Xth INTERNATIONAL WORKSHOP NDT in Progress

Hotel Meritum, Prague, Czech Republic

October 7 – 9, 2019

PRELIMINARY PROGRAM

Monday, 7 October 2019	
09.00 - 17-00	***Registration***
10:00 - 10:30	**Workshop opening**
10:30 - 12:30	**Session 1 – chair: Z. Prevorovsky**
10:30	Jaroslav JOCH **USE OF STRUCTURAL HEALTH MONITORING IN NUCLEAR APPLICATIONS**
11:00	Zdenek PREVOROVSKY **CONTINUOUS AE SOURCE LOCATION IN PIPELINE USING TIME REVERSAL SIGNAL PROCESSING**
11:30	Milan CHLADA **CONTINUOUS ACOUSTIC EMISSION MONITORING BY DATA STREAMING OSCILLOSCOPES**
12:00	Karel HAJEK **INCREASED ACCURACY OF SPECTRAL ANALYSIS IN NDT**
12:30 - 13:30	***Lunch, preparing posters***
13:30 - 16:00	**Session 2 – chair: A. Savin**
13:30	Mirosław WITOS **MAGNETIC STATE OBSERVER IN NDT AND SHM STUDIES**
14:00	Takumi KOBARA **OPTIMIZATION OF APPLIED MAGNETIC FIELD METHODS FOR VARIOUS SHAPE DEFECTS IN EDDY CURRENT TESTING USING MAGNETO RESISTIVE SENSOR**
14:30	Yuto GODA **MAGNETIC NDE SYSTEM FOR DETECTION OF CRACK IN STEEL DECK WITH HIGH LIFT-OFF USING SECONDARY DIFFERENTIAL DETECTION COIL**
15:00	Shunki WAKABAYASHI **OPTIMIZATION IN THE DETECTION PERFORMANCE OF EXTREMELY LOW-FREQUENCY EDDY CURRENT TESTING FOR APPLICATION TO VARIOUS SHAPES OF CORROSION DEFECTS IN THE ACTUAL SOCIAL INFRASTRUCTURE**
15:30	Adriana SAVIN **ARCAN DEVICE EMPLOYED IN CFRP TESTING**
16:00 - 16:30	*Coffee break*
16:30 - 17:40	**Session 3 – Posters – chair: M.Witos**
16:30	Icaro V. M. MOREIRA **BERGEN HIGH - SPEED GAMMA - RAY TOMOGRAPHY VS. GEANT4 SIMULATED DATA: A COMPARISON STUDY**
16:40	Tristan JULIEN **DESIGN OF AN EXPERIMENTAL MOCKUP TO STUDY THE POSSIBILITIES OF ACOUSTIC MEASUREMENTS FOR NUCLEAR REACTOR FUEL ELEMENT TESTING**
16:50	Jan KOBER **VERIFICATION OF DIGITAL TWIN CONCEPT FOR TIME REVERSAL ANALYSIS**
17:00	Maximilian TRAPP **STRUCTURAL ANOMALY IMAGING IN ALUMINIUM AND CONCRETE SPECIMEN USING SEISMIC MEASUREMENTS**
17:10	Dagmar FAKTOROVA **IMPROVEMENT OF MICROWAVE SENSING OF WOODS USING METAMATERIALS STRUCTURES**
17:20	Josef STRYK **AN INITIAL INVESTIGATION ON THE POTENTIAL APPLICABILITY OF ULTRASONIC TESTING TO ASSESS EFFECTS OF CORROSION ON LINEAR AND NONLINEAR ELASTIC BEHAVIOUR OF PRE-STRESSING STEEL STRANDS**
17:30	Pawel MAZUREK **INFLUENCE OF PRE-MAGNETIZATION AND DEMAGNETIZATION OF A STEEL WIRE FOR ITS DIAGNOSTIC SIGNAL**

Tuesday, 8 October 2019	
9.00 - 12.30	*Registration*
9:00 - 10:30	**Session 4 – chair: S. Hirsekorn**
09:00	Sigrun HIRSEKORN **SIMULATION OF ULTRASONIC BACKSCATTERING SIGNALS IN POLYCRYSTALLINE MATERIALS**
09:30	Tomas GRABEC **MODELING OF GRAIN-BOUNDARY SCATTERING OF ULTRASONIC WAVES FOR CHARACTERIZATION OF GRAIN-SIZE DISTRIBUTION**
10:00	Pavel STANEK **EXPERIMENTAL SETUP FOR MPI SENSITIVITY MEASUREMENTS: FIRST RESULTS**
10:30 - 11:00	Coffee break
11:00 - 13:00	**Session 5 – chair: P. Hora**
11:00	Dalibor LUKAS **A UNIFORM PARALLEL FRAMEWORK TO LARGE-SCALE SIMULATIONS OF 3D WAVE-TYPE EQUATIONS**
11:30	Michal MRACKO **USING COMPUTATIONAL TIME REVERSAL METHOD FOR LOCALIZATION OF FORMING AND PROPAGATING CRACK**
12:00	Radovan ZEMAN **APPLICATION OF IMAGE SOURCE METHOD IN TIME REVERSAL OF ELASTIC WAVES**
12:30	Petr HORA **ACOUSTIC EMISSION SOURCES FROM FAST DISLOCATION MOTION**
13:00 - 14:00	*Lunch*
14:00 - 16:00	**Session 6 – chair: J. Krofta**
14:00	Michaela JANOVSKA **CHARACTERIZATION OF BONDING QUALITY OF COLD-SPRAYED DEPOSITS BY RESONANT ULTRASOUND SPECTROSCOPY**
14:30	Adriana SAVIN **INFLUENCE OF RARE EARTHS ON BIODEGRADABLE MAGNESIUM ALLOYS USED IN MEDICAL PROSTHESES**
15:00	Jan KOBER **DETECTING POROSITY OF 3D PRINTED TI6AL4V BY NONLINEAR ELASTIC WAVE SPECTROSCOPY**
15:30	Josef KROFTA **NONDESTRUCTIVE CHARACTERIZATION OF FAULTS IN 3D PRINTED POLYMER SAMPLES**
16:00 - 16:30	*Coffee break*
16:30 - 18:00	**Session 7 – chair: E. Leis-Holzinger**
16:30	Elisabeth LEISS-HOLZINGER **EXPLORINGCHALLENGES IN MULTIMODALITY EXEMPLIFIED BY OPTICALCOHERENCE TOMOGRAPHY**
17:00	Artem USTINOV **X-RAY INSPECTION SYSTEMS FOR ELECTRONIC PARTS**
17:30	Sreedhar UNNIKRISHNAKURUP **NONDESTRUCTIVE EVALUATION OF THERMAL BARRIER COATING THICKNESS DEGRADATION USING INFRARED THERMOGRAPHY AND TERAHERTZ-TDS IMAGING**
19:30 - 22:00	***Social dinner***
Wednesday, 9 October 2019	
9:00 – 14:30	Tour to Dolni Brezany (20 km by bus) **EXCURSION to European laser center HiLASE & ELI-Beams**
	Lunch + WORKSHOP ENDING
15:00 – 17:30	**SIGHTSEEING TOUR IN PRAG**

ABSTRACTS

IMPROVEMENT OF MICROWAVE SENSING OF WOODS USING METAMATERIALS STRUCTURES

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Keywords: microwave testing, wood species, metamaterials, dielectric properties

