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Examination of F/A-18 Honeycomb Composite Rudders for Disbond in the Presence of Water Using Through-Transmission Ultrasonics
T. Krause*, A. Edwards, S. Savage, P. Hungler,
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Numerical Investigation of Acoustic Nonlinearity for Ultrasonic Spectroscopy of Interface Defects in Composites
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*Wave Process Simulation System Laboratory, Moscow, Russia

Characterization of Casting Defects in Carbon Fibre Composite Detected by Ultrasonic Inspection
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*BYTEST Srl, Volpiano, Italy

Application of different ultrasonic techniques for non-destructive testing of the wind turbine blades
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*Ultrasound Institute, Kaunas University of Technology, Kaunas, Lithuania

Detection of Defects in Massive Concrete Blocks by Impact-Echo
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Application of Ultrasonic Cure Monitoring of Thermosets in Research and Production
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Characterization of an ultra-high temperature ceramic composite by ultrasonic testing
A. Talapatra*,
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Characterization of Casting Defects in Composite Carbon Fiber Material Detected by Ultrasonic Inspection
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A Viscoelastic plate theory for the fast modelling of Lamb wave solutions in NDT/SHM applications
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Digital model for prediction and analysis of ultrasonic guided waves propagation in structural health monitoring systems

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Wind turbine blade analysis using ultrasonic guided waves

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The signal processing technique for estimation of the phase velocity dispersion of guided waves

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Application of ultrasonic guided waves for investigation of structural components of tidal power plants

R. Raišutis*, R. Kazys, E. Zukauskas, L. Mažeika, A. Jankauskas, K. Burnham,
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Application of different modelling methods for investigation of ultrasonic guided waves propagation in GFRP and CFRP composites

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Microwave NDT System for Industrial Composites Applications

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Abstract:
Especially for composites like GFRP and NFRP classical NDT procedures either fail,
only show a very limited inspection depth, or they are too expensive to be used at
industrial scale. Microwaves, on the other side, are a promising alternative since
microwaves are able to easily penetrate non-conducting materials including
composites. In addition, the required evaluation circuitry can be designed
economically priced. Inside the material microwaves are reflected if they encounter
material or geometry irregularities. This basic principle can be exploited to create
a microwave NDT system, which allows localizing and classifying various types of
defects within DUTs. This contribution will not only show a practical realization of
a ready-to-use NDT system, but also results of various exemplary tests. It will be
shown how different probe heads can be selected to either go for high lateral
resolution or large penetration depth. Target groups for this presentation are the
non-destructive testing industry and quality-conscious composite manufacturers.

Keywords: Composite, Nondestructive Testing, NDT, Microwave, test system
NDT OF A Composite Using MicroCT Data and Image-based Finite Element Modelling

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Abstract:
Combining high quality CT scan data with computational methods presents itself as a valuable technique for NDT and the investigation of physical phenomena. Crucial to the success of such an analysis is the ability to represent the image data accurately and efficiently. Novel techniques for generating robust and accurate meshes based on radiographic imaging data have recently been developed which can generate meshes for topologies of arbitrary complexity and with any number of constituent materials. These techniques have been applied to the analysis of a ceramic matrix composite (CMC) material with matrix voids in order to identify peak stress concentration, and areas of potential failure through crack initiation.

Keywords: Radiographic Testing (RT), aerospace, automotive, ceramic matrix composites, computed tomography, Finite element method, stress analysis, radiographic testing
Study of Pulsed Phase Thermography for the Detection of Honeycombing Defects in Concrete Structures

