Issue 02 | 2011

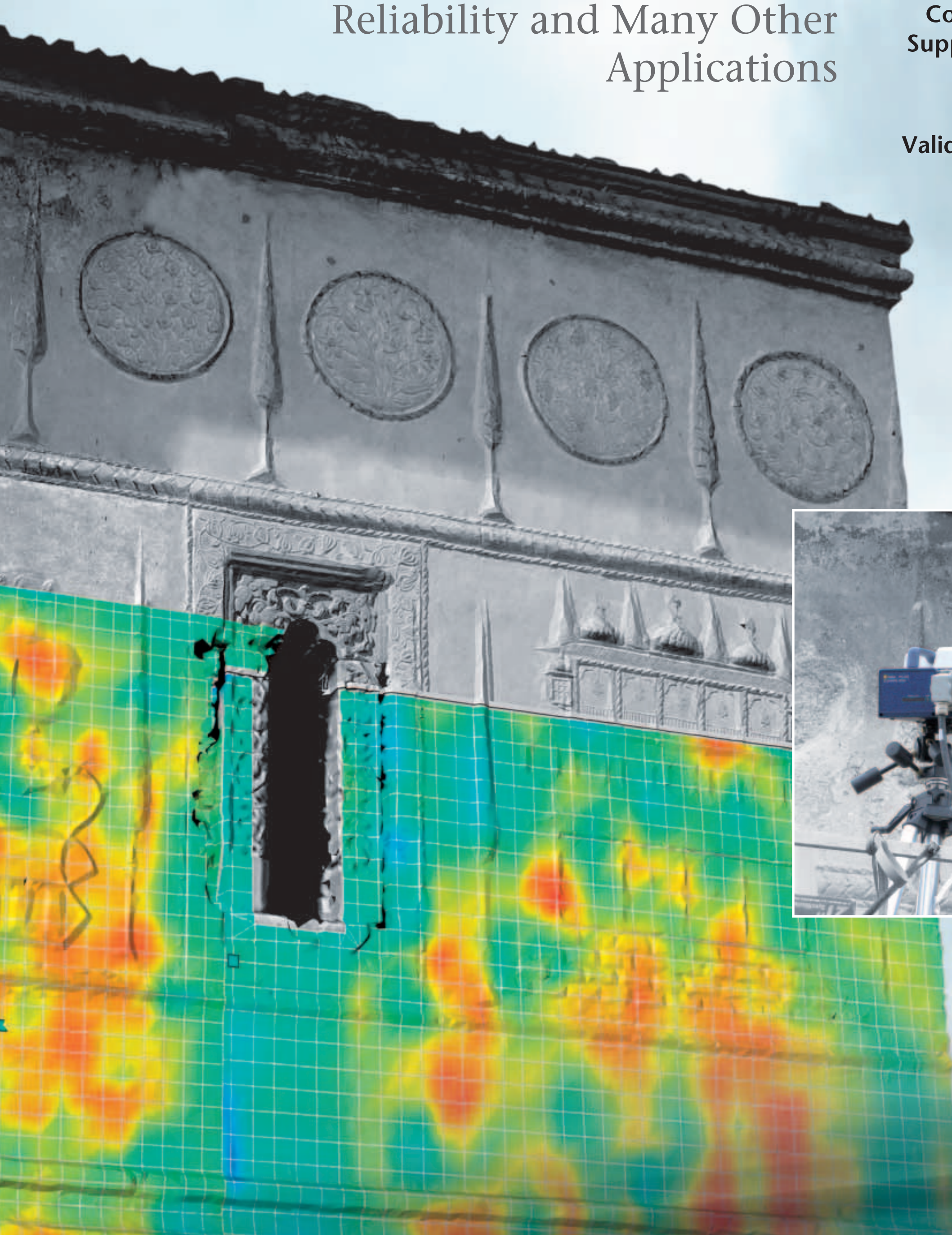
Polytec

InFocus

Optical Measurement Solutions

Non-destructive Testing

for Structural Health Monitoring, Reliability and Many Other Applications



Eric Winkler

Dr. Hans-Lothar Pasch

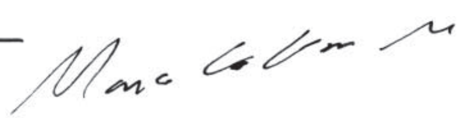
Dear Readers,

As all of us know, the physical properties of engineered structures will deteriorate over time under dynamic load, an effect generally known as material fatigue. Mechanical engineers would refer to the term "high cycle fatigue load". This fatigue is caused by alterations in the material structure or micro-damage, which can develop inside the material and might not be visible from the outside. For structures where safety is a concern, the only way out is continuous or regular inspection (structural health monitoring).

Laser vibrometers from Polytec can, in effect, see inside these structures. The reason is that material alterations lead to changes in dynamic system characteristics – thus internal damage can be identified and located by a targeted analysis of the measured vibration data.

Our customers are increasingly using laser vibrometers for non-destructive testing, beyond the more familiar applications in acoustics and structural dynamics. We are happy to share this fascinating field of application with you and to illustrate it with practical reports and examples.

We hope you will enjoy reading the articles and wish you many new insights and fresh ideas!



Eric Winkler
Optical Measurement Systems

Dr. Hans-Lothar Pasch
Managing Director Polytec GmbH

Groundbreaking News from Polytec

At the end of October the first turf was cut to prepare the ground for expansion of Polytec's Headquarters in Waldbronn, Germany by a further 8,000 square meters. The new building will be finished in 2012 to provide sufficient space for development, manufacturing and sales as well as new application and demo labs for the next 5 – 10 years. This expansion reflects positive business development, a continuously increasing number of employees, and will provide sufficient resources for further growth.

Polytec's UHF-120 Vibrometer Wins 2011 Industry Prize

During the 2011 Hannover Messe trade fair, the UHF-120 Ultra-High Frequency Vibrometer was awarded the 2011 Industry Prize under the microsystems engineering category. The award was judged by a panel of professors and trade press experts according to the level of innovation and future potential of the products. Polytec, as a developer of innovative measurement technology, is frequently awarded renowned research and industry prizes, for instance the 2009 Innovation Award of the German Economy for the robot-assisted automatic RoboVib Test Station and the MessTec & Sensor Masters Award for the Optical Derotator. The industry prize was received by Dr. Karl Spanner, Managing Director of Polytec (see photo, second from right) together with Vice President Eric Winkler and Product Managers Dr. Wilfried Bauer and Dr. Heinrich Steger (left).

Polytec Top Rated Business Partner

Polytec was awarded a top rating in the index of creditworthiness as part of the annual certification of "Top Business Partners" granted by Hoppenstedt, one of the leading suppliers of business information in Germany. In early 2011, Hoppenstedt evaluated 4.5 million companies on a scale of 1 to 6 with regard to creditworthiness and concluded that Polytec ranks within the top 3.3% of the best rated German companies.

2011 Polytec Technical Days and UK Users' Meeting

September 21st/22nd saw over 60 delegates travel to Warwickshire's Heritage Motor Centre to attend the latest Polytec UK Technical & Users Group Meeting. The delegates comprised a mix of existing users and non-users, all with an interest in finding out more about the technology, seeing systems first hand and being able to talk to other users and Polytec engineers about those systems and applications.

As with previous meetings, the technical day covered the instruments and basics of laser Doppler vibrometry, with practical demonstrations of a range of single point and scanning laser vibrometers including the PSV-3D system and the new UHF-120 ultra-high frequency and RSV-150 long distance measuring vibrometers. The 2nd day featured speakers talking about their own Polytec vibrometer applications. The subjects were wide-ranging, covering such diverse subjects as dynamic measurements on rotating structures, human and insect hearing, ultrasonic drilling, microstructures, long range bridge and building response, vehicle brake testing and stress/strain determination. Most delegates were very complimentary about the meeting, going away with fresh ideas to further their work. In Germany, another 60 participants visited a series of Technical Days during October located at Ulm University, Erlangen-Nuremberg University, at the Institute for Microelectronics and Mechatronics Systems (IMMS) in Ilmenau and at Polytec Headquarters in Waldbronn. Attendees were given a unique opportunity to see live demonstrations of many of Polytec's optical measurement systems' product range.

Polytec New Affiliate in Big Partner Networks

By actively maintaining a professional but intimate relationship with our customers as well as with scientific and technical institutes, associations and networks, we learn and understand the requirements that make each new product a better solution. These innovative solutions allow thousands of customers to maintain their own technical leadership and meet future challenges. Among others, new partnerships have been established between Polytec and the MEMS Industry Group®, as well as national and regional associations like the Fraunhofer Vision Alliance and MST BW Mikrosystemtechnik Baden-Württemberg e.V.

More info:
www.polytec.com/partners

www.memsindustrygroup.org

www.mstbw.de

www.vision.fraunhofer.de/en

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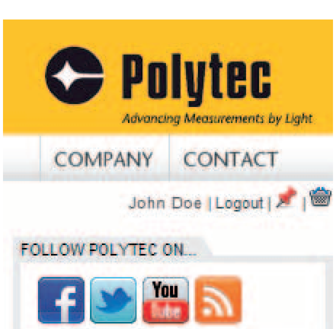

There's always something new to discover. Stay informed about Polytec's latest advances in measurement technology and **register as a Polytec User** to get instant access to detailed technical information, video downloads and software updates. Use **your Info Basket** on our homepage to find your bookmarked pages and to conveniently order hardcopies of any desired application note, InFocus magazine issue or brochure. Subscribe to Polytec's complimentary **e-mail newsletter** or to our **RSS news feeder** to get the information the very minute it's released. If you are interested in special topics and applications, attend our free webinars at the **Polytec Web Academy**.

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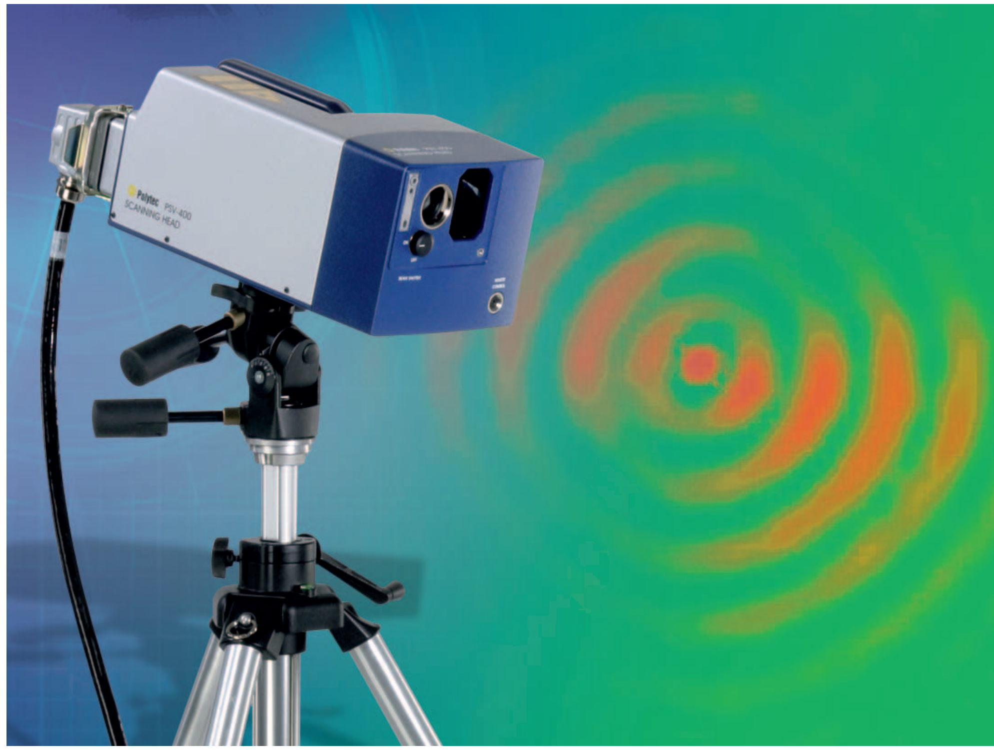
Application Overview

Defect Detection Using Lamb Wave Testing



Defect Detection in Composite Structures

Defect detection is currently of great interest, especially in the aerospace sector but also in the automotive sector and generally in lightweight construction. One of the main reasons is the ever wider availability of composite materials, such as carbon fiber reinforced composite (CFC) structures which, in spite of their extreme lightness and strength, are particularly prone to certain types of structural defect. For safety reasons, the detection of such defects above a certain damage size is critical.

Classically, such components are frequently inspected ultrasonically, provided they can be immersed in a water bath or wetted with water. An ultrasonic transmitter and receiver are generally placed on either side of the test piece because the through-transmission of sound provides better sensitivity than can be obtained using reflection. This enables extremely fast, often automated inspection with very good resolution.