Abstract: In the paper a new approach for the investigation of the dielectric properties of dielectric material will be described, with implementation of artificial metamaterial structure over the aperture of waveguide sensor in order to increase the sensing properties of classical waveguide sensor. The aim is to achieve the optimal design of metamaterial structure for waveguide sensor tuning in microwave X-band. The possibility of metamaterial structure used for upgrading properties of classical waveguide sensor will be emphasized. The numerical simulation of 2D metamaterial structure properties and experimental results for dielectric properties dielectric materials are carried out, resulting in the possible applications of metamaterials to improve the sensing of classical microwave devices, so that metamaterials open a new degrees of freedom in sensor design like a sensitivity increasing in the area of measurement of dielectric properties of materials, which changes can be the indicator of new properties that could lead in some cases to the material failure. In a large range of applications, the information about dielectric properties are required, but not only these, sometimes, for natural dielectric as wood, the direction of the wood grain that is changing from point to point, making the permittivity tensor to become a random values. Wood being a heterogeneous material, it has variable properties that can be a bottleneck in some industrial applications where the material properties should be strictly defined to assure prime quality. Over the past decades the traditional use of wood as construction material evolved to a modern, widely differentiated application domains, as sonic barriers or components in small wind turbine blades, etc. The purpose of the paper was to apply a modern microwave measurement method to determine the dielectric properties of wood samples and validate the results with Dynamic Mechanical Analysis.

MAGNETIC NDE SYSTEM FOR DETECTION OF CRACK IN STEEL DECK WITH HIGH LIFT-OFF USING SECONDARY DIFFERENTIAL DETECTION COIL

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Keywords: NDE, crack, secondary differential coil, high lift-off

Abstract: As about 50 years have passed since the high economic growth period, the aging of metal parts such as the corrosion and cracks is becoming a serious problem, which are used in the highways, bridges and buildings. Thus, a technology to detect the aging of metal parts is required. We have developed magnetic nondestructive evaluation (NDE) technologies for the steel structures. Some highways and brigdes have steel plate under the asphalt or concrete, such as the steel floor slabs of roads. In the NDE of highway and birdge, it is required to inspect the steel material with a distance between the sensor and steel structure (high lift-off). In the high lift-off, the signal from crack is small, and the noise peculiar to the magnetic material makes the signal detection difficult. Therefore, the influence of the magnetic noise should be reduced. In order to reduce the influence of the

magnetic noise, in this study, a detection coil of a secondary differential coil combining two differential coils was developed. By arranging two sets of differential coils in layers, it is possible to reduce the magnetic noise and improve the signal to noise ratio (SNR) by reducing the influence of the applied magnetic field. Beacause of the increase in SNR, a weak signal from the sample with a high lift-off is expected to detect. In addition, the induction coil was also prepared by connecting two coils in reverse, and it can generate a dipole-like induced current under the center of the coil. The induction / detection coil and various power supplies were implemented to a hand cart and this enabled to move the measurement system easily above the sample. To obtain the mapping of magnetic signal, the hand cart was moved from the edge to edge of sample (1 line scan), and the data of nine lines with 30 mm intervals was measured for imaging. We used two steel plates (SM490A) with a crack as a test sample which is 0.7 m in width, 1.0 m in length and 6 mm in thickness. Each sample has surface cracks of 50 and 100 mm in size and 4 mm in depth. In addition, the distance between the sample and the detection coil was 20, 50, and 80 mm, and the angle of the induction coil to the slit was also changed. As a result, it was found that the applied dipole-like current was particularly effective for detecting the slit when the direction of current was orthogonal to the slit. From this result, the proposed induction and detection coil configuration is expected to detect the cracks in steel structures located under the asphalt or concrete.

MODELING OF GRAIN-BOUNDARY SCATTERING OF ULTRASONIC WAVES FOR CHARACTERIZATION OF GRAIN-SIZE DISTRIBUTION

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Keywords: ultrasonic waves, grain-boundary scattering, polycrystalline material

Abstract: Grain-boundary scattering is the major contribution to acoustic-wave attenuation in polycrystalline materials at ultrasonic frequencies. Analytical models, developed since the 1950s, describe the frequency dependence of the attenuation based on characteristic grain size. Numerical studies from the recent years show, that the mean size does not suffice, and the profile of the grain-size distribution must be considered. This, on the other hand, leads to the possibility of characterization of the grain size profile, which is a vital parameter for the resulting properties of the material. However, experimental determination of the attenuation is immensely difficult, and it is often not in a good agreement with the models. Hence, its utilization for material characterization is still limited.
A possible way of advance is the use of surface acoustic waves (SAW). Combined with laser-ultrasonic methods, these allow the characterization of the properties with access to one polished surface. In contrast to the bulk-wave measurements, their attenuation can be characterized along the propagation, not only at boundaries of the sample. On the other hand, a proper theory of scattering-based attenuation of SAW was not even devised. It can be, however, modelled numerically.
In the present contribution, an experimental and numerical study of SAW attenuation will be presented. The experimental work was done using frequency-domain laser-ultrasonic setup, and provided the frequency dispersion of attenuation on a chosen aluminum sample. For the numerical simulations, a model of statistically similar polycrystalline structure was constructed as a Laguerre-Voronoi tessellation. Using this model, a time-domain finite-element simulation of SAW propagation was carried out, with results in a nice agreement with the experiments, especially when considering the standard agreements between experiment and models in the area of bulk-wave scattering.

INCREASED ACCURACY OF SPECTRAL ANALYSIS IN NDT

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Keywords: Spectral analysis, ultrasonic spectroscopy, resonance spectroscopy, DFT, windows

Abstract: Some NDT methods advantageously use

spectral analysis using DFT. These are e.g. methods of nonlinear ultrasonic spectroscopy, resonance spectroscopy but also some others. Despite its indisputable advantages, the use of DFT spectral analysis brings some problems. A major problem is the leakage effect, which is evident in cases where we cannot provide a coherent DFT with synchronous sampling. Related to this is the problem of insufficiently accurate determination of frequencies of dominant harmonic components, which is manifested e.g. in detection of change of resonant frequencies during non-linear effects of tested systems.
A common solution to these problems is the use of new methods for very accurate determination of the frequency of the dominant harmonic signal. This also allows the suppression of the leakage effect in spectral analysis, so that the spectrum obtained is accurate and without the leakage effect in a significantly higher dynamic range than the use of known window functions. The paper shows the possibilities of solving the mentioned problems.

