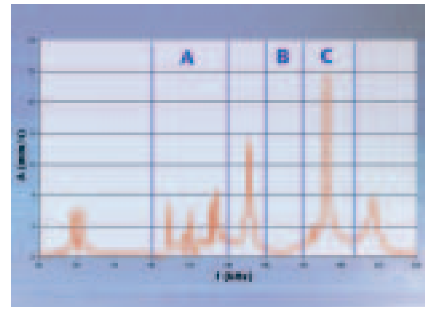


Figure 4: Typical spectrum of a membrane. a) Envelope assessment b) Void area (no peak allowed) c) Area in which there may only be one peak

automatically analyzed for critical characteristics in the spectrum (Figure 4). Individual areas are thereby examined for the shape of their envelope curve, the presence or absence of peaks as well as the number of peaks (peak-splitting). The signal-to-noise ratio is also calculated as an evaluation criteria for the quality of a measurement.

To ensure that during the test, the sample point of the laser vibrometer is always on a flat surface between the perforations in the membrane, an evaluation of the measurement spot is carried out on the basis of the intensity of the laser light reflected back.
If the laser intensity is too low, then the sample point is automatically shifted by a few micrometers using a beam deflector until the full laser intensity is attained (Figure 5).

Summary

Non-contact vibration measurements with the CLV Compact Laser Vibrometer and the QuickCheck software allow extremely quick quality testing and analysis for aerosol generating membranes. The semiautomatic test station has completetd more than 10,000 inspections within the first 6 months of operation. During the course of the measurements, the analysis algorithm has been continuously improved to further minimize the unnecessary rejection of good but wrongly evaluated test items. This measurement system now guaranties continuous quality of the aerosol generation systems and, most importantly, precise, reproducible delivery of the corresponding medication.

* QuickCheck: more info on supplement page E24

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Figure 5: Integration of the Compact Laser Vibrometer equipped with a beam deflector on the test stand

Show More *Profile*

Surface Measurement in Production Environments

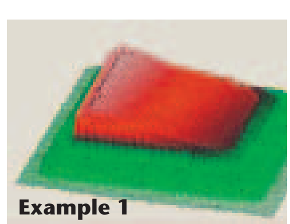
Surface properties, such as roughness, are important parameters for quality assurance. Traditional contact measurement processes (i.e. surface profilometers) can make the surface measurements but take a long time, making them incompatible with the rapid feedback needed for high throughput production control. In addition, because of the contact, there is the risk of damage to the surface of the item being tested. Polytec's TopCam/TopMap white-light interferometer is a state-of-the-art non-contact surface measurement system and an ideal tool to determine smoothness, height differences and parallelism of large surfaces and structures, including soft materials.

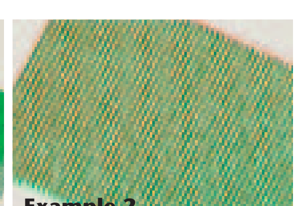
Measurement Principle

The TopCam/TopMap sensor head is a Michelson interferometer in which the test piece is measured against a coplanar, flat reference mirror. Constructed with telecentric optics, the instrument can measure large surfaces quickly. In contrast, competing systems have smaller field-of-views and require that several images are stitched together to cover the same large surface, a process prone to errors. After setting the measurement parameters, the measurement process runs automatically, the topography of the sample is shown in 2-D or 3-D on the screen of the PC and can be analyzed manually or automatically. The results can be transferred in binary format or as ASCII code. This enables a direct data import and export to EXCEL, MATLAB® or in-house databases.

Advantages for Quality Assurance in Laboratory and Manufacturing

High throughput quality control is easily realized using TopCam/TopMap white-light interferometers (see info box). The measurement itself is quick and fully automated, as are the analysis, savings and transfer of the results to the process control software. Further throughput advantages come with macro programming in Visual Basic® or by hiding areas of the image which are not relevant with the aid of masks. Significant contrast differences can make surfaces difficult to measure;





Polytec TopMap/TopCam White-Light Interferometers

Polytec white-light interferometers are designed to make precision topography and flatness measurements in a metrology lab or on-line in the factory.