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Abstract:
This work investigates the applicability and effectiveness of using Pulsed Phase Thermography (PPT) for improving defects detection in reinforced concrete structures. With the results of this project, the construction sector will have new techniques to achieve efficient non-destructive analysis. This will provide full information on the internal condition of concrete structures. The application of PPT in the field of civil engineering for the study of concrete structures is relatively recent. Contrary to previous studies performed on homogeneous materials with a high thermal conductivity, the application of this technique to a material like concrete is more delicate. Indeed, the thermal characteristics of concrete are radically different: the thermal conductivity of concrete is low and the studied thicknesses are much larger. These specificities imply that the scale of time of the analysis is strongly lengthened. The durations of the heating impulse and of the cooling phase are very longer. Moreover, the structure of the concrete is made up of a mixture of gravel, sand and cement. It is not homogeneous. In our case, the study focuses on the detection of an anomaly often encountered in reinforced concrete structures, the "rock pockets" which are also called honeycombing. Rock pockets are zones where some mortar is missing between the aggregates. A poor concrete making, a bad implementation or an insufficient vibration during concreting are generally at their origin. They constitute weak points in the water-tightness and in the stability of the concrete walls. The rock pockets are particularly dangerous when they are near the steel reinforcements, i.e. when they range roughly between 4 and 5 centimeters under the surface. The aim of the present research is the detection up to 6 cm depth from the surface. The principal difficulty involved in the detection of defects in concrete structures by conventional active thermography is the inhomogeneity of heating. Pulsed Phase Thermography is a method that solves this problem because it is less sensitive to this non-uniformity of heating and to surface irregularities. However, PPT requires a digital processing of thermographic images using a calculation software. It is important to conduct a study of the PPT, as it is torn between efficiency and length of analysis. This study should show how this technique can be applied concretely in an industrial process.

Keywords: Infrared Testing (IRT), civil engineering, Concrete, Infrared-pictures, Pulsed-phase-thermography, Civil-engineering, Honeycombing
The Honeycomb Sandwich Infrared Testing Procedure Optimization

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Abstract:
In this work the thermal-physical model of the starved spots in the honeycomb sandwich detection process was considered. The analysis of this thermal-physical model was performed. The optimal test modes were calculated. The experimental verification of the obtained results was made. It has been established that the disturbances presence impedes defects detection. The interferences caused by an emissivity fluctuation and a glue film inhomogeneity suppression way based on corresponding technique of data processing choice was suggested.

Keywords: Infrared Testing (IRT),
The experimental and innovative research on polarization of tensioned rebars coated with sulphur polymer composites

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Abstract:
This paper presents the results of the experimental research and analyses indicating the usefulness of polymer sulphur composites to the protection against corrosion of reinforcement. In paper presents materials also the domain of the personal investigations and the methodology are definite. After the analyze of the initial results the optimum compositions have been chosen to the experimental research. This paper presents investigation results of corrosion rate for steel reinforcement bars that have been covered with polymer coating and have been exposed to tensile stresses in a solution simulating pore-liquid of concrete. Experimental investigation of tendencies that occur during corrosion process of reinforcing steel covered with polymer and exposed to tensile stress has been attempted. To determine an effect of tensile stress on corrosion rate for St3S-b steel that has been covered with sulphuric coating and exposed to aqueous environment that was to simulate pore-liquid of concrete contaminated with chloride ions was an aim of the investigation. The samples underwent loading in an one-axial state of the stress including varied values of tensile stress, at the same time corrosion rate was determined potentiostatically. Potentiostatic investigation has been carried out in order to determine parameters describing corrosion rate of samples tested. Corrosion rate for the steel has decreased by orders of magnitude when covered with protective coating even though this latest became unseal at load exceeding. A small decrease of corrosion rate has been found for the steel that has not been covered with polymer coating when placed in model pore-liquid of concrete and exposed to tensile stress increasing.