SIMULATION OF ULTRASONIC BACKSCATTERING SIGNALS IN POLYCRYSTALLINE MATERIALS

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Keywords: analytical model, microstructure, numerical simulation, polycrystalline, scattering, ultrasound

Abstract: Scattering of ultrasound at grain boundaries in polycrystalline media causes sound velocity dispersion and frequency dependent attenuation along the propagation direction of ultrasonic beams as well as scattering waves within the whole sample. These effects can be used for materials characterization, but concomitantly hamper defect detection and evaluation in components because the so-called grain noise superposes defect signals, and velocity dispersion corrupts defect positioning. Hence, ultrasonic signal evaluation and numerical simulations of ultrasonic propagation and of nondestructive testing and materials characterization procedures must comprise microstructural scattering phenomena.
Statistically distributed single scatterers, the ensemble averaged scattering energy flux densities of which reflect the grain noise of a test block may be used as a grain scattering model [1]. A convenient numerical simulation procedure in order to calculate ultrasonic time signals, e.g. backscattering (A-scans), consists in point source superposition of the scattering waves stemming from the scatterers mimicing structural noise and maybe also from defects and possible reflections at sample surfaces. In a general theoretical approach, ultrasonic scattering wave energy flux densities generated by a given incident wave in microscopically inhomogeneous media are derived from the infinite Born series presentation of ultrasonic displacement vectors, which solve the elastodynamic equation of motion of the medium. The energy flux densities are ensemble averaged respective the microscopic inhomogeneity and analytically evaluated for macroscopically isotropic single-phase polycrystals [2].
The described procedure is applied to the real poly crystalline structure of a Ti(hcp) alloy sample in order to simulate ultrasonic backscattering signals. The 3D orientation map of the grain structure of the sample was imaged by X-ray Diffraction Contrast Tomography (DCT) [3]. The incident ultrasonic beam is described by its center frequency and bandwidth. Each grain is considered as a single scatterer. Then, the analytical results of the general ultrasonic scattering theory and the 3D full-field microscopic data yield the ensemble averaged scattering characteristics for each grain, and, furthermore, may be used to fit a granular microstructure model for this particular sample. Backscattering signals are computed for the real polycrystalline structure of the Ti alloy sample as well as for the granular microstructural model fit.

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ACOUSTIC EMISSION SOURCES FROM FAST DISLOCATION MOTION

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Keywords: acoustic emission, edge crack, dislocation emission, free surface, bcc iron

Abstract: Acoustic emission from the fast dislocations emitted from an edge crack in 3D bcc iron crystal is studied via atomistic simulations by molecular dynamics technique. Acoustic emission patterns arising from the fast dislocation motion in molecular dynamics are visualized via the local kinetic energies of individual atoms and further modeled as a moving source of the stress waves in the anisotropic continuum.

CONTINUOUS ACOUSTIC EMISSION MONITORING BY DATA STREAMING OSCILLOSCOPES.

Milan CHLADA

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Abstract: Computational power of contemporary regular hardware enables to test the new approaches in many fields. In case of non-destructive evaluation and material characterization by Acoustic Emission (AE) method it is possible to monitor highly dynamic damage processes as could not be done before without the capability of continuous signal recording and analysis. Modern portable measuring devices as USB oscilloscopes with data streaming feature can be flexibly controlled by scripts tailored for particular experiment. AE activity can be thereby evaluated online in more detail by specially designed parameters. The running experiment can be controlled by actual state of material damage as well. Such approach is demonstrated during the test of titanium alloys for orthopedic implants. The AE method provided comprehensive data to identify the initial stages of damage and crack propagation in the stressed specimen. AE measuring and evaluating system based on USB oscilloscope TiePie was completely designed and run in Matlab environment, displaying basic AE parameters, audibly monitoring selected AE hits and saving those parameters together with the complete signal stream in binary format for further advanced analysis.

SENSORS CLUSTER BASED CRACK DETECTION IN THIN PLATES

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Keywords: Lamb waves, piezoelectric, sensors, cluster, crack, detection

Abstract: Lamb waves have long been used for cracks detection in plates, They demonstrate a great potential for damage detection in metallic and composite structures. These guided waves are introduced into a structure by an actuator at one point and sensed by another sensor at a different position. As the four stages of any structural health monitoring technique are respectively, detection, localization assessment and prediction, we aim through this work to improve Lamb wave-based technique in order to detect and localize cracks in isotropic plate. So far, the triangulation technique has proven its efficiency for acoustic source localization in isotropic plates. However, the presence of cracks, induce reflections that can alter obtained signals. For this, we aim through this work to highlight the Lamb wave interaction with damage. Finite element method is used for modelling and slot-type defects are to be considered. To the best of the authors' knowledge, the 'L' and 'Z' shape clusters have already been investigated in previous works yet for acoustic source localization. In this work, efficiency of the sensors' clusters for cracks localization in isotropic plates will be studied. Furthermore, other shapes will be suggested for a better characterization of present cracks.

CHARACTERIZATION OF BONDING QUALITY OF COLD-SPRAYED DEPOSITS BY RESONANT ULTRASOUND SPECTROSCOPY

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Keywords: Resonant Ultrasound spectroscopy, Cold spraying, Interface

Abstract: Resonant ultrasound spectroscopy (RUS) is an experimental method suitable for determination of elastic constants and internal friction parameters of solids. Due to its resonant nature, the RUS method is very sensitive to small variations of the elastic constants and is, thus, suitable for detecting structural changes appearing for example in thin surface layers deposited onto the measured sample.
Cold spraying (CS) is a versatile and efficient method for deposition of relatively thick metallic coatings. Unlike the conventional thermal spraying methods such as plasma spraying the CS process does not involve substantial heating or melting of the sprayed powders. Instead, the formation of the coating arises from a severe plastic deformation of the accelerated powder particles upon their impingement at the substrate.
Resonant ultrasound spectroscopy was utilized to determine the mechanical properties of a planar interface between a cold-sprayed iron deposit and an aluminum alloy substrate. The measurements were d Resonant ultrasound spectroscopy was utilized to determine the mechanical properties of a planar interface between a cold-sprayed iron deposit and an aluminum alloy substrate. The measurements were done at a room temperature and with a thermal cycle from room temperature to 500°C. The properties of the interface were assessed by analyzing the resonant frequencies and resonant peak widths of a sandwich-like sample by means of a numerical model. While the as-sprayed deposit at the room temperature exhibited a perfect adhesion to the substrate, the thermal cycle lead to deterioration of the properties due to Fe3Al precipitation and subsequent cracking.

THE USE OF STRUCTURAL HEALTH MONITORING IN NUCLEAR APPLICATIONS

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Keywords: Structural Health Monitoring, nuclear power plant, structure integrity assessment

Abstract: Nuclear plant operators deal with demanding security requirements when dealing with stringent security requirements and with plant lifetime extension. The safety case is based on the inspections and evaluations from plant shutdown. While in the aircraft industry the approach of Structural Health Monitoring (SHM), i.e. continuous monitoring using NDE, has been successfully used for some time, the use of SHM in the nuclear industry has been rather limited. The purpose of our project NEMENUS is to investigate the potential of the continuous monitoring - „early warning" - approach SHM for the use in the nuclear industry.