For quality tests on samples in the lab, the TopMap benchtop interferometer offers the maximum possible flexibility and accuracy. The Z resolution is in the nanometer range and intelligent filter systems and software solutions allow measurements on any surface from extremely rough to polished smooth. In addition, it is simple to preconfigure the instrument so that measurements and part evaluation can be made at the push of a button.

The compact TopCam 3-D camera is optimized for use in production environments. It can be installed on a wide range of production lines, makes measurements quickly allowing high throughput. Due to its robust mechanical construction, it works in a harsh production environment as well as in the laboratory. In addition, measurements can be integrated into automatic process sequences with the aid of simple Visual Basic macros.

More information: **www.topmap.info**

TopMap used in the hard disk drive industry

however, Overlay Technology developed by Polytec can help compensate for these differences and produce excellent measurements.

Applications

Surface measurements are needed in many industries. Components and structures ranging from submillimeter to centimeter size can be found in the semiconductor and data storage industries (refer also to the article "Quality Control for Hard Disk Components" in LM INFO Special 2/2004, page 12), in micro structures and sensors, and in engineering and automotive applications. A few examples follow.

Example 1: Laser Chip
Tilt and bending are important parameters for semiconductor laser chips. These topographical and geometric specifications must be precisely met.

Example 2: Solder Bumps
In the case of SMD printed circuit boards the height of the solder bumps is of great importance. These bumps must be measured quickly across a large surface area right after creation and before assembly, without any cooling off time.

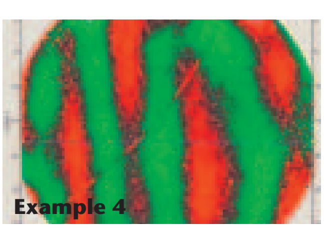
Example 3: Piezo Actuator
Flatness deviations were measured on the annular surface of a piezo component. The results are displayed as color plot and cross section.

Example 4: Film for LCD Monitors
Faults (scratches) and ripples (± 100 nm) are measured on this 2 mm thick transparent film for LCD monitors. The results are shown as a color plot.

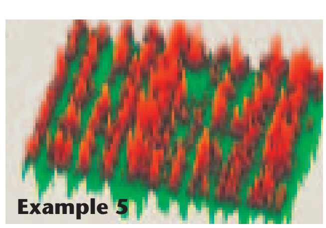
Example 5: Steel Structures
A fine structure was generated through processing and can be measured with the white-light interferometer on a highly polished steel surface.

Example 6: Lab-on-a-Chip
Lab-on-a-chip systems perform sophisticated analysis in a few square centimeters that only a few years ago had to be performed by technicians in an analytic lab. Applications for these chips in molecular biology (bio-chips) are abundant with new applications in medicine, the food industry and environmental analysis on the horizon.

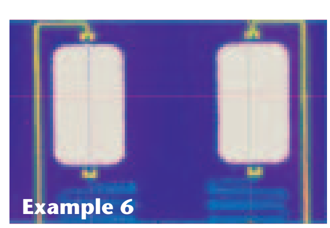
The diagnostic chips are made of a transparent plastic in which channels and chambers have been cut to a precision pattern. The channels draw the sample into the chip where the biochemical reactions take place. Producing many chips with sufficient quality is essential to reducing costs and rapid adoption of the technology. White light interferometery can monitor the quality of the system topography as shown in the images below and on page 20.



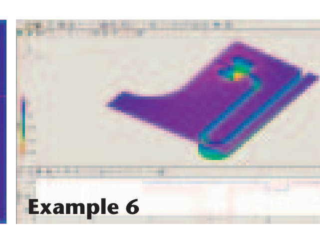
Example 4



Example 5



Example 6



Example 6

That Sounds *Good*

Non-Destructive Material Testing of Parts and Goods Using Vibration Analysis

Material testing using vibration analysis is an innovative approach to on-line quality control. It can be used anywhere that the vibration characteristics, and consequently the structure-born noise, are affected by differences in quality. Many defects can be detected using this approach including structural anomalies such as hairline cracks and cavities, density differences and general manufacturing errors.

Target: Cut Production Costs While Simultaneously Increasing Quality

In many industries the same quality inspection processes that were being used ten or more years ago are still being used today. These traditional processes are often subjective, evaluating surface effects and leaving the true defects hidden from the inspector.