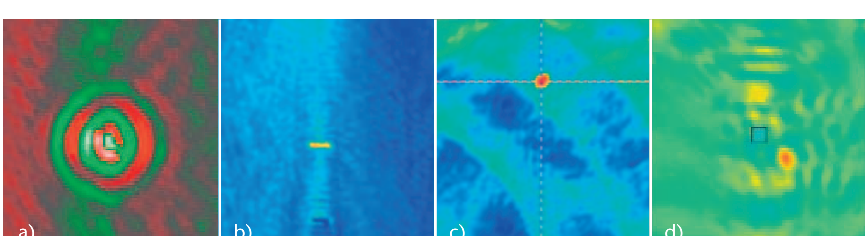
The Alternative: Lamb Wave Tests

A highly promising alternative for test pieces and applications where this approach is not possible, is to investigate the propagation of Lamb waves in the material using laser vibrometry. Lamb waves are vibration waves in plate-like structures that propagate as both bending and compression waves. The propagation is influenced by irregularities of the structure. Lamb wave methods may be used to determine impacts, cracks, delaminations and also adhesion defects in composite structures (Fig.1), possibly even micro-cracks and porosity.

Please read on to learn about Investigations performed at the Helmut Schmidt University at Hamburg (pages 6/7) and about a laser ultrasonic scanning system developed at the Korea Advanced Institute of Science and Technology (pages 8/9). A further potential area of use is in the design of piezo-sensor networks, which are integrated into the component so that material defects can be monitored during operation (see article by T. Windisch et al., InFocus 1/2011). Fundamental research is a further application area for Lamb wave measurements in that, for example, material parameters in anisotropic composite materials can be investigated.

Summary and Prospects

As discussed above, classical ultrasonic inspection carried out in a water bath, where applicable, is generally more accurate, faster and easier to implement. Nevertheless, the Lamb wave method has impressed many customers and users of laser vibrometry due to the nature of this contact-free, elegant measuring technique and its possible use on components which cannot be inspected with classical water-coupled ultrasonic testing, or for on-site inspection of components. Aids have not been developed yet for the automatic identification of defects. A 1-D scanning vibrometer is often sufficient for inspections aimed to simply display defects at the manufacturer's site. For fundamental, detailed research into wave propagation, the PSV-400-3D comes into its own.



Please download the full article as Polytec Application Note VIB-G-23 on **www.polytec.com/applications.**

Fig.1: Wavefield images of various structural defects:
a) impact b) cracks
c) delaminations d) adhesion defect

Hidden Defects Revealed

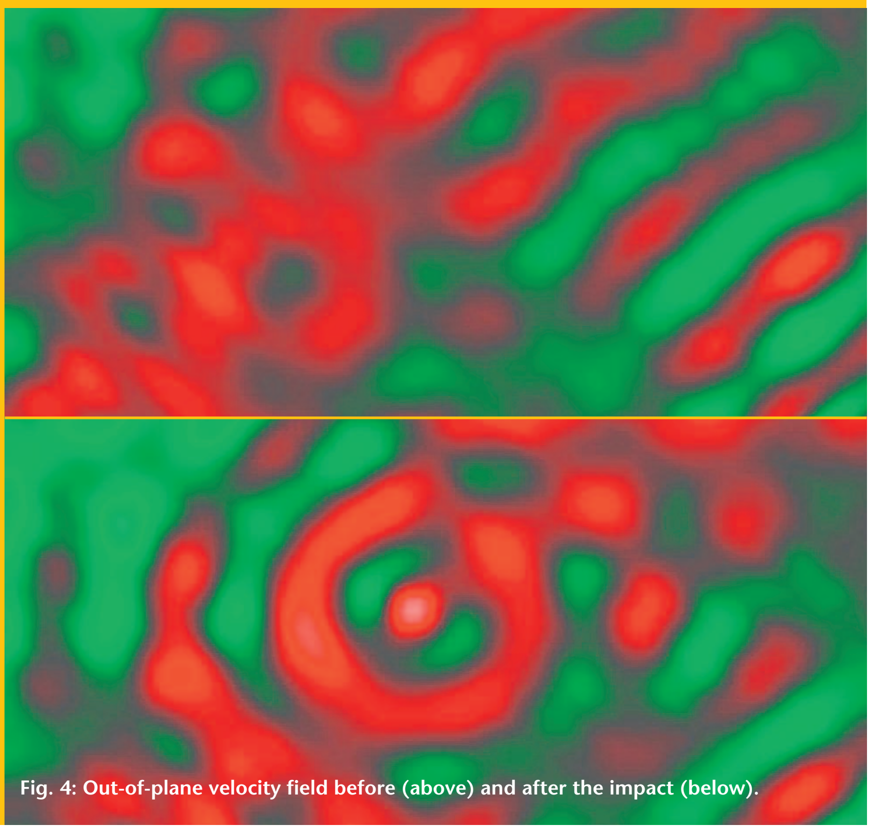


Fig. 4: Out-of-plane velocity field before (above) and after the impact (below).

Scanning Laser Vibrometry for Structural Health Monitoring using Ultrasonic Surface Waves

Structural damage in components is often invisible from the outside. However, ultrasonic waves can be used for Structural Health Monitoring. The propagation of waves and their interaction with defects can be measured and displayed in a contactless, full-surface, high-precision manner using scanning laser vibrometry.

Lamb Waves for Identification of Defects in Fiber-reinforced Composites

In the past, thin-walled, load-bearing components were made almost exclusively of metal sheets, but are today increasingly being made of carbon fiber reinforced plastic panels (CFRP). In those structures, waves propagate as flexural waves and compression waves within the plate. Fig. 1 shows a cross-section through groups of flexural and compression waves in aluminum (actual measured data).

Regardless of whether a material defect or structural damage is located on an inaccessible face or in the middle of the material, a wave, which can be monitored from the accessible face, interacts with it and thus its behavior is changed.

This monitoring can can be easily and effectively achieved using scanning laser vibrometry. Furthermore, current vibration amplitudes in the high tens of nanometer range, and excitation frequencies up to several hundred kilohertz can be achieved without difficulty.

Lamb wave theory assumes ideal elasticity, homogeneity, and isotropy. A good approximation to ideal elasticity can be assumed (in the technically relevant frequency range) for fiber-plastic composites based on thermoset matrix materials. This simplification cannot be made for materials with greater internal damping. By definition, homogeneity is as inapplicable to fiber composites as isotropy. The anisotropy of the elasticity parameters leads to deviations from the otherwise circular shape of the wave fronts.

Besides analytical approaches, numerical calculation methods such as the finite element method quickly reach their limits in the prediction of the propagation and interaction behavior of waves. The realistic modeling of individual carbon fibers would be associated with unacceptably

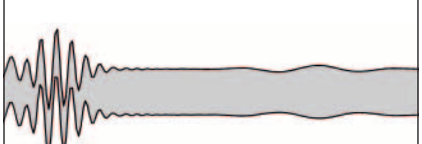
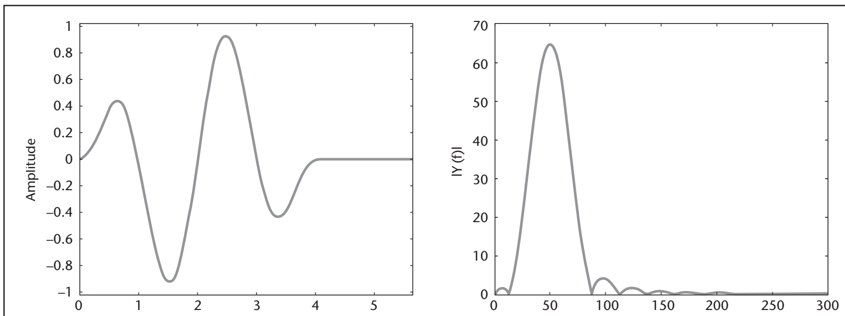


Fig. 1: Flexural and compression waves in aluminum sheet over 250 mm, true sheet thickness 1 mm, true vibration amplitudes less than 100 nm.

Fig. 2: Excitation signal in the time domain (left) and corresponding amplitude spectrum (right).



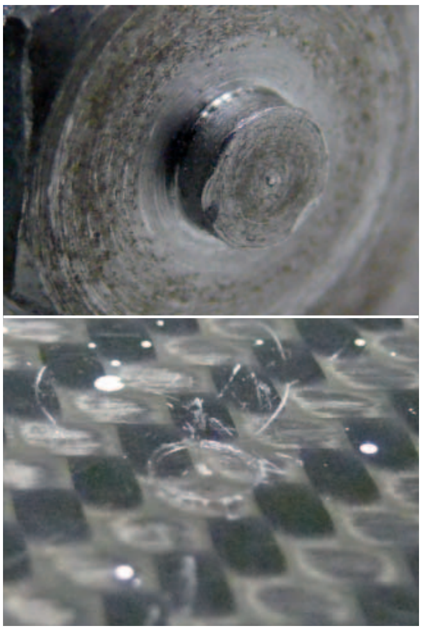


Fig. 3: Above: Front face of the drop hammer. Below: Impression after the 2.5 J impact.

high costs, however each simplification requires experimental validation of its acceptability. Therefore, measurements are essential for modelling the propagation of Lamb waves.

Experimental Detection of Structural Damage Caused by Wave Interaction

Structural damage and material errors are frequently indistinguishable. An important example is impact damage to CFRP structures, which often manifests as delamination, i.e. detachment of individual laminate layers from each other.

3-D measurements are carried out on an undamaged, quasi-isotropically laminated CFRP panel to obtain reference data. The excitation is provided by a sine-windowed burst signal

$$V = sin(\omega t) * sin(\frac{1}{4}\omega t)$$

of two cycles in length applied to a piezoceramic wafer, with the measurements taking place in the time domain. Fig. 2 shows the signal and its amplitude spectrum. Application of the window reduces the unwanted secondary maxima in the spectrum. The experiment is then repeated for different excitation frequencies.

Initially, a group of compression waves passes through the observation area, subsequently, because of the lower phase velocity, a group of flexural waves.

To cause an area of impact damage, a drop hammer with a kinetic energy of 2.5 J and a circular impact area of 12.5 mm^2 (fig. 3, above) strikes the rear side of the panel. This results in an impression on the surface of 0.05 mm in depth (fig. 3, below).

The measurements were repeated under the same conditions after the damage. Fig. 4 (page 6) shows a snapshot of the out-of-plane velocity field in the observation area before (above) and after (below) the impact event. By way of example, a 50 kHz excitation was used here.

In the snapshot, the defect is faintly identifiable due to the circular secondary waves. The difference between the two data records is imaged using the signal processor (software option PSV 8.7 or higher) or via MATLAB. Fig. 5 shows, at the top, only the out-of-plane components; at center, only the in-plane components; and, at the bottom, all the vibration directions simultaneously.

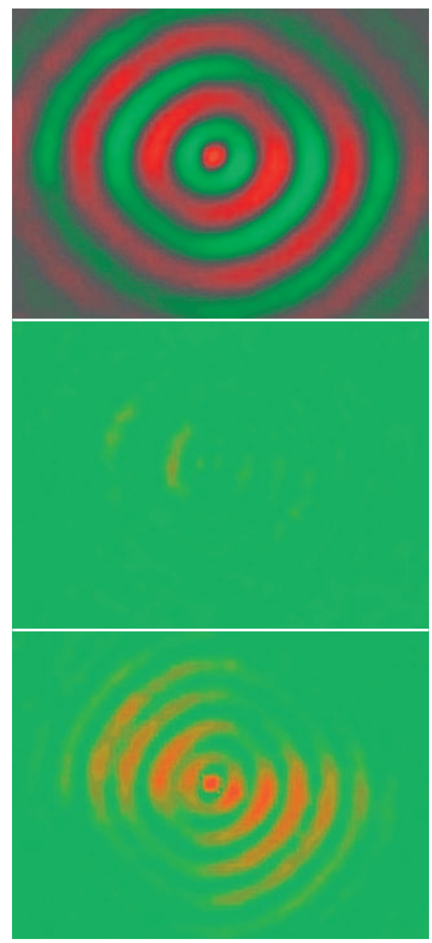
The difference data give a clear indication of the position of the structural damage. Here also it is clearly apparent that out-of-plane vibrations give much clearer results than in-plane vibrations.

Concluding Observations

The observation of Lamb wave propagation using scanning laser vibrometry is a promising tool for damage detection in panel structures. The measurements allow the observation of both compression and flexural waves. The propagation of the entire wave field is made visible, thus permitting conclusions to be made about the structural properties. Systematic errors, which always arise using 1-D measuring technology, can be avoided using 3-D measuring technology and allow for more precise results to be obtained.

Defects are visualized as distortions in the wave field, primarily in the form of secondary waves created from mode conversion. Therefore, using this method, defects can be detected in samples where it would not be possible to detect them using conventional ultrasonic testing or where it would only be possible with considerable extra expense and complexity.

Fig. 5: Difference data (Above: out-of-plane, Center: in-plane, Below: all components).



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Laser Ultrasonic Scanning for Structural Damage Diagnosis

Creation of Ultrasonic Wavefield Images with High Spatial and Temporal Resolutions

This article presents a laser ultrasonic scanning system developed by a research team from the Korea Advanced Institute of Science and Technology (KAIST) and its applications to damage detection and impact localization using Polytec's PSV-400 Scanning Vibrometer.

Fig. 1: The ultrasonic scanning system developed by the KAIST research team.