DESIGN OF AN EXPERIMENTAL MOCKUP TO STUDY THE POSSIBILITIES OF ACOUSTIC MEASUREMENTS FOR NUCLEAR REACTOR FUEL ELEMENT TESTING

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Keywords: Acoustic emission, guided waves, crack, failure, fluid-structure interaction

Abstract: Acoustic Emission methods are used in the CABRI nuclear research reactor of the French Commission for Nuclear and Alternative Energies (CEA) to study the behaviour of fuel elements in accidental condition. The measured signals correspond to elastic waves and fluid pressure waves that are produced by different physical phenomena occurring around or in the rod and propagate respectively in solid materials and in the coolant fluid. These signals make it theoretically possible to detect, identify and locate in space and time some of these phenomena, especially damage mechanisms in the cladding (e.g. distortion, crack propagation, failure). The advantage of these methods is the possibility of use during normal operation of the tested element with a relatively simple instrumentation. In practice, we encounter some issues with the interpretation of the signals. First, several noise sources affect the signals: electronic noise, acoustic noise due to external events (e.g. valves opening), flow noise, and vibration noise due to fluid-structure interaction. Second, the wave propagation from the source to the sensors leads to signal distortions that are not accurately known. To solve these difficulties, we need to improve our knowledge of acoustic emission source and propagation mechanisms. To this end, we are designing an experimental mock-up consisting of a fake fuel rod submitted to some phenomena occurring in CABRI reactor. In that mockup, we will independently reproduce every studied phenomenon and study its acoustic and vibration effects. Acoustic sources' spectra, fluid-structure interaction, wave propagation in the fluid and the cladding, influence of global structure vibrations (low frequency range) on elastic guided waves (high frequency range) and changes in vibration response of the structure could thus be determined for each phenomenon.
In this paper, we describe the design process of the instrumentation of the mockup, based on real CABRI signals observation, guided waves propagation study, and preparatory acoustic tests on fake rod claddings outside the mockup.

OPTIMIZATION OF APPLIED MAGNETIC FIELD METHODS FOR VARIOUS SHAPE DEFECTS IN EDDY CURRENT TESTING USING MAGNETO RESISTIVE SENSOR

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Keywords: Nondestructive testing, Eddy current testing, Magnetic material, Non-magnetic material, Magneto resistive sensor

Abstract: Micro defects occur on the surface or inside metal materials during their production, processing for a metal structure, or caused by the aged deterioration. Therefore, a non-destructive testing that can inspects and evaluates the micro defect of early stage is required. In the conventional eddy current testing, a combination of an induction and a detection coil is widely used. Recently, the magnetic sensor which has high sensitivity and spatial resolution even at low frequencies have been used instead of the detection coil. In this study, the optimization of applied magnetic field for detecting various shapes of defect generated in both magnetic and non-magnetic materials was examined using the eddy current testing with a highly sensitive magnetic sensor. The measurement system consisted of an oscillator, an induction coil, a nano-granular tunnel magneto resistive (TMR) sensor, an X-Y automatic scanning stage, a lock-in amplifier, a differential amplifier, and PC. The magnetic signals were lock-in detected by synchronizing them with the reference signal generated by the oscillator which was also used to drive the induction coil. An alternating magnetic field was applied to the test sample using the induction coil to induce an eddy current. In this study, various shapes of induction coil, such as solenoid, tangential and wire type, were used and the characteristics of response to each coil were compared. The test samples were the aluminum (non-magnetic) and the steel (magnetic) plate with various shapes of defects (pit, slit shape). The eddy current distribution generated from various shapes of defects using various induction coil were also analyzed by the simulation. From the simulation results, it was found that the signal waveform of magnetic field depended on the defect and coil shape, and these results agreed with the measured values when the magnetic signal was scanned over the defect. In the case of wire type,

the change of the magnetic field distribution generated by the eddy current was large when the TMR sensor was placed above the induction wire. In the case of solenoid type, the detection sensitivity increased when the TMR sensor was close to the edge of coil which is apart from the center of the coil. In addition, it was found that the signal change was different between the magnetic and non-magnetic materials. For the non-magnetic material, as the frequency increased, the signal to noise ratio of the detected defect signal increased because the signal is generated from only the eddy current. On the other hand, for the magnetic material, there was an optimum frequency for detecting the defect because the signal is generated due to both the magnetization and the eddy current. As a results, the optimum method of applying the magnetic field for the eddy current testing using magnetic sensor could be clarified.

VERIFICATION OF DIGITAL TWIN CONCEPT FOR TIME REVERSAL ANALYSIS

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Keywords: time reversal, source reconstruction, FEM, model calibration

Abstract: It has been shown experimentally, that it is possible to record signals of elastic wave propagation on a tested structure and perform time reversal focusing on an independent reference structure. Here the possibility of utilizing a numerical model – digital twin, as a reference structure is studied. An experiment was conducted on a strip of Al-alloy with known mechanical constants. In the first step was the numerical model calibrated. A measurement of dispersive wave propagation was performed and compared with equivalent results of the numerical simulation. Material parameters were adjusted accordingly and usable correlation length was determined. Once the model was calibrated, second experimental setup was tested. The experiment was conducted again with the transducer placed in different location with different modality. A limited vibrometer scan was performed and the data were fed into the numerical model. Using time reversal it was possible to localize the source and partially reconstruct the source function. Presented approach could be used for localization of impacts or acoustic emission sources and prospectively for damage detection and sizing.

DETECTING POROSITY OF 3D PRINTED TI6AL4V BY NONLINEAR ELASTIC WAVE SPECTROSCOPY

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Keywords: nonlinear elasticity, additive manufacturing, selective electron beam melting, nonlinear wave modulation spectroscopy, nonlinear resonant ultrasound spectroscopy

Abstract: Selective Electron Beam Melting (SEBM) is a powder bed technology for the production of metallic parts. In order to achieve nominal mechanical properties, microstructural defects have to be detected and avoided. The porous microstructure can contain voids, weak bonds, sharp interfaces and loose particles, all of which was linked with the occurrence of nonlinear elastic wave propagation. A set of Ti-6Al-4V samples with defined internal volume with porosity ranging from 0.2 % to 20 % is experimentally investigated. An Impact Modulation Spectroscopy experiment was performed on the sample set and experimental results were analysed for linear and nonlinear indicators of material porosity. Porosity was indicated by means of Resonant Ultrasound Spectroscopy and its nonlinear counterpart, by a measure of attenuation and by nonlinear modulation.

NONDESTRUCTIVE CHARACTERIZATION OF FAULTS IN 3D PRINTED POLYMER SAMPLES

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Keywords: additive manufacturing, nonlinear elastic wave spectroscopy

Abstract: Fused deposition modeling is the most common 3D print method. Filament is fed through a moving heated printer head and is deposited on the growing work. It can produce models made of thermoplastic materials. Both the equipment needed for production and the filaments needed for printing are relatively cheap. The possibility of inspection of 3D printed samples using ultrasonic nondestructive nonlinear methods was studied. 3D printed samples made of PLA with defined cavities were tested using a number of ultrasonic nonlinear elastic wave spectroscopy methods.

EXPLORING CHALLENGES IN MULTIMODALITY EXEMPLIFIED BY OPTICAL COHERENCE TOMOGRAPHY

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Keywords: Multimodal, Optical Coherence Tomography, OCT, Stimulated Raman Spectroscopy

Abstract: In this presentation, the potential and the challenges of implementing complementary, multimodal methods are discussed, with a focus on the latest approach of combining Optical Coherence Tomography (OCT) and Stimulated Raman Spectroscopy (SRS).
OCT is a non-contact, interferometric imaging method to detect structures within semitransparent, scattering media [1]. Originally developed for biomedical applications, OCT has been continuously gaining ground in the field of material characterization and non-destructive testing (NDT), e.g. as an in-situ analytical tool for monitoring the tablet coating process in pharma industry and detect defects [2].
The combination of OCT with SRS can give additional chemical information but also poses special requirements to the sensor head in case co-registered information is desired. The latter is also true for the combination of OCT with other optical methods like MIR and THz spectroscopy or with acoustic methods (photoacoustic imaging). Such combinations will be briefly presented as well. Multimodal measurement results and limitations of applicability are discussed.