Consequently, false errors can happen, resulting in reduced or delayed production. In addition, many of these test processes are no longer cost effective and it is necessary to look for new and better methods of inspection.

Vibro-acoustic or sound testing is a high performance, alternative technique that must be considered for quality inspection applications.
It is non-destructive and fast enough to provide 100% testing for products in an assembly line. Several industries where serial production of components is routinely done have implemented 100% inspection programs to meet the increasingly stringent customer performance and cost specifications.

The dream of every plant operator is to reduce production costs and simultaneously increase the quality. In many cases these apparently contradictory targets can be pursued and achieved simultaneously by using test systems based on vibration analysis.

Transferring the solution from a development lab to a production line can be quite complex. It is particularly important to ensure that the introduction of this test procedure is within the technical capabilities of the factory employees. Worker acceptance of the quality test results is only attained if operating systems can be managed without intrusive specialists and without any complicated process changes, checks or obstacles.

MEDAV has many years of experience in this field and, today, offers fully automatic systems for vibration-based material testing. The new CrackMaster

System works as a "Black Box" in the manufacturing line, automatically compensating for unavoidable process influences. For example, adaptation to process drift is possible for many manufacturing processes.

The Experts are only Required Once – Setting up a Test System

Rigid bodies demonstrate structural vibrations which can be used for quality testing and inspection. These vibrations, to be more precise the natural deflection shapes, are specific to the component and are affected by the entire assembled product including joints, geometry, materials used, and production processes. Identical parts show the same vibration characteristics. On the other hand, subtle differences between parts affect the structure. For example, fractures and cavities, can lead to measureable deviations in the natural deflection shapes.

Consequently, it is a physically substantiated effect that is evaluated – an important difference when compared to many competing test procedures!

There are several methods that can be used to determine the natural deflection shapes. Once these shapes are known, the quality criteria are derived and a test specific to this component is put together (Figure 1).

The components are inserted into the test rig in the correct position and are made to vibrate by means of an impulse generator. Non-contact sensors are used in practice to measure the vibration: either traditional microphones measuring airborne noise or innovative laser vibrometers for non-contact measurement of structure-borne noise

The process fluctuations are determined for a representative time period from a random sample of parts acquired from running production. Under the assumption that the manufacturing process is running correctly, with the majority of the parts produced as good parts, the CrackMaster test system independently calculates the acceptability thresholds (Figure 2). If one or more of the properties of a component are beyond the acceptability thresholds, then the identified part is rejected.

The program automatically adapts the sorting thresholds over time because it is known that process drifts can affect the measurement enough to compromise the sorting criteria (good – bad difference) determined at an earlier point in time.

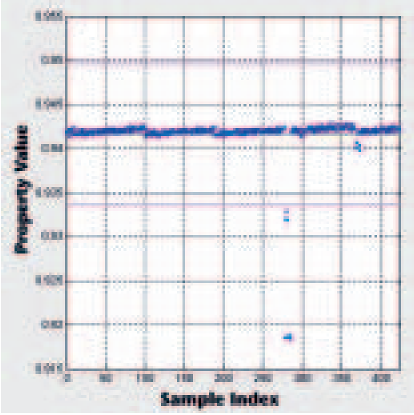


Figure 2: Notice the shift in the measured property over time. The saw-toothed progress corresponds to a change in the base material.

The Job of the Person Responsible for the Test

The test system helps to identify suspicious components in the processing chain and to reject them. But are the suspicious parts really bad parts and are the "typical" parts the good parts?

These questions must be answered by factory test engineers running supplementary tests, such as tensile strength tests or ultrasound tests.

MEDAV provides the expert work by setting up the test system initially and training the staff in its operation.