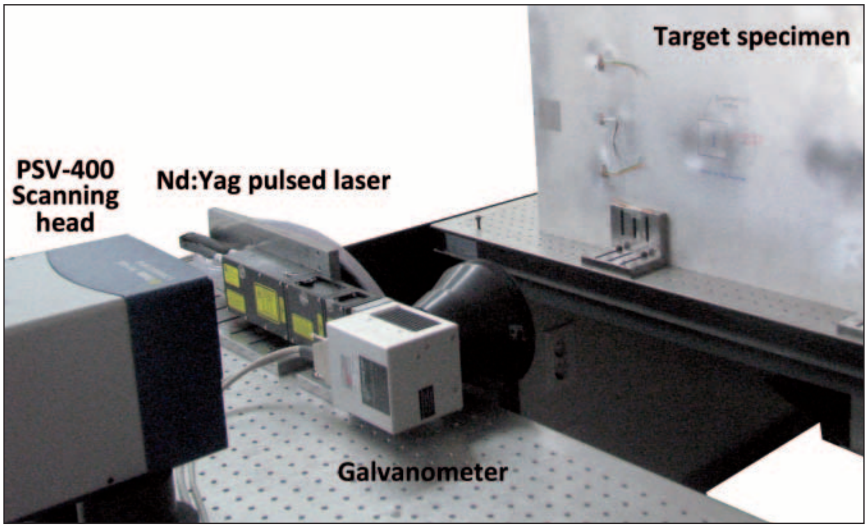


Fig. 3: Multi-layer composite panel provide by The Boeing Company.

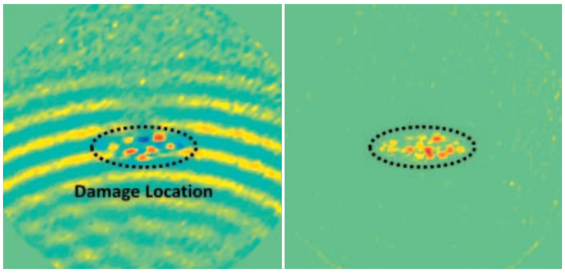


Fig. 4: Delamination detection using the measured wavefield image (left) and additional image processing (right).

The system is composed of a Nd:YAG laser for ultrasonic excitation, a laser Doppler vibrometer for ultrasonic sensing, and galvanometers for scanning. By scanning the excitation laser beam or the sensing laser beam (or both simultaneously), ultrasonic wavefield images can be generated and processed on a target surface to identify and locate defects such as delaminations in composite specimens or cracks in metallic structures. This scanning system can also be used for obtaining training data sets needed for locating impact events within a target structure. This system has a broad range of potential applications because it is able to create ultrasonic wavefield images with high spatial and temporal resolutions without the need for placing transducers on a target structure.

Development of the Laser Ultrasonic Scanning System

Fig. 1 shows the new system developed by the KAIST research group. An ultrasonic wavefield image can be produced by aiming the excitation laser at a fixed point on a target structure and scanning the sensing laser over the target area (Fig. 2a). A reciprocal wavefield image can also be obtained by fixing the sensing laser beam on a single point and moving the excitation laser over the target scanning area (Fig. 2b). Furthermore, the scanning system can be used together with built-in ultrasonic transducers (Fig. 2c) [1].

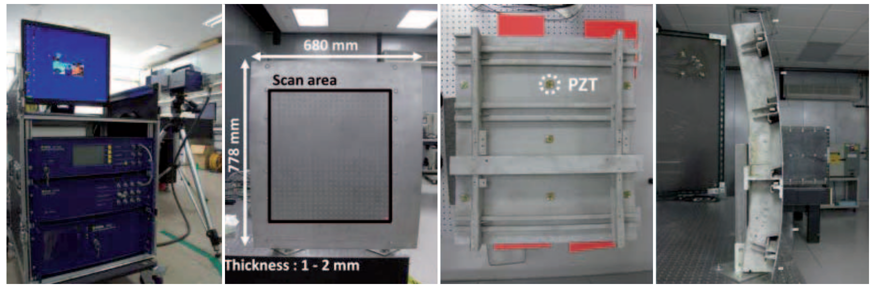
Non-Contact Delamination Detection

This laser ultrasonic scanning system is employed to detect hidden delamination in a multi-layer composite panel provided by The Boeing Company as shown in fig. 3. When propagating ultrasonic waves encounter an internal delamination, they are reflected and scattered in the vicinity of the delamination as shown in fig. 4, left. A standing wave filter was developed by the KAIST research group to further accentuate the effect of the delamination as shown in fig. 4, right [2].

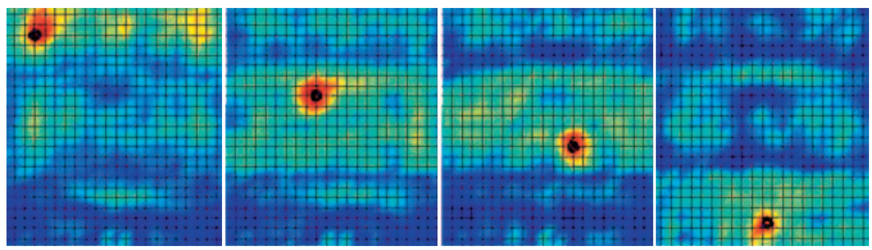
Laser Ultrasonic Training for Impact Localization

Next, the scanning system is used to pinpoint the location of an impact event within an actual aluminum aircraft fuselage segment provided by the Air Force Research Laboratory in Dayton, Ohio (fig. 5) [3]. The curved test segment has two vertical ribs and three horizontal stiffeners, adding further complexities to the specimen. Seven PZT transducers are mounted on the inside surface of the fuselage. First, an impulse response function (IRF) between an impact location and a PZT transducer is approximated by exciting the sensor and measuring the response at the impact location using the PSV-400. Then, training IRFs are assembled by repeating this process for various potential impact locations and PZT transducers.

Once an actual impact event occurs, the impact response is recorded and compared with the training IRFs. Finally, the training IRF that gives the maximum correlation is chosen from the training data set, and the impact location is identified. The correlation maps in fig. 6 demonstrate that the impact events are successfully identified in spite of the complexity of the specimen.



(a) PSV-400 (b) Front view (c) Rear view (d) Side view
Fig. 5: An aluminum fuselage for impact localization tests.



(a) Test 1 (b) Test 2 (c) Test 3 (d) Test 4
Fig. 6: Impact localization results obtained from actual impact events. Red: likely impact locations; black: actual impact locations.

Conclusion

The newly developed laser ultrasonic scanning system is advantageous for damage diagnosis because no transducers need to be placed on a target structure and damage can be automatically detected without using any baseline data. By relaxing the dependency on previous baseline data, the proposed technique can minimize false alarms due to changing temperature and loading conditions. In addition, the scanning system is used to simplify the training process often required for impact localization.

Acknowledgements

This research was supported by the National Research Laboratory Program (2010-0017456) of the National Research Foundation of Korea and the U.S. Air Force Research Laboratory at Dayton, Ohio. The author would also like to thank The Boeing Company.

References

1. Sohn H., Dutta D., Yang J. Y., Park H. J., Desimo M. P., Olson S. E. and Swenson E. D. “Delamination detection in composites through guided wave field image processing,” accepted for Compos. Sci. Technol.
2. Sohn H., Dutta D., Yang J. Y. , Desimo M. P., Olson S. E. and Swenson E. D. (2011), “Automated detection of delamination and disbond from wavefield images obtained using a scanning laser vibrometer,” Smart Mat. Struc., 20, 040517.
3. Sohn H., Desimo M. P., Olson S. E., Brown K. and Derriso M. (2011), “Impact localization in an aircraft fuselage using laser based time reversal,” Proceedings of SPIE, 79841G.

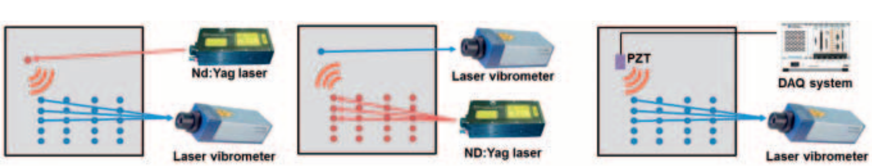


Fig. 2: Three different scanning schemes: (a) fixed-point excitation and sensing scanning, (b) fixed-point sensing and excitation scanning, and (c) surface-mounted PZT excitation and sensing scanning.

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RSV-150 Remote Sensing Vibrometer – The Acid Test

The 110 year-old Müngsten bridge near Solingen, the highest railroad bridge in Germany, was the site of intensive measurements undertaken by German railways operator Deutsche Bahn (DB) alongside Polytec in September 2010.

DB's Bridge Measuring Group in Magdeburg is responsible for the condition assessment of their railroad bridges. Laser vibrometers have proven for many years to be the method of choice for measuring structural displacements required for this purpose. However in September 2010, the Bridge Measuring Group encountered an especially difficult challenge. The Müngsten Bridge near Solingen, at 107 meters high, became the site of the latest measurement-based condition assessment.

During the measurements in September (fig. 1), a prototype of the new RSV-150 Remote Sensing Vibrometer, which was specially developed for measurements over long distances, was used alongside the OFV-505 vibrometer measurement heads. The vibrometers were used to measure the lowering of the crown as well as the horizontal buttress head displacement. The RSV-150 was used to measure this displacement and the bridge abutment was used as a fixed reference point.

To be able to measure the horizontal movement of the buttress head under load at over 135 m, the Bridge Measuring Group attached a projecting structure with a reflector to it in order to ensure optical visibility. Already installed was an OFV 505/-5000 vibrometer measuring system (fig. 2), which the Bridge Measuring Group of Deutsche Bahn has successfully used for

Fig. 2: OFV-505 used for bridge measurements.

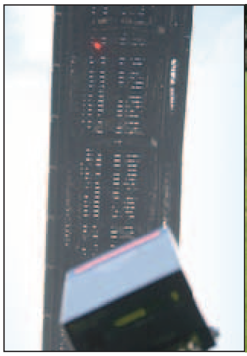

Fig. 1: The Bridge Measuring Group's measurement set-up.

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several years. To provide mechanical excitation, three diesel locomotives coupled together as a unit (approximately 240 tonnes of moving weight) were driven over the bridge with and without braking.

The displacement measurements had to be carried out under these conditions with the maximum possible accuracy. In a direct comparison between the two systems, the RSV-150 Remote Sensing Vibrometer was able to play to its strengths. Even at large distances and with unfavorable weather conditions such as rain and mist (fig. 3), the measurement results were still reliable. In contrast, operation of the OFV-505 required an experienced technician to take a critical look at the measurement results to determine if the system was still within its range of use.

In view of the adverse conditions, the conclusion of the Bridge Measuring Group was: "If we hadn't had your (RSV) system, we would not have been able to measure the buttress head so accurately."

Based on this positive experience the Measuring Group has purchased two RSV-150 systems. Thus, the Deutsche Bahn "Track Measurement Centre" now has the latest most advanced laser optical kit for its measurements and will use it to maintain the safety of rail traffic.

More Info: **www.polytec.com/rsv**

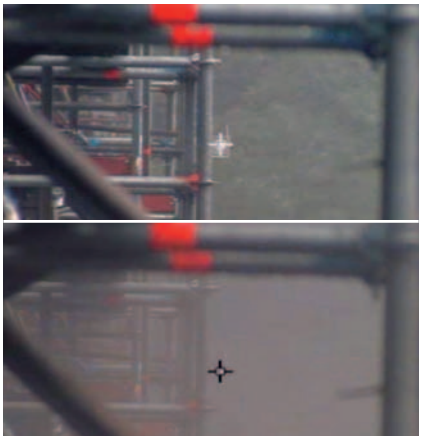

fig. 3: The measurement point for the OFV-505 and RSV-150 in good (above) and poor visibility (below).

Apology: In the InFocus issue of 1/2011 we provisionally reported about the September 2010 measurements and at that time wrote "The results led to the bridge being closed to rail traffic, however in the coming five years it should be completely restored." This statement does not accurately reflect the facts and is consequently revoked.

RSV-150 Remote Sensing Vibrometer

Remote Detection of Vibrations on Large and Distant Structures

Vibration and displacements on structures, machine parts and buildings can now be detected quickly and effortlessly even over long distances. The RSV-150 is designed for condition monitoring and testing of dynamics of structures from a remote distance with a simple point-and-shoot operation. Its advanced laser Doppler interferometer technology saves time by avoiding contact sensor installations and it's ready-to-use for trouble shooting for any vibrational issue.

The Complete Solution

The RSV-150 from Polytec provides a full solution for vibrational analysis: An interferometric optical sensor equipped with long range lens and an in-line video camera for targeting. A green targeting laser allows precise targeting on short and medium distances. The image of the video camera shows precisely the measurement spot at any distance. The RSV-150 is shipped with a rigid tripod system featuring coarse adjustment with a 3-way geared head and additional fine adjustment for precise targeting on remote objects. The controller converts the sensor signals into a voltage output for velocity and displacement that can be used with any data acquisition system or data logger.

Benefits

- High range >100 m depending on the surface reflectivity and the amplitude – allows for remote access to hazardous areas, e.g. explosion hazard or electric hazard for high-voltage electrical power supply components
- µm resolution – reveals also slightest displacements
- True 0 Hz capabilities with mHz resolution – low frequency response and displacement measurements on civil structures
- Wide bandwidth up to 25 kHz – enables condition monitoring e.g. of gearboxes
- Class 2 laser – safe operation without laser safety restrictions
- Easy setup in minutes and point-and-shoot operation – no cabling or measurement point preparation
- Works for nearly all surface properties – even on encrusted and dirty locations and also on hot surfaces like furnaces, pipes etc.