Keywords: NDT-wide, Electromagnetic Testing (ET), Other Methods, civil engineering, steel plant, Reinforcing steel, Corrosion, Polarization, Tensile stress, Sulphur polymer composites
The moisture transport in the composite building materials

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Abstract:
The publication introduces results of experimental measurements which were carried out for the transport of humidity in porous composite concrete in non-stationary conditions to express the moisture profiles with the help of measuring apparatus working on the non-destructive model of electromagnetic microwave radiation. The aim is to verify the mentioned method of measurement for the description of moisture parameters of the composite building materials in practice. It is experimentally made material from more substance with different characteristics which together arrange resulting new feature, and which is not any from single composite (like the example composite building material – concrete, stone, cement, ceramics etc). These materials are developed by Institute of Technology of Building Materials and Components by Brno University of Technology and represents insulating mass with fibrous filling of specific gravity. The usage of the mentioned materials in building activities is based on the material characteristics and attributes. These materials are as subject for the following examination. We deal with the samples of materials, based on the products usage. Characteristic material is porous structure as well as composite building material, which includes aggregate gradation in range 0 up to 8 mm or possible in range 4 up to 8 mm.

Keywords: Electromagnetic Testing (ET), electromagnetic microwave radiation (EMWR), composite building material, transport of humidity
Nondestructive laser optoacoustic method of local elastic moduli and porosity measurements of particles reinforced isotropic composites

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Abstract:
The problem of nondestructive testing of the actual state of composite materials is of great importance because of essential decrease of their strength caused by defects and structural changes of a material arising by manufacturing and exploitation. Mechanical properties and structural features (e.g. elastic moduli and porosity) provide valuable information for residual service life evaluation of composite products. In the present work we have proposed and realized experimentally the laser optoacoustic method for the measurements of local elastic moduli and local volume fraction of air pores (porosity P) of isotropic composite materials. It is based on measurements of phase velocities of thermooptically excited longitudinal and shear ultrasonic waves in the frequency range 0.5-50 MHz. Porosity was determined using the dependence of phase velocity of longitudinal acoustic wave on porosity for a porous material and theoretical calculation of phase velocity in a composite material with the two-phase medium model. The thickness of investigated samples can be 0.1-70 mm, the locality of testing in the lateral dimension is 1-2 mm. The best relative accuracy of the Young-, shear moduli and the Poisson’s ratio measurements is 4-6%, of the porosity measurement – 2%. A number of aluminum alloy (silumin) matrix composite samples reinforced with SiC particles with the mean size of 14 microns in a different mass concentration n(SiC), as well as with aluminum oxide (corundum) nanoparticles was investigated. The investigated samples were disks of the diameter d=40 mm. We determined the porosity P in the center and in the periphery areas of each sample. The increase of n(SiC) leads to the growth of P, that in the center of each sample was slightly higher than in the periphery. This in turn causes the decrease of elastic moduli in comparison with the values theoretically calculated with the two-phase medium model. It was found that to provide the increase of elastic moduli by reinforcing of a metal matrix composite with SiC particles the incipient material porosity should not exceed 2-2.5%. So the developed laser optoacoustic method enables one to analyze experimentally the influence of the composition, sizes and the concentration of reinforced particles, as well as the effect of technological features of production on the elastic properties of composite materials.

Keywords: Ultrasonic Testing (UT), elastic moduli, porosity, laser optoacoustic method, isotropic composites
The elastic moduli measurement of high-melting nanoparticles modified metal matrix composites with the laser optoacoustic method

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Abstract: The problem of nondestructive monitoring of composite materials is very urgent, because structural changes arising during materials manufacturing and exploitation can significantly reduce their strength. Therefore mechanical properties such as elastic moduli can provide valuable information for residual life evaluation of composite products. In the present work we proposed and experimentally realized the method of local elastic moduli measurement of isotropic metal matrix composite materials based on laser excitation and piezoelectric detection of ultrasound (the laser optoacoustic method). Its main advantage over the traditional ultrasonic methods is the effective generation of short and powerful probe acoustic pulses, that is necessary for diagnostics of heterogeneous composite materials with strong absorption of ultrasound. The realized experimental setup allows to carry out the measurements of longitudinal and shear acoustic waves phase velocities in the frequency range 0.2-100 MHz. The thickness of investigated samples can be 0.1-70 mm, the locality of testing in the lateral dimension is 1-2 mm. The Young’s, shear moduli and Poisson’s ratio were calculated from the values of longitudinal and shear wave velocities. Well-known expressions of elasticity theory were used. The best relative accuracy of measurements is 4-6%. The investigated composite samples were manufactured by reactive cast of aluminum with titanium particles (07 series) and the mixture of titanium and synthetic diamond particles (50 nm and 150 nm) added into the melt (09 and 10 series). As a result of the reaction the intermetallic phase of Al3Ti was formed. The elastic moduli of 07 series samples grow with the increase of the melt dwell time before sample forming, that is governed by the Al3Ti fraction growth with the higher values of elastic moduli in comparison with aluminum. So the intermetallic strengthening takes place. The 09-10 series samples had densities less than the initial matrix, because of the porosity at the level of 3-5% appeared during the manufacturing. So the elastic moduli of all the samples of these series are 15-20% less than that of the aluminum matrix. So the initial composition and the melt dwell time have strong influence on the elastic moduli of the investigated composite samples. Therefore the laser optoacoustic method can be helpful in development of the optimal conditions of materials manufacturing with enhanced strength properties.