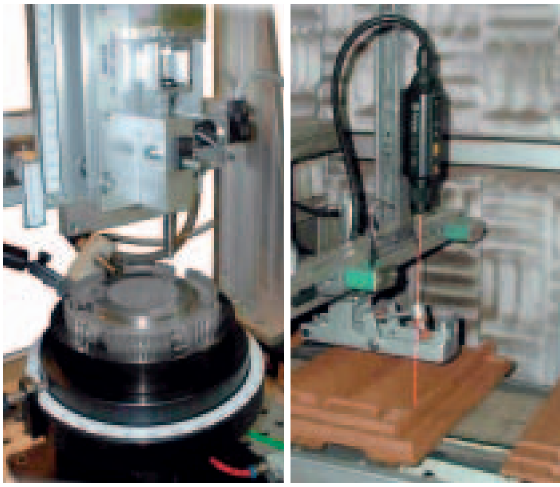


Figure 1: Examples of test rigs: 1) for a rotationally symmetric component with a microphone (on the left); 2) for a line-integrated roof tile test system with a laser vibrometer (on the right).

While on-line, the operator enjoys the "Black Box" and MEDAV enjoys the satisfied customer.

Applications for vibration-based material testing can be found in foundries, forges, glass and ceramics industries, pressing plants and many other areas.

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Make *No Break*

Laser Based, Non-Contact Speed Sensor Reduces Breaks on High Speed Paper Unwind

In response to a significant number of breaks during splicing operations on a continuous coater, a paper mill installed a Polytec LSV Laser Surface Velocimeter on its high speed paper unwind. Controlling tension during splicing with the use of the LSV has proved to be a key factor in attaining higher efficiency at the unwind station.

Flying Splice

In paper production, a flying splice is a method of switching from one paper roll to another by joining the beginning of one roll to the end of the other roll, thus avoiding machine stoppage. With high speed paper unwinds continually pushing higher speeds, speed matching of the parent reel to the expiring reel has become more critical. At these high speeds, typical methods of calculating speed may not suffice.

Tension Control by Polytec LSV

A U.S. based paper mill had a significant number of breaks during splicing operations (average one break per day) on a continuous coater, causing a significant loss of production. The mill believed that a high percentage of the breaks were due to mismatched speeds between the parent reel and the expiring reel, and thus installed a Polytec LSV-5000 Laser Surface Velocimeter (current model is LSV-6000) on the high speed paper unwind (5,200 ft min^{-1}) supplied by Metso Paper. Since the initial installation, online data from the velocimeter have supported the mill's analysis. A significant reduction in sheet breaks has clearly illustrated that precise matching of speeds during the unwind operation becomes more critical as paper machine speeds increase. Controlling tension during splicing with the use of a Laser Velocimeter has proved to be a key factor in attaining higher efficiency at the unwind station.

Control Loop Integration

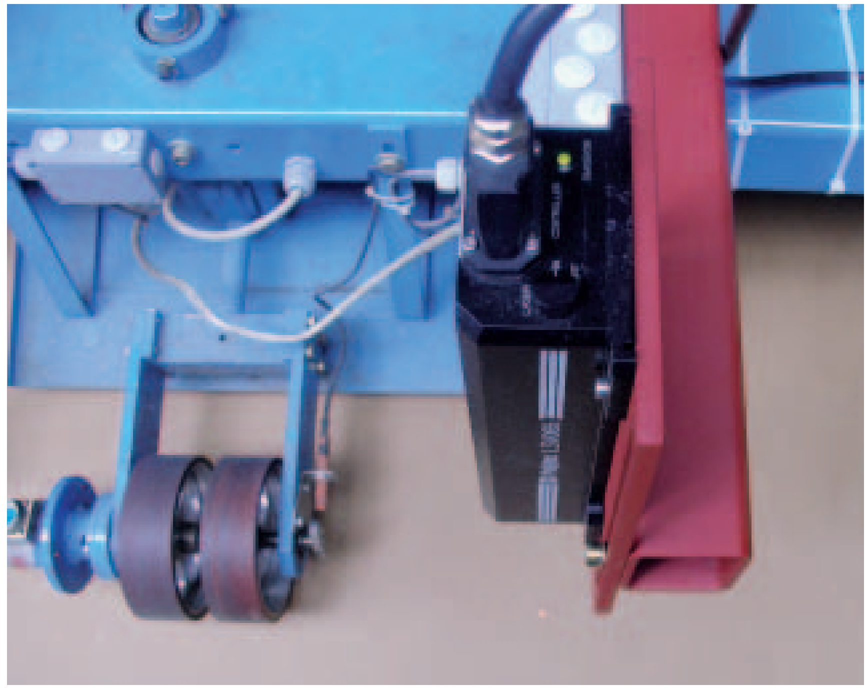
The mill's existing control loop was based on measuring the diameter of the parent reel at very slow speeds with an ultrasonic sensor. Final surface speed, at the time of splicing, was calculated based on this initial diameter

Paper machine (photo: Metso Paper Inc.)

measurement and the RPM of the reel at speed. However, in practice, the mill found that at higher speeds the actual diameter of the parent reel increased with increasing speed due to centrifugal force. The result was an error in calculated surface speed at the time of splicing.