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Condition-based Maintenance in Open Cast Mining

Fig. 2: Support roller.

Fig. 3: RSV-150 Remote Sensing Vibrometer.

Non-contact and Cost-effective Monitoring and Differentiation Between Good/bad Support Rollers on Conveyor Belts in Open Brown Coal Cast Mining

Worth its Weight in Coal!

Brown coal is a source of energy that is important for the security of energy supplies, is available worldwide and is a relatively cheap source of energy because it is extracted in open cast mining. However, open cast mining is very capital-intensive so it is of primary importance for the conveyor belts to be constantly available if production is to be organized cost-effectively. Preventive maintenance is therefore a key task in open cast mining operations.

The dimensions of an open cast mine are enormous. The mine stretches over an area of 5 x 5 km². The seam of coal is about 60 m thick and is up to approx. 400 m below the surface, meaning the overlying rock has to be dug away first. This means that conveyor belts are required as well as bucket-wheel excavators to transport brown coal and excavated material in open cast mining.

The conveyor belts (fig. 1) have up to 12 MW driving power, are 2.8 m wide, typically 1.5 to 3 kilometers long, and move at speeds of e.g. 7.5 m/s. The belt is carried by support roller arrays that consist of 3 support rollers each. Monitoring this technology regularly is already challenging because of the dimensions and distances involved.

The Challenge of Monitoring the Condition of Equipment

Instead of a 100% measurement of all support rollers, the challenge of condition monitoring was to identify rollers with a single defect in areas where an increased noise level had been noticed or measured, but simple acoustic measurements would not be suitable to detect the array containing any support rollers with defective bearings. Therefore, the R&D department at RWE searched for a technology to be able to recognize defective bearings

Fig. 1: Conveyor belts for excavated material.

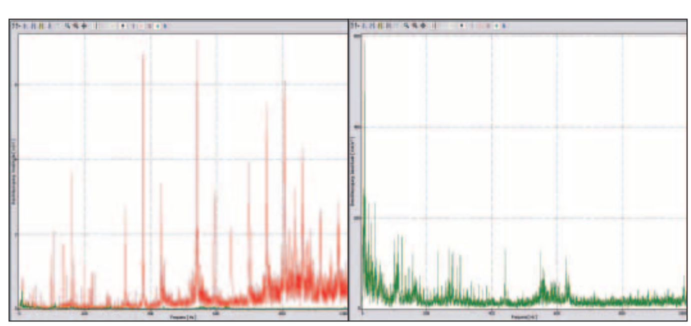

Fig. 5: Comparison of spectra of a defective bearing (red) and a good bearing (green).

on support rollers during operation (fig. 2) and to investigate their vibrational behavior over a broad frequency range.

The spectral signatures of good and defective bearings have already been ascertained in tests. Now all that is needed is reliable and fast measurement technology to acquire the spectra. The option of gluing on accelerometers, or attaching them with magnets would take too much time for every roller and the dirt on the rollers would mean that the measurement point would have to be cleaned every time. In addition to that, user safety needs to be taken into consideration. The support rollers are tight up against the conveyor belt moving at great speed and are thus in an area with a high risk of injury.

Non-contact Laser Vibration Measurement

A viable alternative is a non-contact process that can be used from a safe distance. The RSV-150 Remote Sensing Vibrometer (fig. 3) is perfectly suited for this task. This optical solution saves the installation time while simultaneously ensuring safety, as it is possible to make a measurement over several meters. In the application shown here, the stand-off distance was 5 to 7 m. The RSV-150 is a universal instrument for non-contact acquisition of surface and structural vibrations over large distances. Depending on the amplitude and the backscattering properties of the surface, the distance from the object can be between 5 m and 150 m. fig. 4 shows the target alignment in the video image.

Good/Bad Differentiation now Possible with no Trouble

The examinations with the RSV-150 Remote Sensing Vibrometer show the following:

- A support roller array containing at least one defective roller can clearly be distinguished from those consisting of only good rollers (fig. 5). The spectra are very different. Additional resonance peaks and their harmonics, caused by defective bearings, appear in the spectrum of the defective roller. As only the spectral frequencies are decisive and not the amplitudes, the alignment of the vibrometer is only of secondary importance. Furthermore, the study proved that during operation, even good support rollers show high-frequency resonances, probably caused by slipping sealings. These resonances were hard to hear due to the high frequencies, but caused a lot of trouble during the automatic evaluation of measurement results produced during a trial on a support roller test rig of RWE Power AG.
- Measurements can be made from both sides of the conveyor belt. The spectral signature of the defect is transmitted to the measurement point. The vibrometer is sensitive enough to measure both spectral characteristics.
- The vibrometer is not sensitive to ambient noise, in particular there is no cross-talk when making a measurement on a defective support roller array merging the characteristics into those of a good array across the framework.

The Efficient Solution Provided by RWE: the Mobile Sensor

The mission of the maintenance department of RWE Power AG was to perform test measurements at two conveyor belt systems with about 100 support roller arrays each. To save time, the sensor was attached to the 4 wheel drive vehicle (fig. 6) using a self-built sensor support based on a big suction cup. This means that a mobile measurement and evaluation center is available. The condition can already be evaluated on location (fig. 7). The mains power is supplied to the RSV-150 via the on-board supply system of the vehicle.

Optimization Options

The measurement rate between two support roller arrays is about a half minute if one roller is measured from each vehicle position respectively. However, it is also possible to measure three rollers in sequence from one vehicle position, as the amplitudes are not decisive for evaluating the damage. The decisive information on a defective roller is only provided by significant occurrence of resonances of defective bearings and their harmonics. The RSV-150 is sensitive enough to make measurements on rollers from different angles and distances without any impact on the signal quality being observed. This means that the measurement rate and thus also the efficiency can be increased.

More Info: **www.polytec.com/rsv**

Fig. 4: Measurement point with position of the laser beam in the video image of the RSV-150.

Fig. 6: Measurement technology in use on location.

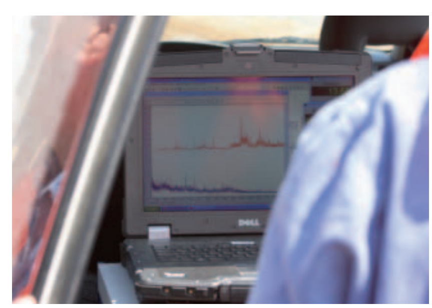

Fig. 7: Graphic representation of the results in the back of the vehicle.

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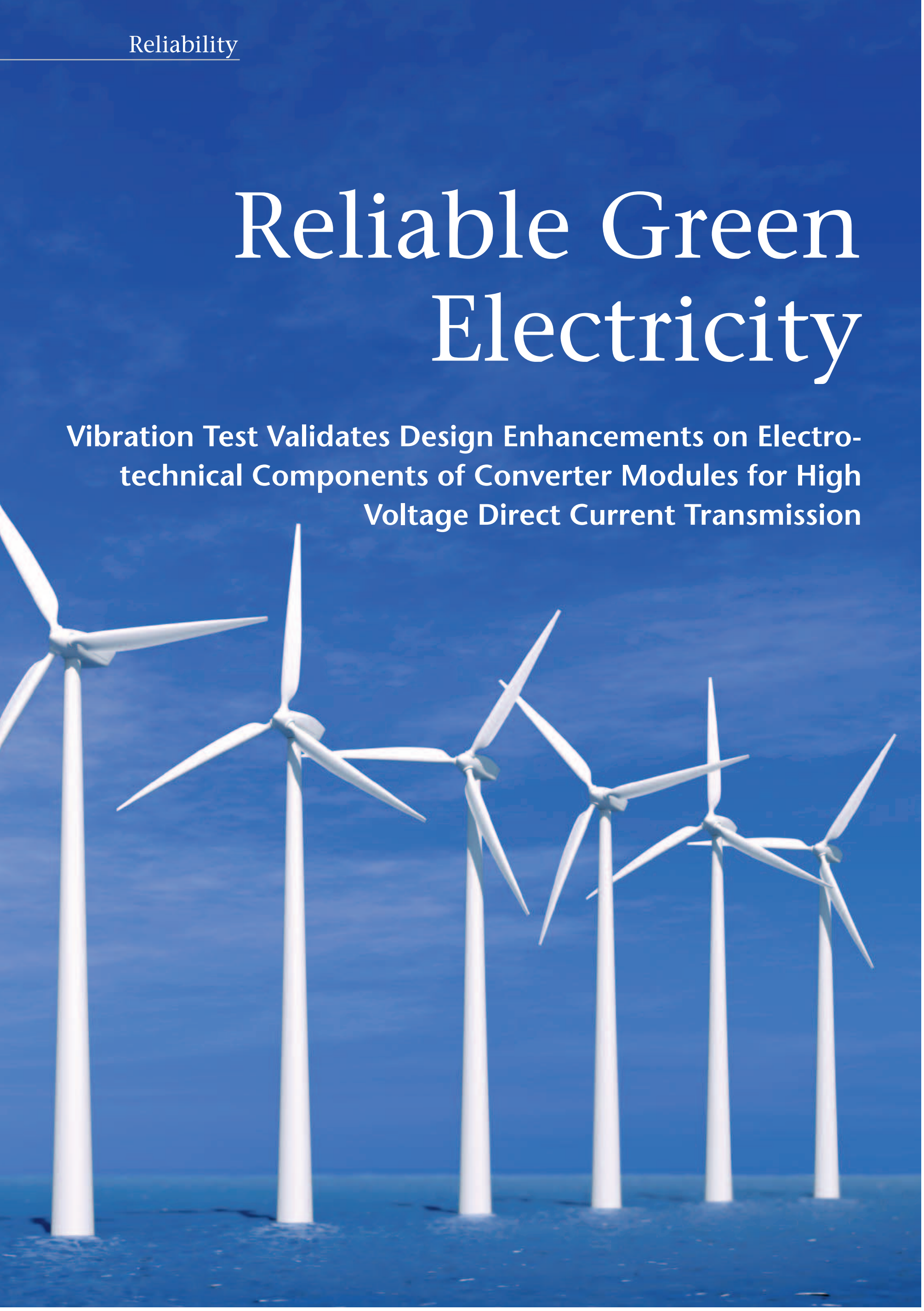

Reliable Green Electricity

Vibration Test Validates Design Enhancements on Electrotechnical Components of Converter Modules for High Voltage Direct Current Transmission

Introduction

Offshore wind farms, much like drilling platforms, are often more than 50 km off the coast. They are connected to the mainland grid over longer distances using high voltage direct current (DC) transmission systems. These systems and their components, supplied by Siemens Energy, must fulfill extreme demands with regard to reliability and provide a service life of more than 30 years. To achieve this, the electrical energy of numerous wind turbines is “collected” at sea in a local alternating current (AC) grid, then converted to DC using a rectifier, before being transported to land via sea cable. There it is again converted, via an inverter, into AC and fed into the high voltage grid. During operation, the technical systems are subjected to a wide range of stresses and strains. For example, mechanical vibrations in the converter structure arise from its rectification function. The electrical current produces mechanical forces which generate vibrations that could excite eigenmodes in the structure. An awareness of this condition is necessary in order to implement a design that will prevent component overload. The determination of the eigenmodes permits targeted design improvements, the success of which can then be practically verified, using vibration tests.

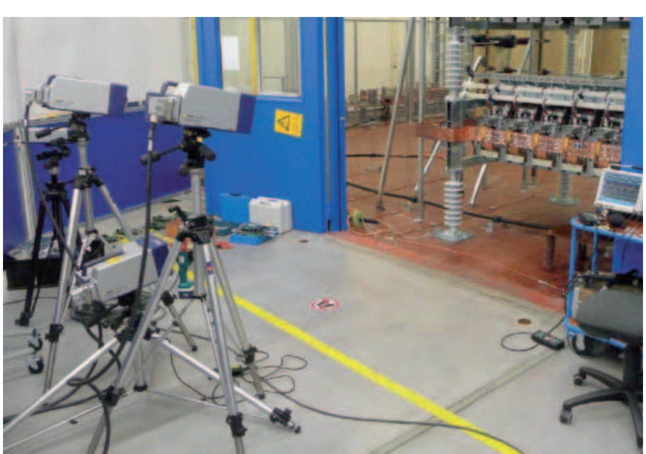

Fig.1: HVDC test facility, scan heads positioned in front.

Fig. 2: HVDC test facility, scan heads set-up for testing the rear side.