Keywords: Ultrasonic Testing (UT), laser optoacoustics, phase velocity, composite materials, elastic moduli, ultrasound
Non-Destructive Testing Evaluation of Low Velocity Impact Damage in Carbon Fiber-Reinforced Laminated Composites

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Abstract:
Fiber-reinforced laminated composite materials are widely used in aircraft, modern vehicles and light-weight structures. With their high elastic modulus, high strength, and capability of being tailored for a several applications, these materials offer definite advantages compared to more traditional structural materials. However, their behaviour under impact is of concern since those events may occur during manufacturing, normal operation or maintenance. The situation is critical for impacts that induce significant internal damage undetectable by visual inspection, which causes large reductions on the strength and stability of the structure. New standardized tests to assess the impact tolerance (ASTM D7136 and D7137) lose some of its appeal by its destructive nature as well as costs involved. Non-destructive techniques such as ultrasonic phased array or experimental modal analysis can be complementary in the evaluation of damage and structural integrity. In this paper, the results of both destructive and non-destructive experiments carried out on 48 composite specimens are presented. A good correlation between incident impact energy and delaminated area as well as variation of eigenfrequencies is noticed. This study does not only provide a better understanding of the impact phenomenon but can also help in design and implementation of new test procedures for structural assessment.

Keywords: Ultrasonic Testing (UT), Other Methods, aerospace, low velocity impact, damage detection, non-destructive testing, modal analysis, ultrasound phased array, Carbon fiber composite
Examination of F/A-18 Honeycomb Composite Rudders for Disbond in the Presence of Water Using Through-Transmission Ultrasonics

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Abstract:
The flight control surfaces of F/A-18 aircraft are composed of carbon/epoxy skin and aluminum honeycomb core composite material that has a known susceptibility to water ingress. The rudder has failed in flight due to moisture induced bond degradation between skin and core. Manual through-transmission Ultrasonic Testing (UT), applied to the rudder surface, currently identifies disbond as a reduction in received signal amplitude. However, water within the honeycomb cells provides significant sound transmission, which may mask disbond. In this study, water was first identified within two in-service rudders using thermography. Precise water locations were then mapped by neutron radiography. Time-base analysis of through-transmission A-scans, obtained using squirter technology, permitted discrimination of cell wall signals from signals that had passed through water within the cells. Examination of received cell wall signal intensities, modeled for disbond in the presence of water, demonstrated potential for identification of disbond even when water was present.

Keywords: Ultrasonic Testing (UT), aerospace, Honeycomb Composite Rudders
Numerical Investigation of Acoustic Nonlinearity for Ultrasonic Spectroscopy of Interface Defects in Composites

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Abstract:
The article is devoted to an innovative non-linear acoustic technique of non-destructive testing (NDT) of composites. Modern composites have a very complex inhomogeneous structure with a large number of interface bond-lines. Along these bond-lines there are interface defects, such as delaminations, microcracks, debonding and weakening of adhesive bonds. This leads to the necessity of distinguishing from each other a signal from given defects and a signal from interface bond-lines. The task becomes more complicated because interface defects have a very small thickness of micro or even nanoscopic scale. Conventional techniques of ultrasonic testing have a very low sensitivity of these defects detection. The article describes a novel acoustic-mechanical approach to numerical modeling of nonlinear acoustic interaction of ultrasonic wave with interface defect. The results of computer simulation of this nonlinear acoustic interaction are analyzed. It is suggested a simple technique of nonlinear ultrasonic spectroscopy for detecting and sizing the interface defects.