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A UNIFORM PARALLEL FRAMEWORK TO LARGE-SCALE SIMULATIONS OF 3D WAVE-TYPE EQUATIONS

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Keywords: Ultrasonic waves propagation, large FEM si-

mulation, parallel scalability, hundreds computational cores

Abstract: In many engineering areas such as nondestructive testing of materials and structures investigation of ultrasonic waves is of a great importance. In the talk we first recall the finite element (FEM) approximation theory of the initial-boundary-value problem for the wave equation, which is documented by numerical experiments. In particular, we discuss simulations of thin-walled structures by convenient FEM (continuous displacements, discontinuous stresses) that suffers from the shear-locking effect meaning that the discretization error is inversely proportional to the thickness of the structure. As a remedy we present a novel mixed FEM (tangential-continuous displacements, normal-normal-continuous stresses), which is locking-free.
Second part of the talk is devoted to a uniform framework for parallel implementation of matrix-vector product and inner-product regardless of the used type of elements, e.g. Lagrange or Nedelec. The linear systems arising within an implicit time-discretization scheme are preconditioned by proper smoothers. Finally, we present parallel scalability of our approach up to a billion equations and hundreds of computational cores.

INFLUENCE OF PRE-MAGNETIZATION AND DEMAGNETIZATION OF A STEEL WIRE FOR ITS DIAGNOSTIC SIGNAL

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Keywords: technical diagnostics, steel wire, pre-magnetization, demagnetization, magnetomechanical effects

Abstract: Values of a residual magnetic induction change as a result of the work of a steel wire, i.e. its bending, stretching or twisting. The value of the induced magnetic field in the wire is also affected by the damage occurring. Under the influence of cyclically changing work loads, due to the effects of magneto-mechanics, changes in electromagnetic properties occur both in the wires and in the entire steel wire rope. Anomalies of the residual magnetic field are used to identify imperfections of steel wire ropes such as broken wires, deformations, wear and corrosion. The most common method of non-destructive testing of steel wire ropes is the active magnetic method, which uses imperfections leaked by a strong, formatted by an external source, magnetic field. In this case, the steel wire rope is magnetised only before or during the test, thus losing important diagnostic information. An increasingly popular method using a residual magnetic field leakage does not require pre-magnetization. Magnetic flux leakage (MFL) detection has the advantages of accurate positioning obvious target defect. The MFL information on the surface of the wire rope can be converted into magnetic images so that the circumferential and axial position of the wire rope defects can be displayed more intuitively. By fusing the visible and magnetic images, it is possible to use of their information and the defect recognition rate can be improved.
The article focuses on the very process of magnetization and demagnetization. In detail, the magnetomechanical effects are discussed: direct and inverse. As far as the measurement is concerned, it is presented as follows. Three identical, new steel wire samples from the production line, were subjected to the processes: one of them was magnetized with a strong magnetic field (like in a active method), the other was subjected to a demagnetization process (passive method), while the third was left unchanged. A diagnostic signal was recorded for each of these samples using the SpinMeter-3D sensor. The signal was measured in the three axes of the Cartesian system. Then, each of these samples was subjected to two-way bending until breaking. Diagnostic signals for each of these samples were registered again and next obtained results were compared very closely. The results obtained allowed for the formulation of certain conclusions and dependencies.

BERGEN HIGH-SPEED GAMMA-RAY TOMOGRAPHY VS. GEANT4 SIMULATED DATA: A COMPARISON STUDY

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Keywords: NDT, CT, Gamma-ray, Geant4, Monte Carlo

Abstract: Monte Carlo based methods have been applied for the simulation of the passage of particles through matter in several different kinds of applications. This paper is a comparative study of differences in data produced by a real tomography and data provided by a simulation tool based on Monte Carlo method with the goal to understand the differences between the actual and simulated data as also to map all physics process happening during a real tomograph experiment. The paper will first describe the Bergen HSGT (High-Speed Gamma-ray Tomograph), UiB tomography system designed for industrial real-time tomography, and Geant4, a toolkit for the simulation of the passage of particles through matter. Then, the modeling of the real tomograph into Geant4 tool will be described with details about the geometry, physics, particles, and scoring. Finally, the findings of the comparative study between Geant4 and Bergen HSGT is presented.

USING COMPUTATIONAL TIME REVERSAL METHOD FOR LOCALIZATION OF FORMING AND PROPAGATING CRACK

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Keywords: Time reversal, explicit finite element analysis, elastic wave propagation, non-destructive testing, crack localization.

Abstract: The time reversal (TR) method has found its application in many fields concerning wave propagation. Our object of interest is the application in non destructive testing (NDT). In NDT, this method can be used for tracing the source of vibrations in solid bodies, the source being a crack or some other defect. The TR method uses a backward wave propagation for refocusing and reconstruction of the original source. The TR process consists of two steps. In the first step – the Frontal task, a real body is loaded at the given place with the defined loading signal and an output is recorded in a prescribed position of the body. In the second step – the Reverse task, this responding signal is reversed in time and loaded into the computational model so as to locate so called scatterers (e.g. cracks). In computational TR method, both steps are performed numerically. Here we focus on localization of an initializing and a propagating crack in the prestressed finite element (FE) model. We also study how the length of the computation (number of reflections of the elastic waves) influences the probability of localization of the crack. Special attention is paid to the way of prescription of the loading signal.
For numerical solution, we use the linear FE method, with the lumped mass matrix, a one-point Gauss integration rule and an hourglass control. For the direct integration in time the explicit central difference scheme is employed. This integration scheme is conditionally stable and reversible in time.
We evaluate the quality of localization mainly by observing the total energy distribution at the end of the Reversal task. We compare results for several lengths of computation (between 1 000 and 50 000 time steps). The conclusions show that with increasing length of computation (more information loaded into the model) the probability of localization of the crack also increases (the energy refocuses in the location of the source of vibrations).

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CONTINUOUS ACOUSTIC EMISSION SOURCE LOCATION IN PIPELINE USING TIME REVERSAL SIGNAL PROCESSING

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Keywords: Continuous AE, source location, pipe elbow, waveguides, time reversal

Abstract: Reliable location of Acoustic Emission (AE) sources is one of the most important inverse problems in non-destructive testing (NDT) and structural health monitoring (SHM) of engineering structures. Standard AE source localization procedures often fail at more complicated structures with wave dispersion, velocity or geometry changes, etc. Localization of continuous AE signals generated by leakage, i.e. random noise is much more difficult than that of short burst signal sources. Eeffective tool for all such situations is time reversal (TR) signal processing [1], which results in space - time wave focusing, partial source signal reconstruction and more precise source location than other used techniques (up to 1 mm). After artificial AE source location tests on various plates, reported in [1], we applied TR technique on large steam pipeline (4140 x 245 x 37.5 mm) and small pressure vessels to prove its practical use under real industrial conditions. Leakages were simulated with random noise signals emitted by piezoelectric transducers. AE signals were recorded during the real leaks on power plant. Those signals were overlapped with other more intensive signals reproducing real large background noise on power plant (water flow in the pipe). Noise mixture was detected by AE transducers mounted on 1m long waveguides welded to the tested structure. Long signals from two transducers were recorded, time reversed and rebroadcast to the structure using reciprocal TR method. Maximum of their cross-correlation denotes the leakage source on structure surface. More detailed surface scanning around roughly pre-localized source was necessary to precise localization. Scanning can be realized e.g. by scanning laser interferometer or numerically in a perfect computer model of the structure.