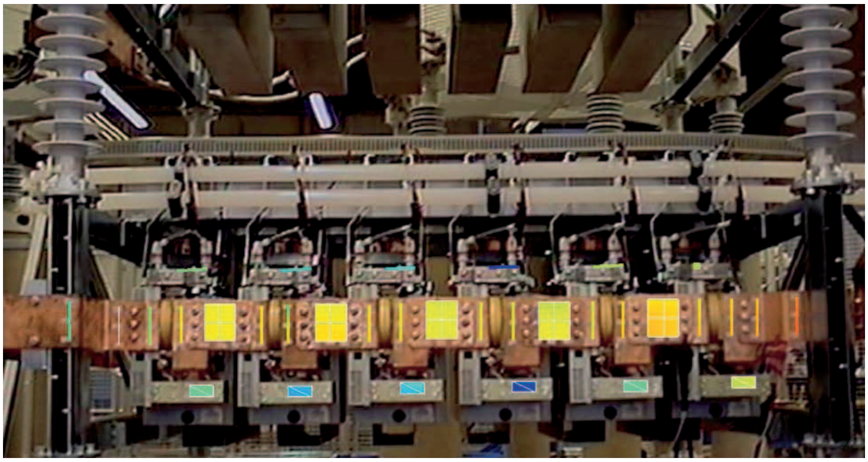

Fig. 3: Vibration modes on the semiconductor modules on the front of the converter.

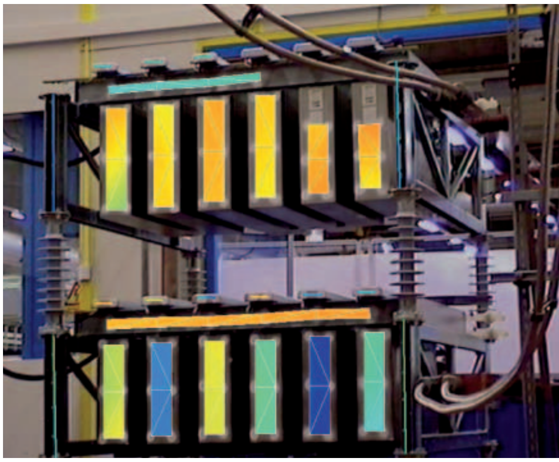

Fig. 4: Vibration modes of the converter measured on the rear side of the power capacitors.

Experimental Set-up

The vibrations occurring on a converter module during operation were measured using a PSV-400-3D Scanning Vibrometer. The module forms part of a test facility which is supplied from the national grid and functions as a "miniature model" with similar characteristics to the original. (fig. 1 and 2). Due to high voltages, much of the measurement instrumentation was set up outside the test area. Only the measuring heads were positioned inside, close to the module. An OFV-505/5000 Single-Point Vibrometer was used as a reference sensor, transmitting its output signal via BNC cable to the data management system (DMS). The reference signal enables subsequent stitching of data obtained from measurements taken from different directions.

Pre-tests

In a first test series, the vibration properties of selected components were investigated. Various positions on the mechanical structure were of interest. Loading spectra had to be determined for qualification prior to design and development.

The measurements took place at various levels up to full load and under many operating scenarios. In total, including setting up and determining the noise levels, some 20 measurements were carried out, each of which lasted 10 minutes. Each measurement comprised 52 measurement points with a frequency span of 800 Hz, a resolution of 1 Hz and 10 averages (complex measurements, i.e. both real and imaginary parts).

Validation Experiment

Additional measurements were made in order to validate vibration-optimized converter modules, comprising six power modules and their corresponding power capacitors. The entire block was initially measured from the front and in the original state under various current loads (fig. 3).

Further measurements were carried out, systematically exchanging various components. Later, additional measurements were performed on the rear side of the converter (fig. 4).

A major advantage was that data from both front and rear measurements could be subsequently combined, resulting in an overall visualization of the vibration characteristics of the entire system.

Conclusions and Outlook

The 3-D scanning vibrometer measurements rapidly provided eigenmode data over large areas of critical converter module components. The customer was highly satisfied with the measurement service provided and the system used, especially the PSV Software, due to its simple operation and visualization tools. Besides the improvement of the design aimed at preventing failure due to the operating frequencies, low frequency resonance vibrations in the Hz-range of the entire system can also be determined, which could, for example, be of importance in earthquake simulations. For this purpose a sufficiently large vibrating table or shaker can be controlled by the Polytec system interface, generating the frequencies required for measurement of complex motion spectra. The 3-D scanning vibrometer shown here can therefore sample the motion of the system and visualize the motion characteristics and areas where resonance may occur.

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Bringing Ultrasonic Fatigue to Light

High Frequency Stress and Strain Measurements During Ultrasonic Fatigue Testing with 3-D Scanning Vibrometry

In recent years piezoelectric ultrasonic facilities have been used more and more to investigate the fatigue behavior of high performance metals, e.g. titanium alloys or metal matrix composites (MMC) in the very high cycle fatigue regime. This innovative testing technique requires adequate tools for calibration and measurement such as 3-D scanning vibrometry, which offers a lot of advantages.

Fig. 1: Experimental setup for ultrasonic fatigue testing.

Motivation

Many modern engineered systems, such as heavily stressed motor parts or offshore structures, have to resist more than 10 million cycles due to either high frequency loading or a lifetime of up to more than 30 years. This cycle range is named the Very High Cycle Fatigue (VHCF) regime. For a reliable application of these high performance components, a detailed knowledge of the fatigue behavior of materials used in the VHCF regime becomes more and more important. Conventional testing facilities can only perform long duration tests at frequencies of up to 200 Hz.

The Ultrasonic Testing Facility

In order to realize for example 10^{10} cycles in short time periods, an innovative ultrasonic testing facility for tension-compression experiments was developed at the Institute of Materials Science and Engineering (WKK) at the University of Kaiserslautern in Germany. The loading principle of the testing system is based on a piezoelectric converter, which is designed to resonate fatigue specimens at a frequency of 20 kHz with a standing longitudinal wave that causes fatigue in the material. An eigenfrequency of 20 kHz is therefore an essential property of the specimen. Finite element analysis is used during the design process in order to ensure an adequate specimen design.

The 3-D scanning laser vibrometer promised to be an effective instrument to measure the eigenfrequencies and eigenmodes and verify our finite element model. Stress and strain evaluation using conventional techniques such as strain gages is quite difficult due to their tactile nature during high frequency oscillation. Therefore the potential of 3-D scanning laser vibrometry for high resolution non-contact stress and strain measurement during ultrasonic fatigue was evaluated.

Experimental Setup

A PSV-400-3D Scanning Vibrometer from Polytec was used for the experiments at the WKK. The positioning of the three laser heads, shown in fig. 1, was chosen to ensure accessibility to the tapered region of the fatigue specimen. Very low displacement amplitudes of 30 nm were selected for determining the eigenfrequency and eigenmodes, and to prevent unwanted fatigue damage of the material. The strain measurements were focused

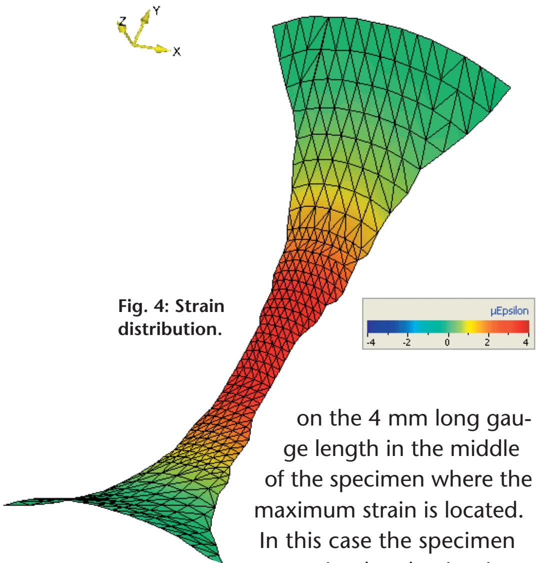

Fig. 4: Strain distribution.

on the 4 mm long gauge length in the middle of the specimen where the maximum strain is located. In this case the specimen was stimulated at its eigenfrequencies with high displacement amplitudes of up to 42 µm.

Selected Results

Correlation with the FE model was performed with specimens in their initial state (prior to fatigue). The frequency response (in fig. 2a) indicates an eigenfrequency of 20.06 kHz and the eigenmode at this frequency (top of fig. 3) shows the expected longitudinal oscillation. Both results fit very well to the calculated FE results. Furthermore, the detailed visualization of the high frequency oscillation confirms that the specimens are oscillating correctly for this investigation.

Similar investigations were carried out on a specimen that had been loaded with a stress amplitude of only 50% of the yield strength. In spite of this, fatigue failure occurred after 1.2 * 10^9 cycles due to interior fatigue damage. In comparison to the initial state, the eigenfrequencies reduced because of this subsurface fatigue damage. The eigenmodes in the range of 20 kHz also show clear differences (lower half of fig. 3). An asymmetric velocity distribution along the specimen and a considerable inhomogeneity in the area of the fatigue failure were observed.

Fig. 4 shows the strain distribution during the high frequency oscillation with a maximum in the middle of the specimen. The correlation between stress amplitude in the gauge length measured with the 3-D scanning system and displacement amplitude at the free end measured by Polytec´s CLV-2534-2 single-spot vibrometer shows an increase of stress amplitude with an increasing displacement amplitude. A comparison with the correlation based on the FE model shows a high degree of congruence (fig. 5).

Conclusion

The work presented here illustrates possible applications of 3-D scanning vibrometry in the field of ultrasonic fatigue testing of metals. The results of investigations of the eigenmodes of specimens with different fatigue states indicate the potential to characterize the current fatigue status and to locate fatigue failure. 3-D scanning vibrometry is capable of non-contact local strain measurement with a high spatial resolution and offers an alternative to strain gages for evaluation of high mechanical stresses along the gauge length during ultrasonic fatigue testing.

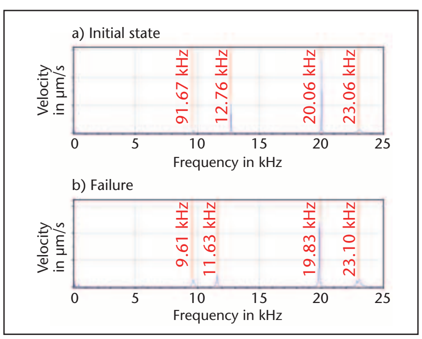

Fig. 2: Frequency response.
a) initial; b) after fatigue damage.

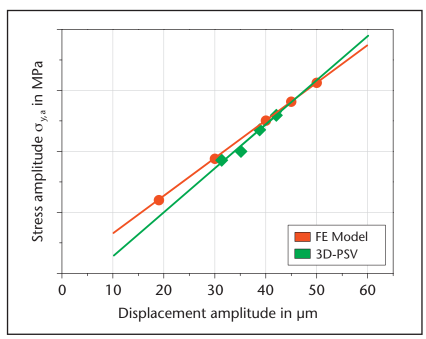

Fig. 5: Comparison of FE model and measurement.

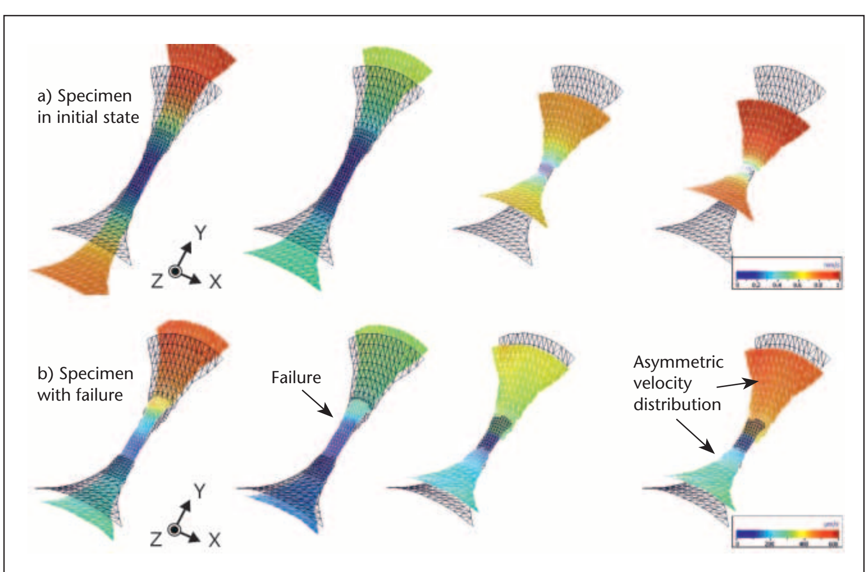

Fig. 3: Deflection shape; above: initial; below: after fatigue damage.

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Measuring with Lasers

Optimizing Valvetrain Dynamics at Porsche Engineering

Laser vibrometry has established a firm place in the automotive sector over the past few years. This non-contact process is used at Porsche Engineering to investigate and improve the dynamic behavior of valvetrains during engine development.

Valvetrain Design

Top performance with optimum fuel consumption requires a perfectly tuned engine. The valvetrain, at the foundation of such tunings, always has the potential for improvement. Heavy demands are placed on these components, particularly in the case of sports car engines, by offering the largest possible opening cross-section in combination with short valve opening periods at high rpm. It is for this reason that developers in this area are constantly striving to improve the properties of valvetrains.

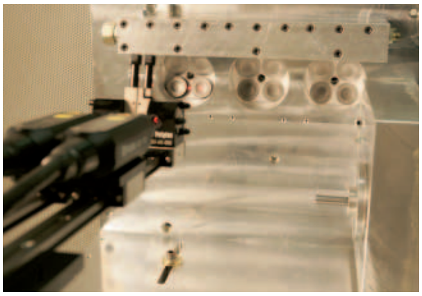

Fig. 1: View of the valves of the test sample, mounted to the cylinder head mock-up. In the foreground is the laser vibrometer.