Keywords: Ultrasonic Testing (UT), aerospace, power plant, Opposite phased transducer, Numerical method, Modeling and Simulation, Composite material, Interface defect, Nonlinear wave/defect interaction, Nonlinear ultrasonic spectroscopy, Subharmonic and superharmonic, Period-doubling bifurcation
Characterization of Casting Defects in Carbon Fibre Composite Detected by Ultrasonic Inspection

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Abstract:
Technological innovations applied in the aeronautical sectors prefers the use of structures that are in able to have great advantages in terms of performance with a significant weight reduction. This involves research and development of new materials, in which composite materials have an high importance in the study of new concept structural architecture. Objective of the presentation is the correlation of results obtained using non-destructive testing, ultrasonic method in particular, with the discontinuity which produce an indication in carbon fiber composites. The indication can be found by ultrasonic method in form of attenuation signal and/or reflection signal. The characterization of typical defects enucleated in CFRP materials (Carbon Fiber Reinforced Polymer) or CRP (Carbon Reinforced Plastic) will therefore be supported by a significant activity of material testing laboratory. Laboratory activity will be directed to the identification, quantification and characterization of the discontinuities due to problems and/or failure during the production process.

Keywords: Ultrasonic Testing (UT),
Application of different ultrasonic techniques for non-destructive testing of the wind turbine blades

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Abstract:
Wind power is a source of environmentally safe and renewable energy. In order to fully exploit the energy of wind power all construction elements of the wind turbines should be inspected periodically against the faults due to fatigue, continuous stress and etc. One of the main elements of the wind turbines are the blades, which are complicated objects for inspection by the conventional NDT techniques, because they are made from anisotropic composite materials, are multi-layered, have variable thickness and have an arbitrary curved surface. The objective of this study was to adapt different ultrasonic techniques for the inspection of wind turbine blades. The measurements were performed using air-coupled ultrasonic technique using Lamb waves and pulse-echo immersion ultrasonics using a moving water container with two different transducers. The measurements performed show that the adapted air-coupled ultrasonic technique using Lamb waves is the most promising in terms of implementation as it only requires access to one side and is non-contact. However, the pulse-echo immersion testing can identify the position and size with better accuracy. Obtained results show that different ultrasonic techniques enable to identify different defect properties (type, geometry, the defective layer of the multi-layered structure). Therefore, the best results are achieved combining different techniques.

Keywords: Ultrasonic Testing (UT), air-coupled, wind turbine, composite, ultrasonic testing
Detection of Defects in Massive Concrete Blocks by Impact-Echo

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Abstract:
Artificially inserted honeycombs, plastic ducts or steel bars were detected in massive concrete blocks by impact-echo. This approach is based on resonance method with wide band spectral analysis. Several steel bars of diameters 22 and 32 mm were intercepted at the depth between 50 and 55 mm from the face of the front wall of the block. Also air-filled plastic duct and three of four artificial honeycombs were significantly detected using impact-echo device. This method seems to be very promising in the field of non-destructive testing of massive concrete structures situated in powerplants, foundations of powerful engines, concrete dams, etc.