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INFLUENCE OF RARE EARTHS ON BIODEGRADABLE MAGNESIUM ALLOYS USED IN MEDICAL PROSTHESES

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Keywords: biodegradable materials, magnesium alloys, rare earths, ultrasonic methods

Abstract: Biodegradable materials are used as alternative implants for orthopedic applications due suitable strength, fatigue resistance, ductility and biocorrosion resistance which are features for biodegradable implants. Mechanical properties can be improved by adding alloying elements. The decrease of the corrosion rate of Mg can be induced by modifying the structure and phase distribution. Thus, Mg alloys have been designed to meet the requirements of bone repair implant materials by adding Calcium and Yttrium. Usually Ca is added to control corrosion rate of Mg alloys and thinning grain boundaries. Rare earths are often used as addition elements to improve alloys properties as biocompatibility and creep resistance. Mg based alloy with Ca and Y had been proved to be a biocompatible material, osteoconductive and biodegradable and can be used in bone repairs. The system is defined as Mg100-(n+x) Ca(n) RE(x), varying the RE concentration in order to slow the degradation process. Beside morphological characterization with SEM, EDX, non-invasive testing is required to be carried out the determination of mechanical characteristics. The interest in this study is to analyse the influence of Yttrium over elastic properties of these alloys in order to choose the best values appropriate with human bones, using Resonant Ultrasound Spectroscopy and ultrasound method.

ARCAN DEVICE EMPLOYED IN CFRP TESTING

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Keywords: Arcan device, CFRP, mechanical tests, FEM, complex stresses

Abstract: CFRP are used in most wide domains due their low density, lack of mechanical fatigue phenomena and high strength –to weight ratio. Low strength to impact on the normal direction to fiber's plane, leads to delamination and fiber breaking and these must be nondestructive evaluated in order to avoid further damage propagation. Also, the behavior of interlaminar fractures of composites is investigated numerically and experimental, the test being carried out with Arcan specimens that offer the possibility to use a single type of specimen in order to extract the fracture properties. The variation of loading direction between 00 and 900 towards the fibers direction allows the obtaining of different complex state of stress. From electromagnetic point of view, CFRP structure represents an inhomogeneous structure of electric conductive fibers embedded into a dielectric material, thus an electromagnetic configurable architecture (CA) can be used to evaluate the materials. Starting from apriori knowledge about Iosipescu specimen, the modelling will be carried in FEM software to optimize the shape of the specimen, in order to obtain more uniform stresses in cross section. A FEM is performed for Iosipescu specimen, designed for pure shear, when it is mounted in Arcan device and loaded in order to obtain some complex states of stress as close as possible to those encountered in practice. The studied material is Carbon Fiber Reinforced Plastics used in aerospace industry. In order to adopt an appropriate form of the specimens, an analysis is required before the tests are carried out.

EXPERIMENTAL SETUP FOR MPI SENSITIVITY MEASUREMENTS: FIRST RESULTS

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Keywords: Magnetic particle inspection, sensitivity, multi-directional magnetization, magnetic field polarization

Abstract: During the development process of MPI equipment it is very helpful to know the detection ability of MPI process. Such an ability depends on material properties of the body under test, applied magnetic field, defect shape and size, and detection particle properties. There is not enough information published, so that in-house experiments are justified. An experimental setup for MPI sensitivity measurement is presented in this paper. The setup consists of four coils and a two steel plates attached to the coils. The steel plates are magnetized by the flux generated by the coils. The coils are situated at the vertices of a square and the opposite coils are electrically connected in series therefore the setup can be fed by two independent current waveforms. These current waveforms generate two perpendicular magnetic field components on the plates therefore it is possible to generate arbitrary tangential magnetization on the surfaces of the steel plates. A standard QQI gauge is placed on the steel plate in the middle of the coils. If the setup is fed by two sine waveforms of the same frequency and arbitrary phase shift the tangential magnetization of the steel plates is elliptical polarized. The coils are fed from a pair of arbitrary-waveform generators amplified by a pair of power amplifiers.
Using this setup the sensitivity of MPI can be measured for a various parameters. Measurement setup as well as first experimental results are presented in this paper.

AN INITIAL INVESTIGATION ON THE POTENTIAL APPLICABILITY OF ULTRASONIC TESTING TO ASSESS EFFECTS OF CORROSION ON LINEAR AND NONLINEAR ELASTIC BEHAVIOUR OF PRE-STRESSING STEEL STRANDS

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Keywords: Electrochemical corrosion, cracking, ultrasonic testing, linear and nonlinear behaviour, pre-stressing steel strands

Abstract: Corrosion of pre-stressing strands causes a deterioration of condition of civil engineering structures like bridges, therefore periodic inspections are necessary to prevent collapse of such structures. The corrosion of steel is a slow process however it can be well reproduced in the lab using accelerated corrosion process. Monitoring the amount of corrosion in a sample is of great importance to predict the integrity and the residual life-time of structures. The ultrasonic techniques were proposed as valid methods of analysing the data recorded during the monitoring. In this paper we show results of our experimental study and the application potential of ultrasonic techniques to analyse the effect of damage induced by accelerated corrosion on the linear and nonlinear elastic behaviour of a steel strands. These initial results show the possibility for the application of nonlinear ultrasonic testing methods for monitoring of condition of strands which are built into bridge girders.

STRUCTURAL ANOMALY IMAGING IN ALUMINIUM AND CONCRETE SPECIMEN USING SEISMIC MEASUREMENTS

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Keywords: structural anomaly detection, Kalman filter, unscented hybrid simulated annealing, inverse problem

Abstract: The prediction of heterogeneous material distributions, the identification of faults in materials and structures or reconnaissance in soil are only a few among numerous examples of engineering applications that require advanced detection methods. In this work, we present an anomaly detection method based on propagation of seismic waves with a potential for application during mechanized tunnelling. Most of the advance reconnaissance methods used nowadays rely on travel time measurements or migration techniques and therefore do not use all of the information hidden in seismic waves. In contrast, a full waveform inversion provides a detailed image of the ground. The algorithm of unscented hybrid simulated annealing is a non-deterministic and gradient-free full waveform inversion approach, which combines the algorithm of simulated annealing with the unscented Kalman filter. As the inversion parameters are free to choose in this algorithm, a large portion of the parameter space is reduced if the shape of the structural anomaly is roughly known. Additionally, the starting model does not have to be close to the real model as the algorithm bases on the non-deterministic exploration of all parameter configurations. Therefore, it is not prone to the effects of local minima like gradient-based approaches. In this work, the algorithm of unscented hybrid simulated annealing is validated on laboratory-generated seismic data. An experimental setup is built, which allows seismic investigations in the ultrasonic range with frequencies between 50 kHz and 2 MHz. Ultrasonic transducers trigger the excitation of elastic waves into the investigated medium. For waveform acquisition, a laser interferometer is used as it enables a contact-free recording of the seismic waves. Ultrasonic measurements are conducted on aluminium and concrete specimen, which contain structural anomalies like drilling holes and material changes. The algorithm of unscented hybrid simulated annealing is used in order to find the positions and sizes of the drilling holes as well as the shapes and material parameters of the structural anomalies.