Fig. 2: Pre-validation of a valvetrain layout on a single-valve test bench.

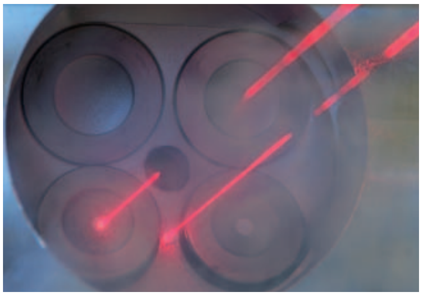

Fig. 3: Measurement and reference laser beams of the vibrometer.

A test bench (fig. 1) can be used during the early stages of development to ascertain whether or not the valvetrain can actually offer the characteristics indicated in a specification document, and whether it will be able to withstand the demands placed on it as a result. The engineers at Porsche Engineering use special lasers to examine valvetrain dynamics without physical contact and therefore no interference. This allows the behavior of the valve to be measured at different speeds. The title image reveals the measurement and reference beams using smoke.

Measurements on the Test Bench

To take measurements, the cylinder head is pressurized with oil just as in normal operation on a mock-up test bench (fig. 2). Oil temperature and expansion can be adjusted accordingly. These parameters are specified in an electronic database and are monitored.

A high-performance electric asynchronous motor drives the entire timing assembly and can be programmed to simulate actual operation.

The chain drive is replicated in full with all intermediate gears, guides and tensioning rails, including the chain tensioner. In this way valvetrain dynamics can be examined along with all the external influences and reactions, such as the chain drive polygon effect, damping influence of the hydraulic chain tensioner, and variable camshaft moments.

Before taking measurements, the laser beam is positioned to strike the valve head perpendicularly. A second laser beam is positioned as a reference beam parallel to the first and adjacent to the valve seat. In fig. 3, both measurement and reference laser beams can be seen as they have been made visible by smoke. With the reference established, the relative movement between the two points is then measured and can therefore show the isolated movement of the valve without the influence of sprung mass. In this way, valve lift and valve speed can be recorded exactly.

Data Acquisition and Evaluation

Porsche Engineering uses a Polytec HSV-2002 High-Speed Vibrometer that was developed especially for measuring Formula 1 engines. It can record speeds of up to 30 m/s as well as displacements (strokes) up to 160 mm.

The data acquired are recorded and saved in a time-synchronous manner. The Rotec RAS system used by Porsche Engineering can record analog signals at a resolution of 16 bits and a sampling rate of 400 kHz. Speed signals up to a frequency of 1 MHz and a resolution of 40 bits can be recorded. An integrated software package enables rapid analysis of the data obtained (fig. 4).

Deploying this system enables Porsche to measure the effects of different cam contours, spring stiffnesses, spring progressions and valve drive masses, for example. The influence of these modifications can then be assessed by examining valve closure speeds (fig. 5) and valve accelerations and by calculating contact power processes and Hertzian stresses. Additionally, analyses of torsional vibrations can provide further information on operational behavior.

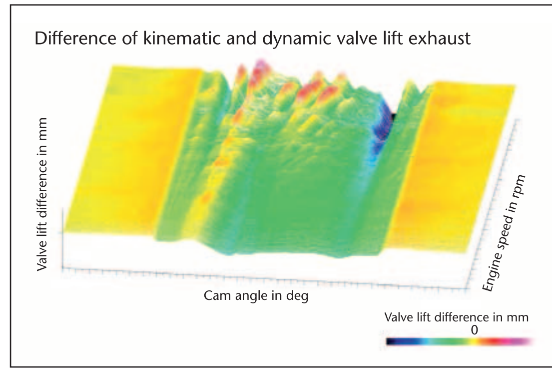

Fig. 4: Differences of kinematic and dynamic valve lift due to dynamic effects.

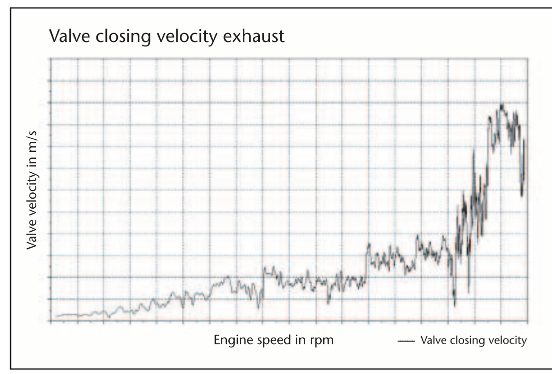

Fig. 5: Increasing valve closing velocity with rising engine speed.

Owing to increasingly complex valvetrains now being produced with ever shorter development periods, valvetrain analysis is gaining more and more significance. By using laser vibrometry at an early stage of development, Porsche Engineering is examining the valvetrain for kinematic properties, dynamics, and stress in the desired RPM range. The necessary valvetrain development modifications were targeted and evaluated on several projects through the use of laser vibrometry, and thus avoided costly and time-intensive development loops.

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Bad Vibrations

An Investigation of the 3-D Vibration Transmissibility on the Human Hand-Arm System Using a 3-D Scanning Laser Vibrometer

Introduction

Vibration transmissibility on the hand-arm system is very important in order to understand and simulate the biodynamic response of the system. Such knowledge can be further used to help understand vibration-induced discomforts, injuries, and disorders. Both conventional accelerometers (which, however, affect the results due to their mass) and single-axis laser vibrometers [1, 2, 3] have been used to measure the transmitted vibration. Further simulations of the system require multi-axis transfer functions. Therefore, the objective of this study is to investigate the vibration transmissibility on the human hand-arm system subjected to vibrations in three orthogonal directions (x_h, y_h, and z_h).

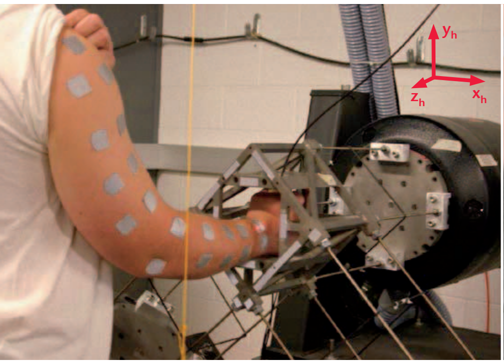

Fig. 1: 3-D hand-arm test system, together with the posture of a test subject.

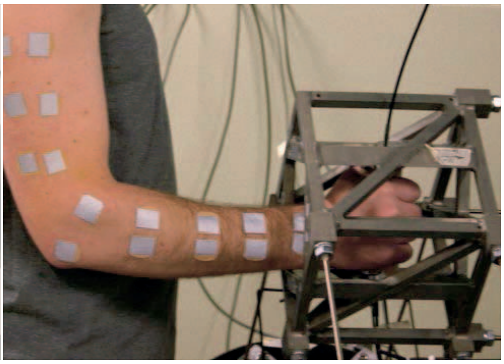

Fig. 2: Attachment of retro-reflective tape.

Method

Seven healthy male subjects participated in the study. As shown in fig. 1, the experiment was carried out on a novel 3-D vibration test system (MB Dynamics, 3-D Hand-Arm Test System). The z_h direction is along the forearm, y_h direction is along the centerline of the instrumented handle in the vertical direction and x_h direction is in the horizontal plane normal to y_h-z_h plane. Each subject was instructed to maintain grip and push forces at 30±5 N and 50±8 N, respectively, with his dominant right hand with elbow angle between 90° and 120°, and shoulder abduction between 0° and 30°.

The vibration controller was programmed to generate broadband random vibration in the frequency range of 16 – 500 Hz along each direction. The overall rms acceleration in each direction was 19.6 m/s^2. The coherence of the three axial spectra was taken as 0.9. The three-axis accelera-

Polytec

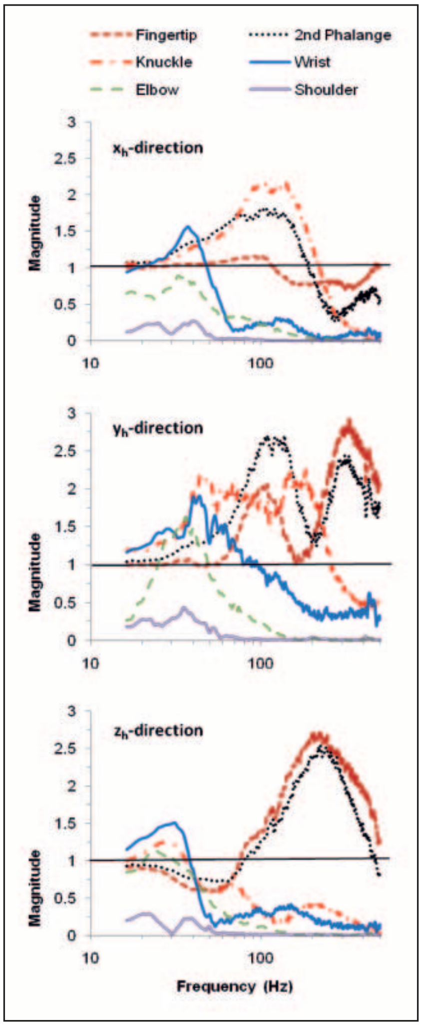

Fig. 3: Magnitudes of the tri-axial vibration transmissibility at the different locations.

tions on the handle were measured using a tri-axis accelerometer installed inside the handle, which provided the reference signals for deriving the vibration transfer functions in the three directions.

The vibration transmitted to the top surfaces of the major substructures of the system (fingers, back of the hand, wrist, forearm, upper arm, and shoulder) was measured using a Polytec PSV-400-3D Scanning Vibrometer. To avoid the effect of hairs and to obtain a good reflection, a piece of retro-reflective tape was attached to a piece of first-aid tape that was firmly attached to the skin of the hand-arm system at the desired measuring locations, as shown in fig. 2. Each transfer function was expressed in the frequency domain from 16 to 500 Hz, with an equal frequency interval of 0.5 Hz.

Preliminary Results and Discussions

The measured transmissibility functions varied greatly among the subjects but their basic distributions are similar and are demonstrated here using the data measured with one of the subjects. Fig. 3 shows the magnitudes of the tri-axial transmissibility, which is generally a function of frequency, measured at six important locations. The function varied greatly with the measurement location and vibration direction. There is at least one dominant peak or resonance in each transmissibility function. The dominant resonances at the wrist, elbow, and shoulder in the x_h- and y_h-directions were in a similar frequency range (30 to 50 Hz). In the z_h-direction, they were at marginally lower frequencies (20 to 40 Hz). The resonances on the fingers were at higher frequencies and they varied in a wide frequency range (80 to 400 Hz).

The resonances observed at the wrist, elbow, and shoulder were fairly consistent with the first resonance observed in the driving-point biodynamic response [4]. This suggests that the entire hand-arm system vibrates more or less in phase in this resonance frequency range and that this resonance primarily depends on the biodynamic properties of the palm-wrist-arm substructures. The major finger resonance was also well correlated to that observed in the corresponding driving-point response, suggesting that it primarily depends on the biodynamic properties of the fingers.

A reported study [5] found that the frequency dependence of the vibration power absorption density (VPAD) of a finger is similar to that of the vibration transmissibility at frequencies higher than the first resonance of the hand-arm system. While the finger VPAD may be a good measure of the finger vibration exposure, the finger resonances observed in this study suggest that the frequency weighting defined in the current standard (ISO 5349-1, 2001 [6]) is unlikely to be suitable for assessing the risk of the finger vibration injuries and disorders.

References

1. Sörensson, A., and Lundström, R., 1992. Transmission of vibration to the hand, Journal of Low Frequency Noise and Vibration 11: 14-22.
2. Deboli, R., Miccoli, G., and Rossi, G.L., 1999. Human hand-transmitted vibration measurements on pedestrian controlled tractor operators by a laser scanning vibrometer, Ergonomics 42 (6): 880–888.
3. Concettoni, E. and Griffin, M., 2009. The apparent mass and mechanical impedance of the hand and the transmission of vibration to the fingers, hand, and arm. Journal of Sound and Vibration 325(3), 664-678.
4. Dong, R.G., Welcome, D.E., Xu X.S, Warren C., McDowell T.W., and Wu J.Z., 2011. 3-D Mechanical Impedances Distributed at the Fingers and Palm of the Hand. Proceedings of the 12th International Conference on Hand-Arm Vibration, Ottawa, Ontario, Canada.
5. Wu, J.Z., Dong, R.G., Welcome, D.E., and Xu, S.X., 2010. A method for analyzing vibration power absorption density in human fingertip. Journal of Sound and Vibration. 329:5600-5614.
6. ISO 5349-1, 2001: Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 1: General requirements. International Organization for Standardization, Geneva, Switzerland.