The LSV verified these errors to be as great as 20 – 30 ft min^{-1}. Although the mill attempted online measurements of real diameter with several sensors, including ultrasound and lasers, they found that the readings were too unstable for controlling the drives. Initially, the LSV was installed as a monitoring device to measure the true surface speed of the parent reel, with the quadrature encoder output integrated into the control system for future use as a possible feedback device. Review of the data after one week of operation showed a noticeable difference between the calculated speed and the true surface speed, as measured by the LSV, demonstrating the correlation between surface speed and the tension variations during splicing. This data enabled the mill to predict when a break would occur due to mismatched speeds.

These results encouraged the mill to integrate the LSV into the control loop as a trim device that fine-tuned the final speed of the parent reel before splicing. It has utilized this outer feedback loop ever since. The new control loop measures the parent reel diameter at slow speeds and uses this value as the initial input for ramping the drive system roughly to the specified speed. However, once in range, the measurement from the LSV is used to precisely match the parent reel with the expiring reel just before splicing. By integrating the surface speed signal into the control loop, the mill now consistently matches parent reel speeds to within ±5 ft min^{-1} at about 5,000 ft min^{-1} (±0.1%). The result was a significant reduction in tension variation during the splice, which eliminated breaks due to mismatched speeds.



LSV-065 Laser Sensor Head and encoder wheels measuring the surface speed of paperboard

Project Justification

A missed splice can cost a mill from $500 to $8,500. These costs cover various recovery operations and processes, downtime, and equipment. In addition, matching of the reel speeds also minimizes mechanical shock and stress to the machinery resulting from the splicing event, which might reduce maintenance costs in the long run. By analyzing the total cost per missed splice and the number of missed splices related to mismatched speeds or tension, a mill can determine if a justification exists for such an upgrade. The ROI from the installation at the mill discussed in this article was less than one year.

Conclusions

The LSV Laser Surface Velocimeter directly measures surface speed, thus providing an accurate, repeatable, and reliable method of determining the true surface speed of the parent reel before splicing. The result is elimination of breaks due to mismatched reel speeds.

Other applications of LSV technology include:

- Precision length verification at the paper machine and winders
- Differential sheet speed for stretch or draw calculations
- Speed matching of turn-up roll and sheet speed at paper mills
- FFT analysis of velocity variations on sheet, felts, drums, etc.

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Team Up – *Meet Polytec Worldwide*

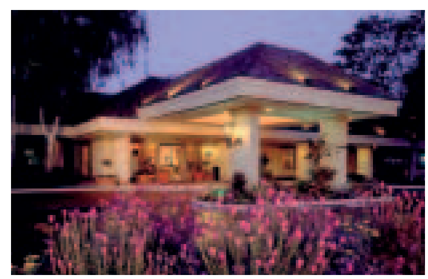
Outstanding Attendance

2005 North American Vibrometer Users Meeting

In September Polytec, Inc. hosted an expanded four-day Vibrometer Users Meeting at the Four Points by Sheraton in Sunnyvale, CA. With over 80 pre-registered, attendance was outstanding. Polytec provided lunch each day and a pleasant lakeside dinner on day three. By having several meals together, both Users and Polytec representatives were encouraged to get to know each other and exchange requirements for tomorrow's vibrometer measurements.

On the first day, scanning vibrometer software basics were taught followed by advanced scanning software topics on day two. On days three and four, a technical seminar covered laser vibrometer measurements in two topical sessions: Microstructure Characterization (10 invited speakers) and Macro Structure Characterization (5 invited speakers). The invited speakers discussed dynamic structure characterization regarding a wide range of objects from MEMS to Electric Motors to On-line paper quality monitoring (page 12).