CRYSTAL AND MAGNETIC STRUCTURES, MAGNETIC AND FERROELECTRIC PROPERTIES OF SrFe11.9In0.1O19

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Abstract: The investigation of strontium ferrites partially substituted with diamagnetic ions (Al, Nb, Zn etc.) [1, 2] has attract an attention due to their high functional properties. The high coercive force (Hc 160 * 103 A/m) with a sufficiently high residual induction allows to receive permanent magnets with a satisfactory specific magnetic energy. Their high electrical resistivity (ρ 108 Ohm* cm) allows to use hexaferrite magnets in the presence of high-frequency magnetic fields. Currently, these materials have received practical application in magnetic recording devices of information [3], as permanent magnets [4] and absorption area of decimeter and centimeter electromagnetic radiation.
Recently, a large ferroelectric polarization was found in strontium [5] and barium [6, 7] hexaferrites that opened a new direction for potential multiferroic candidate to the conventional ferrimagnetic oxides, such as SrFe12O19, which holds similar perovskite-like lattice units in its hexagonal structure. The perovskite BiFeO3 shows weak magnetism, which somehow limits its practical application. Therefore, preparation materials where a large ferroelectricity and strong ferromagnetism coexist would be a milestone for modern electrics and functionalized materials. However, the reasons of appearance of ferroelectric polarization in barium ferrites are still not clear.
The sample SrFe11.9In0.1O19 has been obtained by conventional solid reaction method. Its crystal and magnetic structure has been investigated by neutron diffraction method in a wide temperature range. The presence of spontaneous polarization has been discovered at room temperature. The refinement their crystal structure have been carried out in frameworks of centrosymmetric P63/mmc (№ 194) and non-centrosymmtric P63mc (№ 186) space groups. Analysis of refinement results allows explaining reasons of appearance electric polarization in strontium hexaferrites as result of unequal distortions of neighbouring octahedrons (tetraedrons and trigonal- bipyramids).

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NONDESTRUCTIVE EVALUATION OF THERMAL BARRIER COATING THICKNESS DEGRADATION USING INFRARED THERMOGRAPHY AND TERAHERTZ-TDS IMAGING

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Keywords: TBC, pulse phase thermography, THz, Thickness degradation

Abstract: Being hot gas path components, the super

alloy flaps and spacers of the gas turbine engine are coated with ceramic Thermal barrier coatings to withstand the high temperatures. During prolonged exposure at high service temperatures, the microstructure of the ceramic layer changes and it undergoes sintering. This can lead to an increase in its thermal conductivity during service. Such increase in the conductivity is undesirable because it would reduce the ability of the ceramic coating to provide the required thermal insulation to the underlying substrate. During service the coatings degrade because of erosion by hot gas and also by localised wear due to rubbing of flaps with spacers. It is necessary to assess the condition of the coatings as a function of service life through suitable non-destructive means. Pulse phase thermography and THz-TDS techniques are used to evaluate the degree of degradation of the TBC top coat thickness. Infrared thermography has the advantage of fast inspection of a large area. In this work, we used a numerical simulation aided calibration and development of a regression model to quantitatively analyse the thickness degradation in TBC system undergone variable time of thermal exposure. These measurements were later verified using well detailed THz-TDS imaging. Experimental results of both technique indicate that these two techniques are feasible for the evaluation of thickness degradation in TBC system

X-RAY INSPECTION SYSTEMS FOR ELECTRONIC PARTS

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Keywords: X-ray, detector, non-destructive testing, CMOS sensor, BGA component, soldering quality, X-ray control

Abstract: An X-ray inspection is one of the basic methods of non-destructive testing along with optical inspection. Lack of Russian manufacturers in this sector of measuring equipment was a barrier for implementation of the State program «Development of the electronics and radio electronics industry, 2013–2025». High sensitivity X-ray flat panel detector and inspection system concept for non-destructive testing of electronic components were developed. The detector is based on CMOS sensor with pixel pitch 50 um. Key features of the flat panel detector are: limiting spatial resolution 10 LP/mm, reading speed 30 fps, anode voltage range from 20 to 300 kV. Availability of technologies for the production of microfocus sources and flat panel detectors allows creating X-ray inspection system for electronic components for the needs of the microelectronics industry.

OPTIMIZATION IN THE DETECTION PERFORMANCE OF EXTREMELY LOW-FREQUENCY EDDY CURRENT TESTING FOR APPLICATION TO VARIOUS SHAPES OF CORROSION DEFECTS IN THE ACTUAL SOCIAL INFRASTRUCTURE

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Keywords: Nondestructive testing, ELECT, corrosion near the ground, Magnetic spectrum curve

Abstract: near ground and the thinning rate. In this study, the inclination angle of the magnetic sensor probe and the distance between two sensors were optimized by measuring a test sample, and the quantitative evaluation of the thinning rate and the corrosion position that has not been clarified until now were investigated. When the The aging of steel pipes used for lighting and sign poles that are a part of social infrastructure is becoming a problem. This aging is often caused by the corrosion of steel pipes generated near ground which is located several tens of millimeters from the ground line. The accident that the structure collapses has been reported due to the growth of ground corrosion defects. Currently, a general maintenance inspection is visual inspection performed by excavating the ground. However, it is difficult to detect the corrosion defects near the ground quickly and quantitatively with such an inspection method. We have developed the integrated magnetic sensor probe with two tilted sensors for the extremely low-frequency eddy current testing (ELECT) in order to detect the corrosion near the ground from

the ground surface. Using this probe, a correlation could be obtained between the signal attenuation due to the corrosion inclination angle of the sensor probe was decreased, the change rate of the signal intensity increased, and the corrosion at a deep position could be also detected. Under this conditions, the distance dependence which is the relationship between the signal intensity and the defect position from the sensor was measured and the obtained data was normalized with the signal intensity measured at the uncorroded area. As a result, it was possible to clearly extract the difference between the signal intensity at the uncorroded area and the corrosion defect. In addition, when the samples with different thinning rates were measured, the signal intensity depended on the thinning rate, and it was possible to evaluate the thinning rate of corrosion defects quantitatively. Furthermore, a method to estimate the position of corrosion defects was examined using the measured data of two magnetic sensors. The improvement of the change rate in signal intensity acquired by the two sensors was attempted by reducing the distance between sensors. Since the signal intensity changed with the distance between the sensors and the defect, it was also possible to estimate the position of the corrosion defect quantitatively. Therefore, the developed system can be applied to various shapes of corrosion defects generated

MAGNETIC STATE OBSERVER IN NDT AND SHM STUDIES

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Keywords: fatigue of material, non-destructive testing (NDT), structural health monitoring (SHM), magnetometer, measurement, signal analysis

Abstract: During the operation of machines and mechanical devices, there is a risk of damaging critical elements that may result in serious failures, unplanned downtimes, financial losses, and damage to the health of personnel or third parties. In order to reduce the above-mentioned hazards, periodic non-destructive tests (NDT) are performed and/or the work parameters and structural health are monitored (CM, SHM). The effectiveness of preventive actions, described by the probabilities of diagnosis POD, is the resultant of the expected diagnostic symptoms (knowledge about the process and accompanying phenomena), the choice of observation method (NDT, SHM), the quality of the measurement path, software quality and diagnostic criteria used for numerical analysis.
The article presents the project for the use of magnetic magnetometers in the 0 - 500 Hz band for remote, non-contact monitoring of object operation and assessment of the technical condition of ferromagnetic elements and systems. At the beginning, the theoretical foundations of passive magnetic tests and applied magnetometers (multi channels 3 D system) have been presented. Next, selected results of laboratory tests and applied measurement data analysis methods are presented. Then selected results of tests carried out on the real object are presented, among others Kaplan turbine and turbine jet engine. Finally, discussing the results of research, the strengths and weaknesses of the magnetic state observer were pointed out.
It has been experimentally demonstrated that a remote magnetic state observer provides qualitative and quantitative diagnostic information that can be used in NDT and SHM.