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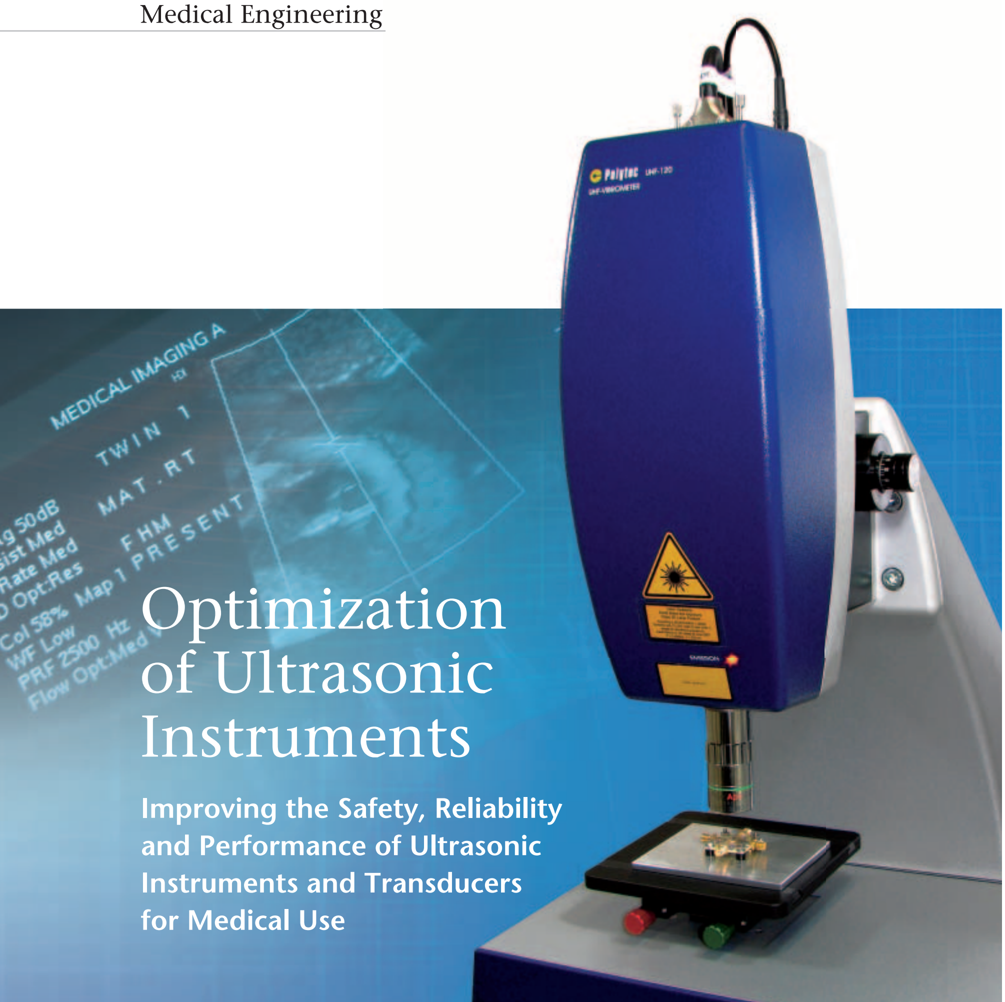
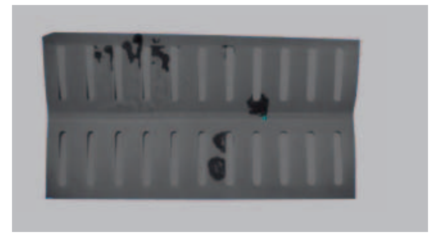


Optimization of Ultrasonic Instruments

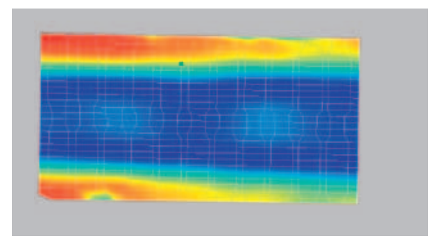
Improving the Safety, Reliability and Performance of Ultrasonic Instruments and Transducers for Medical Use

Ultrasonic imaging methods have been in use for many decades and are now an indispensable standard diagnostic tool in hospitals and in almost all doctors' practices and medical clinics. The next step is the use of ultrasound-supported or ultrasonics-based instruments in the operating theater and during outpatient treatment.

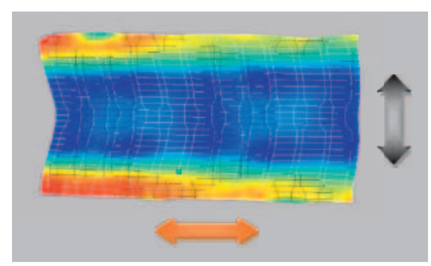
Example: Ultrasonic Knife



Blade of an ultrasonic knife.



RMS distribution (effective amplitude values) of the vibration after measurement with the 3-D Scanning Vibrometer.



Deflection shape at 22.4 kHz. The motion is almost entirely in the direction of the orange arrow, perpendicular to the cutting direction (gray).

The Aim: Verifiably Safer Design and Performance Optimization of Medical Ultrasonic Instruments

Two different applications can be distinguished from one another

1. Invasive instruments providing direct mechanical contact
2. Instruments with an indirect mode of action focusing ultrasound energy for either imaging or treatment of a condition

The first group includes ultrasonic scalpels, coagulators, aspirators and instruments for intravenous thrombus removal, liposuction and dental plaque removal. Common to all of them is that they come into direct contact with the tissue. If an instrument fails, for example due to fatigue, instrument fragments or detritus can remain inside the patient and cause acute or long-term injury. This must be absolutely avoided by the correct design and application of the instrument.

The second group includes instruments for shock wave therapy and for the application of focused ultrasound energy (HIFU). Here the site of the generation of the ultrasonic energy and its intended effect are spatially separated from each other. Efficiency and spatial precision play a greater role. The risk due to mechanical failure of the ultrasound generator is much smaller.

Use of Laser Doppler Vibrometers

The following properties of laser-based vibration measurement are highly advantageous regarding the development of ultrasonic instruments in medicine:

- Complete freedom from the effects of contact feedback: The vibration of the test object is not influenced by the measuring instrument.
- High spatial resolution: Due to the high frequencies and often filigree-type structures, it must be possible to precisely spatially resolve deflection shapes in measurements. For example, the laser, with its few µm diameter beam is able to measure thin cuts or wires.

- The possibility to measure in transparent media, for example when considering the influence of damping.
- The ability to measure high frequencies: In principle there is no frequency limitation. Currently the highest mechanical vibration frequency that can be measured is 1.2 GHz.

Instruments

Depending on the application, various measuring instruments are available. Single-point vibrometers permit measurement of the amplitude at one point and are used in the verification of specified characteristics (amplitude, frequency). They vary in terms of bandwidth and the direction of the measurement (in-plane, out-of-plane or all three components, 3-D).

Scanning vibrometers are used to measure complete deflection shapes dependent on the frequency. Due to the surface-based measurement principle, the data obtained are suitable for the validation of FE calculations. Out-of-plane systems (PSV-400) and three-dimensional measuring systems are available for this purpose, and their measurement data can also be used to calculate the dynamic stress and strain distributions.

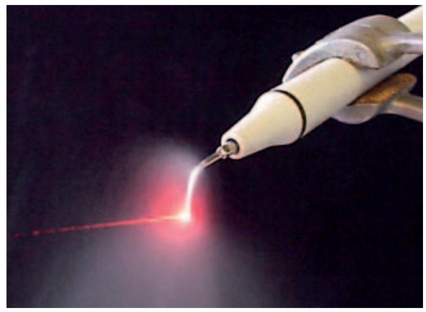
Summary

Laser vibrometry is ideally suited as a tool for the verification of FE simulations both for invasive and diagnostic medical ultrasonics instruments. Thanks to its linearity well into the high MHz range and the complete lack of feedback effects, coupled with high lateral resolution, this technology is suitable for nearly all structural dynamic tasks. Calculation methods derived from the basic technology for sound field visualization and for fatigue strength (strain/stress) add further applications.

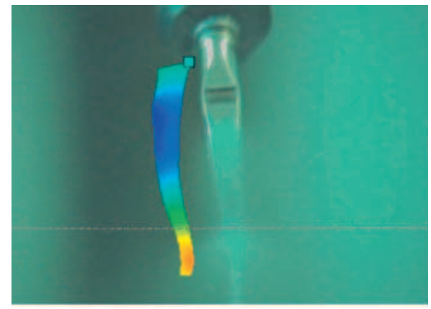
Consequently laser Doppler vibrometry is a tool suited to the development of efficient, reliable and effective instruments for the doctor and surgeon.

Please download the full article as Polytec Application Note VIB-U-01 on **www.polytec.com/applications.**

Example: Dental Scaler Instrument

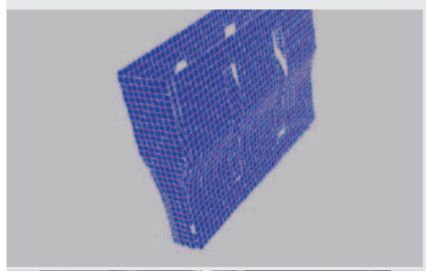


The laser of the scanning vibrometer measures the surface of a dental ultrasonic scaler.



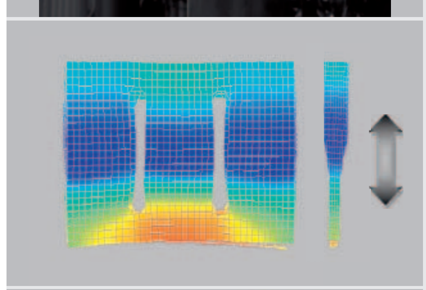
Snapshot of the 3-D animation, together with the video image of the scaler tip.

Method Toolbox: Integration of 3-D Measurement Grids

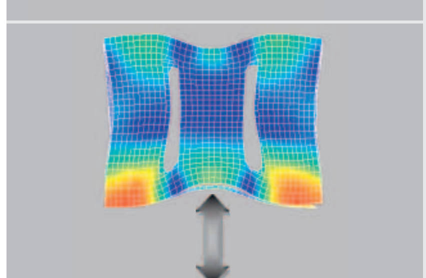


The measurement mesh of an ultrasonic tool tip in this case is determined by precise geometry measurement using triangulation of the three PSV-3D laser beams.

Alternatively the mesh can be imported from the FE program into the measuring system and then aligned with the measurement object using a number of reference points.



Example of a desired deflection shape: The deflection shape measured at 20 kHz largely corresponds to the vibration necessary for the desired process (arrow direction). The movement is fairly uniform over the whole length of the active surface.



Example of an undesired deflection shape: At a somewhat higher frequency, another mode occurs in the foreground, which superimposes a bending eigenmode on the active movement. This means that unsatisfactory results can be expected.

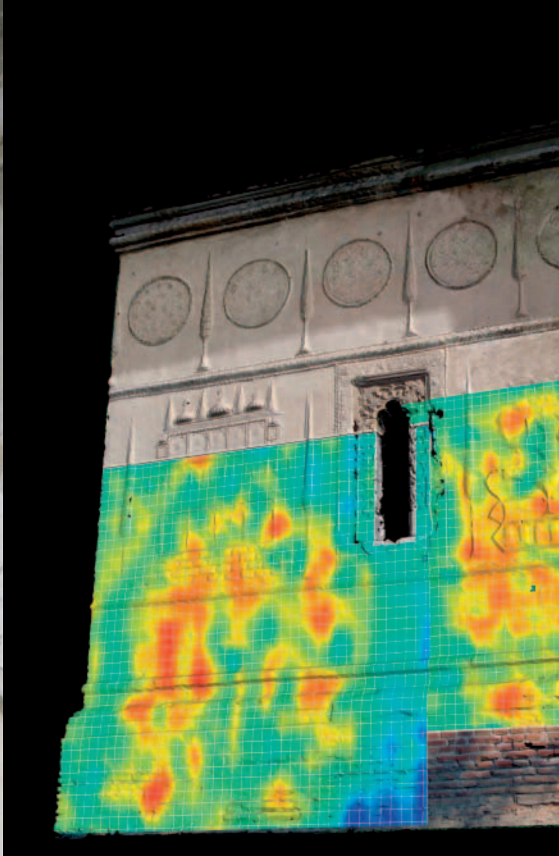


Fig. 4: Overlapped vibration map on textured digital model of the south wall of the Fundenii Doamnei church (1699), Bucharest.

Employ ART and Enjoy Art

Scanning Vibrometry for Non-destructive Testing of Artwork

One of the most fascinating fields of activity for a scientist or an engineer is cultural heritage investigation and conservation. For many years it has been known and largely accepted that restoration is no longer only an art, it is also based on and influenced by ART (Advanced Research Techniques).

Non-contact Methods for Artwork Investigation

Due to some special features, optoelectronics is often claimed to assist and support laboratory investigations, and more importantly on-site investigations. There are possibilities to identify a material's composition and to map the distribution of various materials over a large surface. One of the most non-invasive techniques that does not stress fragile and precious surfaces (paintings, documents, murals etc.) is Laser-Induced Fluorescence (LIF), a non-destructive remote spectroscopy method. Laser-Induced Breakdown Spectroscopy (LIBS) also remotely delivers very accurate information about material composition. Information about thermal emissivity, top layers covered by black encrustations, and possible infiltration routes into historical walls are easily extracted from thermograms. These days there are many analytical methodologies and techniques to determine an artwork's chemical composition, but less attention has been paid on structural diagnostics instrumentation.