An informal round-table discussion and a hands-on product workshop followed the presentations. To conclude the meeting, an Apple iPod was given away to a lucky Polytec User, reminding us that vibrometer technology is helping create and improve all sorts of products even the small disk drive in the famous iPod.



More info: **ww.polytec.com/usa/users**

"Interesting and Helpful"

UK Vibrometer User Group Meeting 2005

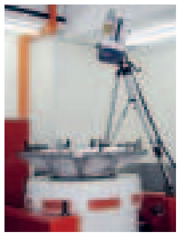
Lambda Photometrics, the UK division of Polytec, held its 4th User Group Meeting over two days in November at the Photonics Cluster facility in Birmingham. With 25 attendees over the two day event, there was a good mix of existing and potential vibrometer applications. The presentations included insect hearing applications, MEMS device development, high resolution dynamic characterization of piezoelectric materials, and measurement of acoustic fields generated by high power sonar and medical devices.

The second day concentrated on vibrometer technology covering the basics of laser Doppler vibrometry. Also, there were practical demonstrations of the new PSV-400-3D Scanning Vibrometer, a system that characterizes the 3-D dynamic characteristics of macro structures, and the MSA-400 Micro System Analyzer, an instrument for dynamic and static characterization of micro structures. The PSV-400-3D was recently added to the Universities Research Equipment Loan Pool.

The meeting was very interesting and helpful, with some users increasing their wish list for future equipment!
www.lambdaphoto.co.uk

"More Testing Capabilities"

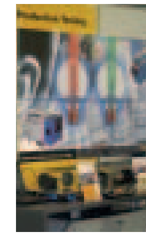
Very First Vibrometer Seminar in Malaysia



The first Laser Doppler Vibrometer Seminar in Kuala Lumpur was organized by our new representative Logicom. More than 20 university and industrial participants used this opportunity to get the latest information.

Also in attendance was a researcher from MIMOS, an organization which recently received the first MSA Micro System Analyzer in this region. A 2nd seminar was held in Logicom's vibration lab in Prai, Penang where Polytec's PSV-400 Scanning Vibrometer was demonstrated in conjunction with Logicom's 3,500 kg LDS shaker system. The PSV-400 adds significant testing capabilities to Logicom's vibration lab and is available for demonstrations and testing services for Malaysian customers.

Adieu MeasComp!



In September it was time to say goodbye to Meascomp, an event built around sensor and computer-based measurement technology at Wiesbaden. The participants were informed of the most current innovations at Polytec, especially the possibility of stitching together complete 3-D vibration data sets from several views of large objects. MeasComp will not disappear completely – its successor will be the annual international Sensor+Test/MeasComp trade show in Nuremberg. Polytec is looking forward to welcoming you to this show.

"Extremely Positive Response"

First User Seminars in South Africa

The first South African Vibrometer User Seminars took place at the Universities of Pretoria and Stellenbosch. They attracted a total of 55 participants who learned about Polytec's non-contact vibration measurement instruments. University experts contributed interesting reports about their practical experience using vibrometers. Because of the success of these seminars, a new seminar is scheduled for 2006.

Hot Autumn

Vibrometer Seminars all over Europe!

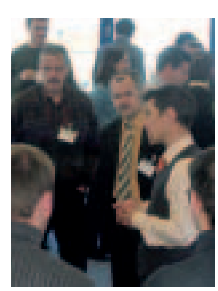
In Vélizy, France, Polytec held the "2ème Séminaire des Utilisateurs de Vibromètres Laser", a technical seminar where the participants had the opportunity to make real measurements using the PSV-400-3D Scanning Vibrometer in the SOPEMEA test laboratories. SOPEMEA is a well known test service provider with substantial experience on improving aerospace materials and equipment.
In Madrid, Spain, 35 eager participants attended the "Jornadas sobre Ultimos Avances en Vibrómetros Láser 3D" to learn more about vibrometer technology and it's application. Both the seminar and the workshop were arranged by our local representative, Alava Ingenieros, who catered food that was simply delicious.

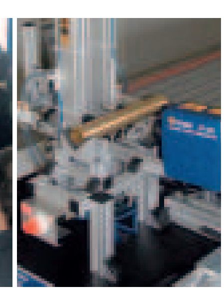
More seminars were held by our Austrian representative, LB-acoustics, in Prague, Czech Republic, gathering 25 existing and potential customers, and in Slovenia where 6 attendees mainly from the university got to know the benefits of laser vibrometry.