Keywords: Ultrasonic Testing (UT), civil engineering, concrete, impact-echo, defect
Application of Ultrasonic Cure Monitoring of Thermosets in Research and Production

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Abstract:
The characterisation of the curing process of epoxies by ultrasonic is a well known diagnostic /1/. Meanwhile this diagnostic is used to study the cross linking process in some other materials, such as rubber or EVA for solar cell encapsulation. An outstanding application is the diagnostic of the curing process in composite materials applied in aviation and automotive industries consisting of carbon or glass matrix and B-stage resin. Results for composite materials were published for example by Döring et al /2/ using a conventional NDT hardware and adapted software. This paper presents for different materials a comparison of ultrasonic measurements using a new hardware and usual laboratory diagnostics as Differential Scanning Calorimetry (DSC9; Dynamic Mechanical Analysis (DMA) and oscillating rheology demonstrating the effectiveness of ultrasonic diagnostic in production and research. Meanwhile the usage of ultrasonic diagnostic does not need so much experience of the user and often it is easily possible to integrate this method directly into the production process to optimize the cycle time and to document the course of the curing process. The presented data demonstrate that the ultrasonic diagnostic is able to fill the gap between the laboratory methods and a diagnostic included directly in a tool. /1/ Alig, I., D. Lellinger, and G.P. Johari, Relaxations In Thermosets .28. Ultrasonic Studies Of Curing Kinetics Of Ethylene-Diamine-Cured Epoxide. Journal of Polymer Science Part B-Polymer Physics, 1992. 30(8): p. 791-799. /2/ http://www.ndt.net/article/wcndt00/papers/idn482/idn482.htm

Keywords: Ultrasonic Testing (UT), aerospace, automotive, power plant,
Characterization of an ultra-high temperature ceramic composite by ultrasonic testing

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Abstract:
The ultra high temperature ceramic composites (UHTCC) are of interest for hypersonic vehicle leading edge. The ultrasonic testing is one of the widely used non-destructive testing (NDT) for the material characterization. The aim of investigations described in this article is measurement of the mechanical properties of two ceramic composite by pulse-echo ultrasonic testing. These two samples (ZrB2-20%ZrC-20%SiC-5%Si3N4 and ZrB2 -20%SiC- 5%Si3N4) were fabricated by hot pressing into 25mm diameter and 4mm thickness discs. The measurements were performed using pulse echo ultrasonic technique and ultrasonic transducers with the frequencies 5.0 MHz. It was determined that the velocity of ultrasonic longitudinal and shear waves varies when the frequency is changing. Ultrasound velocity measurements were used to evaluate mechanical properties of UHTCC. These composites were prepared from ZrB2, SiC, ZrC and Si3N4 by ball milling and hot pressing.

Keywords: Ultrasonic Testing (UT), elastic modulus, Ultra high temperature ceramic composite (UHTCC), ultrasound velocity measurements, Poisson’s ratio, fracture toughness.
Characterization of Casting Defects in Composite Carbon Fiber Material Detected by Ultrasonic Inspection

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Abstract:
Technological innovations applied in the aeronautical sectors prefers the use of structures that are in able to have great advantages in terms of performance with a significant weight reduction. This involves research and development of new materials, in which composite materials have an high importance in the study of new concept structural architecture. Objective of the presentation is the correlation of results obtained using non-destructive testing, ultrasonic method in particular, with the discontinuity which produce an indication in carbon fiber composites. The indication can be found by ultrasonic method in form of attenuation signal and/or reflection signal. The characterization of typical defects enucleated in CFRP materials (Carbon Fiber Reinforced Polymer) or CRP (Carbon Reinforced Plastic) will therefore be supported by a significant activity of material testing laboratory. Laboratory activity will be directed to the identification, quantification and characterization of the discontinuities due to problems and/or failure during the production process.