APPLICATION OF IMAGE SOURCE METHOD IN TIME REVERSAL OF ELASTIC WAVES

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Keywords: Time Reversal, Image Source Method, Acoustic Emission Sources, Minor Focus

Abstract: The paper deals with the Image Source Method (ISM) and the minor focuses within Time

Reversal (TR). The ISM is presented, i.e. approach of construction of Green functions as a sequence of wave arrivals from the source to the given point through various paths, and their usage to simulate wave propagation in solids. The ISM is applied to simulate the process of TR in rectangular plate where the minor focuses are observed, and their properties are derived. Experiment is conducted in order to verify the simulated observations. A rectangular aluminium plate is equipped with a piezoelectric transducer and a vibrometer is used to measure velocities on its surface. One-channel time reversal and cross-correlation-based method using the direct propagation are performed. Occurrence of the minor focuses within experimental results prove derived properties to be correct.

LASER SHOCK PROCESSING FOR NOVEL APPLICATIONS

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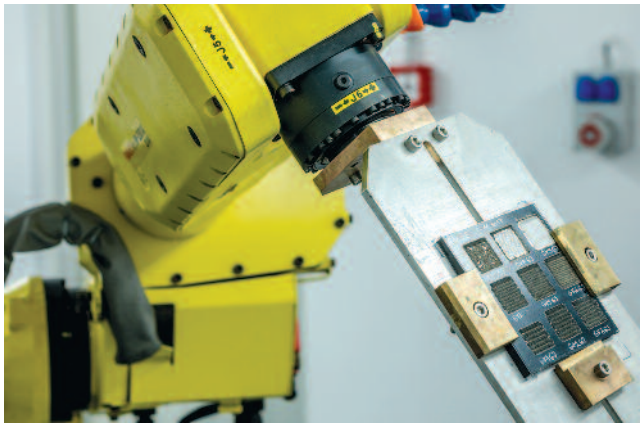
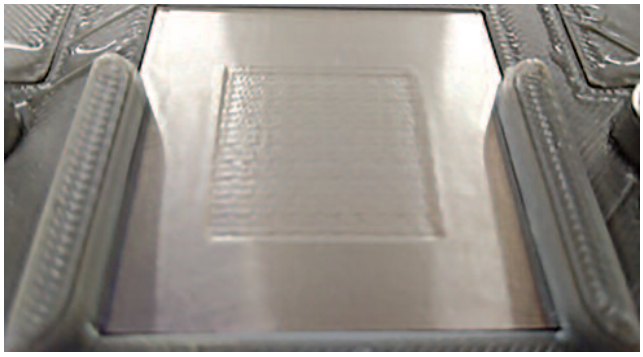
Laser shock peening (LSP) is a surface treatment process designed to improve mechanical properties and fatigue performance of various metals and alloys. The method utilizes a high intensity laser beam to generate strong pressure shock waves on the material surface. Fatigue life of components treated this way is increased due to compressive residual stresses of large magnitudes which prevent surface crack formation and crack propagation. So far, LSP found use mainly in aircraft industry. Thanks to increasing laser productivity, however, this surface treatment method may be used for other industrial applications, too.

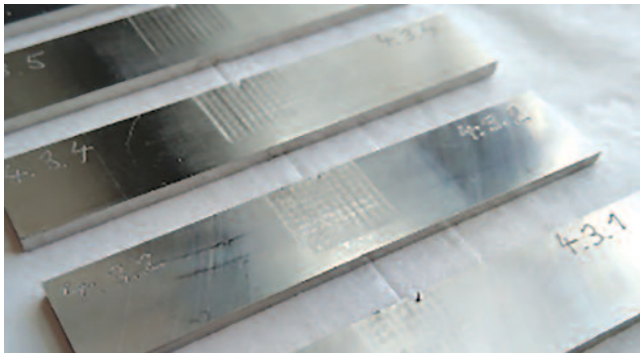
Equipment technology parameters
Load capacity: 20 kg (special cases up to 300 kg);
Max. Workpiece size: 1 m;
Experience with materials: Ti-alloys, stainless steel, Al-alloy, copper, Co-Cr;
Process beam size: Up to 5 x 5 mm;
Productivity: up to 1000 cm^2/hour;
Results: Uniform strengthening of surface layer up to 1.5 mm depth, extension of fatigue lifetime;
Testing methods: Residual stress measurement by X-Ray diffraction and hole drilling (ASTM standard E 837), measurement of fatigue strength and lifetime.

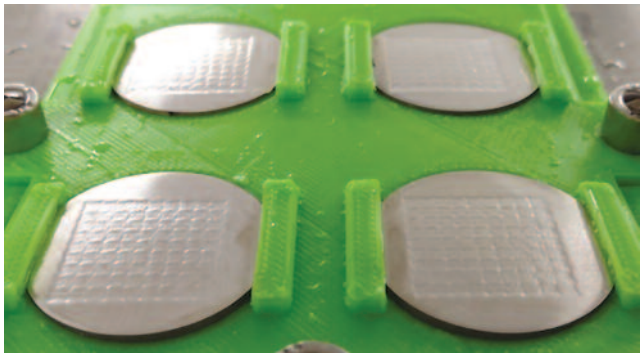
After several years of planning, the HiLASE research center launched its Laser Shock Peening (LSP) program in 2016, shortly after the commissioning of the powerful laser system Bivoj. LSP utilizes high energy nanosecond laser pulses to create deep compressive residual stresses in treated material surfaces which increases hardness, prevents stress corrosion cracking and leads to significant prolonging of fatigue



materials are aluminum and steel alloys, polycrystalline or monocrystalline copper, titanium, cobalt-chrome and magnesium alloys. At the beginning, the samples were mostly flat while more complex shapes such as tube segments, 3D printed structures and multiple cutting, drilling and forging tools have been modelled and treated recently. As for the results, The LSP team has already had several industrially viable accomplishments. For example, it managed to double the wear resistance of problematic forging tools and increase the high cycle fatigue lifetime of stainless steels used in nuclear industry more than ten times.







lifetime of critical industrial parts susceptible to fatigue failure. A protective enclosure has been erected around the treatment area, laying foundations to first LSP station in central Europe. Gradually, full automation of the process has been achieved where the movement of the sample carrying robotic arm is integrated with the laser operation, thus ensuring high processing speed without the loss of precision. The laboratory is equipped with an in-house X-ray diffractometer and hole drilling machine for post treatment residual stress analysis. Over the past three years, samples of distinct shapes and made of various materials have been treated. Among the

Station for Laser Shock Peening

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