Production Testing

Presentation Day at Waldbronn

In November, about 40 participants came to Polytec headquarters to attend a seminar on non-contact optical metrology in production environments. The physical basics of laser vibrometry, velocimetry and interferometric topography measurement were explained and then followed by hands-on demonstrations of the equipment. Invited speakers from Faulhaber Group and Pari GmbH talked about their experience making measurements for quality control and the benefits of vibrometry compared to conventional quality control methods (pages 10 and 18). A second event is already scheduled for 2006.





More info on upcoming events: www.polytec.com/usa/events

Polytec

2006 Trade Fairs and Events

Reference our web site www.polytec.com/usa/events for the most up-to-date information and links on trade fairs and events!

Feb 01 – Dec 12, 2006	Journée Technique SIMTEC	8 locations, France	LM
Mar 27 – 31, 2006	Industrie 2006	Paris, France	LM
Apr 04 – 06, 2006	Aerospace Testing Expo Europe 2006	Hamburg, Germany	LM
Apr 24 – 28, 2006	TUBE 2006	Düsseldorf, Germany	LSV
Apr 26 – 28, 2006	DTIP 2006	Stresa, Italy	LM
Apr 27 – 29, 2006	Micromachine 2006	Beijing, P.R. China	LM
May 01 – 04, 2006	AISTech 2006	Cleveland, OH, USA	LSV, LM
May 07 – 11, 2006	NanoTech 2006	Boston, MA, USA	LM
May 08 – 09, 2006	Braking 2006	York, UK	LM
May 09 – 11, 2006	Automotive Testing Expo Europe 2006	Stuttgart, Germany	LM
May 09 – 12, 2006	Control 2006	Sinsheim, Germany	LSV, LM, TOP
May 30 – Jun 01, 2006	Sensor+Test 2006	Nuremberg, Germany	LM, TOP
Jun 04 – 08, 2006	Hilton Head 2006 MEMS Workshop	Hilton Head Island, SC, USA	LM
Jun 07 – 08, 2006	Quality Expo 2006	Detroit Novi, MI, USA	LM, TOP
Jun 19 – 22, 2006	AIVELA 2006	Ancona, Italy	LM
Jun 27, 2006	Microscience	London, UK	LM
Jul 02 – 06, 2006	ICSV - 13th International Congress on Sound & Vibration	Vienna, Austria	LM
Sept 04 – 07, 2006	Photon ´06	Manchester, UK	LM
Sept 18 – 20, 2006	ISMA 2006	Leuven, Belgium	LM
Sept 19 – 22, 2006	10ème CFTL 2006	Toulouse, France	LM
Sept 06 – 08, 2006	Automotive Testing Expo China 2006	Shanghai, P.R. China	LM
Sept 13 – 14, 2006	Diskcon 2006	Santa Clara, CA, USA	LM, TOP
Sept 18 – 20, 2006	ISMA 2006	Leuven, Belgium	LM
Sept 19 – 22, 2006	Innotrans 2006	Berlin, Germany	LM
Sept 20 – 22, 2006	Aluminium 2006	Essen, Germany	LSV
Oct 04 – 05, 2006	2006 US Vibrometer Users Meeting	East Coast, USA	LM
Oct 17 – 18, 2006	9th German Vibrometry Seminar	Waldbronn, Germany	LM
Oct 17 – 19, 2006	MesurExpo 2006	Paris, France	LM
Oct 17 – 19, 2006	OPTO 2006	Paris, France	LM
Oct 25 – 27, 2006	Automotive Testing Expo US 2006	Detroit, MI, USA	LM
Nov 05 – 10, 2006	IMECE 2006	Chicago, IL, USA	LM
Nov 14 – 16, 2006	Aerospace Testing Expo US 2006	Anaheim, CA, USA	LM
Dec 04 – 06, 2006	InterNoise 2006	Honolulu, HI, USA	LM

The right column denotes the Polytec product lines that will be displayed:
LM = Laser Measurement Systems; LSV = Laser Velocimeter; TOP = Topography Measurement

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