Remote Acquisition vs. Traditional Diagnostics

For example, determining the multilayer structure of a large mural could be carried out in the time-consuming traditional way, which is by repeatedly tapping point by point and relying on the expertise of the restorer and on their good hearing. Obviously, this typical diagnostic process is accomplished mainly through manual and visual inspection and the results vary from restorer to restorer.

The basic idea behind employing laser Doppler vibrometry is to substitute human senses and contact sensors with measurement systems capable of remote acquisition. On-site set-ups are quite compact, easily managed and ergonomic (fig. 1). The laser Doppler vibrometer set-up is based on acoustic excitation by a loudspeaker system. In many cases the surfaces are very slightly vibrated by mechanical and acoustical actuators, while a laser Doppler vibrometer scans the objects measuring surface velocity, producing 2-D or 3-D maps.

Example – Painted Canvas

Think for example of a wooden wall of a historic church covered by ancient painted canvas (fig. 2) with hidden detached areas. These defects can be easily spotted by laser Doppler vibrometry as regions where velocity is higher than in neighboring areas (fig. 3). The results can be used to determine subsequent repair or conservation measures.

Example – Stucco Decoration

Painted stucco is not only an ancient form of decoration, but also a precious artistic and historic "memory". As a building material, stucco is well appreciated all over the world and has been used throughout almost all ages. Being quite durable, attractive, and weather-resistant, it was used even for entire wall surfaces.
Its enemies are high temperature gradients and shocks. Any incipient detachments have to be identified and repaired. In historical reconstructions, laser vibrometers can identify structural resonance frequencies thus providing a complete characterization of these defects.

Fig.1: Members of the INOE group working on-site. About 300 m² of the building's walls were evaluated, with measurement points every 10 to 15 cm, in less than 2 days.

Fig. 2: Detail of painted canvas on a wooden wall in a church in Bucharest.

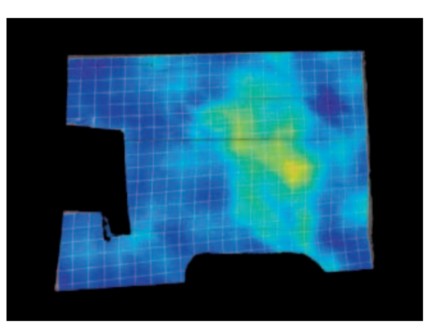


Fig. 3: Vibration map of painted canvas.

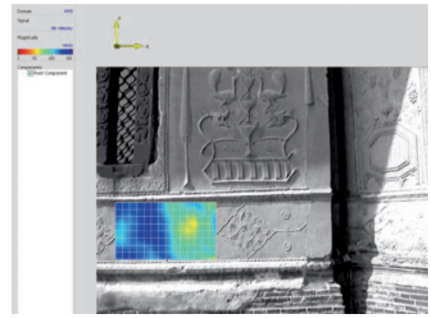


Fig. 5: Detail of complex multilayer diagnostic report.

This holds true as well for massive structures. Fig. 4 and fig. 5 show vibrations maps that pinpoint detachments with various dimensions on large walls of the Fundenii Doamnei church (1699), a beautiful and interesting historic monument in Bucharest, its outside entirely covered by stucco.

Conclusion and Outlook

The range of laser Doppler vibrometry applications have been successfully tested and recommended for different types of movable or decorative artworks such as frescoes, icons, mosaics, ceramics, inlaid wood and easel paintings. Laser Doppler vibrometry is so far the most impressive investigation technique for restorers and conservationists who are dealing with multilayer structures with possible hidden detachments, delaminations and fragile top surfaces. A succinct list of the advantages of this technique includes limited intrusiveness, the non-contact, remote measurement principle, ample frequency response, high sensitivity, transportability, and easy data management.

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New Non-contact LSV-2000 Length and Velocity Sensor

The LSV-2000 Laser Surface Velocimeter, the latest member of Polytec's compact instrument class, determines the direction of motion (forward or reverse), and also recognizes standstill conditions (v=0). The direct, non-contact measurement of product length and speed, coupled with the high precision, reliability and consistency of the LSV-2000 enables users to fully optimize the production process and thus save costs. www.velocimeter.us

The new LSV-2000 measures reliably on almost any solid surface, whether controlling processes utilizing carbon steel, shiny aluminum or oily sheets; producing round wire and cable; or manufacturing paper, cardboard or tissue.

The new optical system design offers depths of field and velocity ranges that are independent of the sensor standoff distance. This leads to significantly more application possibilities, especially for sensors with short standoff distances. For example, in the event of varying material thicknesses or varying pipe diameters, a shorter standoff distance, with the new, larger depth of field, may well meet the process requirements, rather than using a sensor with a long standoff distance. Thanks to its compact design the LSV-2000 is perfectly suited for use in small spaces, such as in C-Frame Thickness Gauges for rolling mills or scanning systems in paper mills and film processing lines. In addition, the LSV-2000 offers accessories for use in hostile environments. Air wipes, water-cooled plates and rugged, fully water-cooled housings are some of the accessories available for applications in dirty, dusty or high temperature process areas.

When used as a footage counter, Laser Surface Velocimeters allow users to reliably reduce process scrap through accurate and precise length measurements, enabling process optimization to ensure a fast ROI. Likewise, accurate and repeatable measurement of material speed at two points (differential speed measurements) enables users to reliably measure and control process parameters for achieving specified material properties and quality, as is the case in applications such as mass flow, elongation, stretch and draw.

Fig. 1 (left): LSV installation at the melt shop of TMK-Ipsco Koppel Steel.

Fig. 2 (right): Polytec LSV laser measuring system for cut-to-length control in a corrugator.

A Broad Range of Applications

- Speed measurement
- Slippage detection and speed synchronization
- Coil length measurement
- Speed calibration

- Part length measurement for goods in pieces
- Cut-to-length control
- Encoder calibration
- Spool length
- Ink-jet marker control
- Speed balancing
- Speed and length measurements in hot environments

Non-contact Velocity Measurement in the Corrugated Board Industry Compared to Conventional Methods

The aim of this study was to improve the dimensional stability of the sheet lengths at the cross cutter of a corrugator. The laser measuring system was used instead of an encoder wheel in the cross cutter control (fig. 2). The cut sheets were then remeasured manually. Continuously changing plant velocities represent the greatest challenge for the measuring systems. The LSV instrument from Polytec achieved the best results – no deviations of greater than ±1 mm were measured under all operating conditions. This high absolute accuracy and repeatability of the laser measuring system cannot be achieved with the conventional idler encoder and feed roller encoder.

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

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

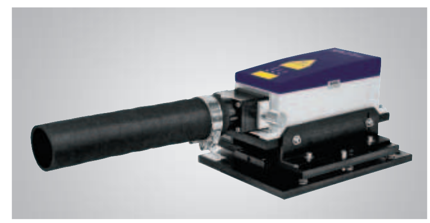
The melt shop of TMK-Ipsco Koppel Steel in Koppel, PA has a 4 strand billet caster producing rounds in the range of 5.5 and 6.5 inch diameter for seamless tube products (fig. 1). In May of 2010, TMK-Ipsco Koppel installed 4 Polytec LSV laser velocimeters on the 4 strand caster with a standoff distance of 1500 mm, a depth of field of 150 mm and a watercooled housing with air wipe. Previously, an evaluation had been conducted by installing a single LSV laser velocimeter resulting in cut length tolerances approaching ±1.0 inch – a significant improvement upon the existing contact wheel, which from experience provided cut length tolerances with variation up to ±4 inches. Introduction of these laser systems has since resulted in a significant reduction in safety factors, improved process repeatability and has eliminated the need for continued process calibration and correction factors for each strand. In addition, little to no maintenance is required.

Source: P. M. Nawfel, Improving Cut Length Tolerance and Long Term Consistency In Continuous Casters with Laser Velocimeters. AIST Iron & Steel Technology Conference and Exposition, 2–5 May 2010, Indianapolis, Ind., USA.

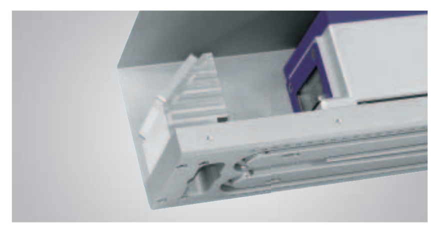
More Info: **www.velocimeter.us, www.velocimeter.co.uk**

LSV Accessories – a Complete Solution for Your Measurement Task

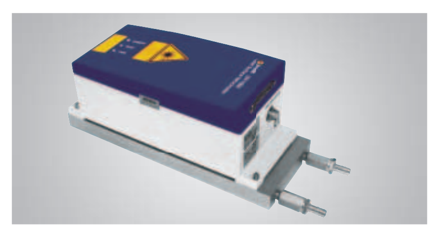
LSV-A-110 Connection Box



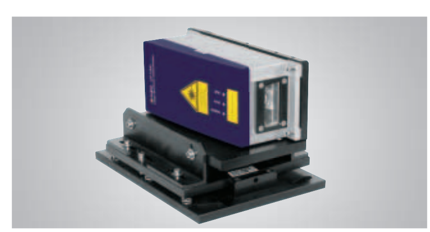
LSV-A-120 Air Wipe with quick-exchange window



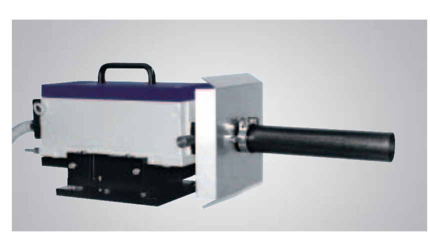
LSV-A-124 C-Frame Accessory Kit



LSV-A-122 Cooling Plate



LSV-A-130 Mounting Platform



LSV-A-121 Cooled Protective Housing

Polytec

Trade Shows and Conferences

Jan 29 – Feb 02, 2012	MEMS 2012	Paris, France
Jan 30 – Feb 02, 2012	IMAC XXX Conference and Exposition on Structural Dynamics	Jacksonville, FL, USA
Feb 15 – 17, 2012	Convertech Japan	Tokyo, Japan
Mar 06, 2012	Instrumentation, Analysis & Testing Exhibition	Silverstone, UK
Mar 06 – 08, 2012	Automotive Testing Expo India	Chennai, India
Mar 11 – 15, 2012	Smart Structures and Materials/NDE	San Diego, CA, USA
Mar 26 – 30, 2012	TUBE 2012	Düsseldorf, Germany
Apr 11 – 13, 2012	FilmTech Japan	Tokyo, Japan
Apr 17 – 20, 2012	Analytica	Munich, Germany
Apr 23 – 27, 2012	Hannover Messe	Hannover, Germany
Apr 25 – 27, 2012	APACT Advances in Process Analytics and Control Technology	Newcastle, UK
May 07 – 10, 2012	AISTech Iron & Steel Technology Conference	Atlanta, GA, USA
May 08 – 10, 2012	Spacecraft Technology Expo 2012	Los Angeles, CA, USA
May 16 – 18, 2012	Japan Automotive Engineering Exposition	Yokohama, Japan
May 21 – 24, 2012	2012 IEEE Int'l Frequency Control Symposium	Baltimore, MD, USA
May 22 – 23, 2012	WAI Operations Summit & Wire Expo 2012	Dallas, TX, USA
May 22 – 24, 2012	15th Int'l Conference on Low Frequency Noise and Vibration and its Control	Stratford-upon-Avon, UK

Polytec Web Academy

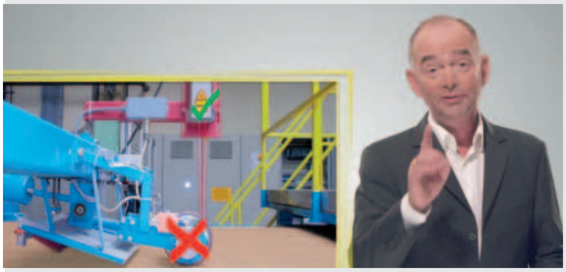
Polytec Web Academy

Feb 07, 2012	An Introduction to Non-Contact Vibration Measurement
Feb 08, 2012	Characterize, Analyze and Validate Surface Metrology with Innovative, High Precision, Optical Surface Profiling Systems
Feb 09, 2012	RSV-150 Long Distance Vibrometer
Mar 06, 2012	Improving Performance of MEMS Designs Using Dynamic Characterization
Apr 10, 2012	An Introduction to Non-Contact Vibration Measurement
Apr 11, 2012	An Intro to Scanning Laser Vibrometry for Non-Contact Vibration Measurement
Apr 12, 2012	Characterization at Ultrasonic Frequencies Using Laser Vibrometry
May 01, 2012	An Introduction to Non-Contact Vibration Measurement
May 02, 2012	Non-contact Methods for Aerospace Structural Analysis and NDT

For more information visit: **http://polytec.webex.com**.

New Multimedia:

All About Laser Surface Velocimetry



Polytec's LSV laser length & speed sensors are used in a wide variety of industries. A new LSV video provides an overview of the technology, markets and applications, as well as the benefits compared to traditional contact speed & length measuring techniques. To learn more, read the new article "Laser surface velocimeter" on Wikipedia, or view and download the video at **www.polytec.com/video**.

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