Keywords: Ultrasonic Testing (UT), non-destructive testing, carbon fiber composite, carbon fiber reinforced polymer (CFRP), ultrasonic method, carbon reinforced plastic (CRP)
A Viscoelastic plate theory for the fast modelling of Lamb wave solutions in NDT/SHM applications

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Abstract:
Guided ultrasonic waves have many useful properties that can be exploited for non-destructive testing (NDT) and structural health monitoring (SHM) applications. However, much information and analysis regarding the generation and propagation of these waves is needed before automatic processing and analysis techniques can provide useful information for reliable fault monitoring. Moreover, the knowledge of dispersion characteristics is crucial for the optimization of sensor networks in terms of sensor placement and number of sensors. On that account, the present work introduces a higher order plate theory for modelling disperse solutions in viscoelastic fibre-reinforced composites. This approach offers a higher computational efficiency and simplicity in comparison to traditional exact elasticity methods, while providing an adequate description of the structure global response in the low frequency range which is the most used in Lamb wave applications. The proposed method was applied to several examples in order to obtain numerical results in anisotropic elastic and viscoelastic plates. Some comparisons to experimental data are presented, and the effectiveness and limitations of the method are discussed.

Keywords: Ultrasonic Testing (UT), Plate Theory, Viscoelasticity, Fibre Composite, Structural Health Monitoring, Lamb Waves
Digital model for prediction and analysis of ultrasonic guided waves propagation in structural health monitoring systems

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Abstract:
Structural Health Monitoring (SHM) systems based on ultrasonic guided waves are one of the most promising non-destructive damage detection and characterization strategies for engineering structures. SHM systems help to improve the safety and durability of critical structures combining an array of embedded transducers for capturing real-time data from wide variety of engineering components. However the implementation of such systems is complicated and faces problems related to limited amount of measuring positions, verification of the monitoring technique and complicated interpretation and analysis of captured signals from measurements. The computer model which makes interpreting and analyzing guided wave signals of an object under investigation easier was developed. The proposed model takes into account material properties such as dimensions, anisotropy, group velocity of guided waves and also positions, orientations and directivity patterns of ultrasonic transducers. The model enables to predict the propagation of different guided wave modes in rectangular plates, to measure delay times between single modes, to predict waveforms of the signals, received from structure, to analyze wave reflections and to retrace its propagation paths. This paper presents the principle of proposed model including generation, propagation and reception of guided waves. The model is demonstrated by simulation of guided wave propagation in GFRP composite plate with embedded MFC transducers. Simulation results were compared with experimental data, obtained from GFRP bending experiments during Compair framework project 7 in TWI laboratory in Great Britain. Good coincidence between experimental and modeled results was obtained in the case of delay time measurements and retracing guided wave propagation paths. However the research showed that proposed model is not so effective predicting waveforms and amplitudes of guided wave modes due to unknown relations between efficiency of generation of different modes.

Keywords: Ultrasonic Testing (UT), Structural Health Monitoring, Guided Waves
Wind turbine blade analysis using ultrasonic guided waves

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Abstract:
One of the most important parts of the wind turbines are their blades made of the glass fiber reinforced plastic (GFRP) composite layers glued together using the epoxy. The investigation of wind turbine blades is complicated due to the curved surface, multilayered structure and different mechanical and acoustical properties of the materials used in the construction. Since guided waves can propagate over long distances in a plate-like structures, these waves have a great potential for being applied to the non-destructive testing (NDT) of wind turbine blades. The purpose of this paper is to obtain theoretical phase cph and group cgr velocities dispersion curves and to verify them experimentally, in order to apply ultrasonic guided waves for non-destructive testing of composite structures having complicated geometry. However, in order to solve this task the structure, material’s properties of the zones to be inspected should be determined. The dispersion curves of phase and group velocities of propagating guided waves in wind turbine blade were calculated using the semi-analytical finite element (SAFE) method, for each distinct wind turbine blade zone. The pitch-catch method has been selected for experimental investigation of wind turbine blades, because this type of inspection can be performed having access just from one side of wind turbine blade. According to this technique the transmitter was attached at fixed position and the receiver was scanned. Two contact type broadband transducers with central frequency of 150 kHz were used. The main advantage of this technique is that it enables to obtain all propagating waves in the object under investigation. The rough estimation of the dispersion curves is obtained using two-dimensional fast Fourier transform (2D FFT). The analysis of experimental results has shown that the most efficient excitation was of asymmetric A0 wave mode, which in the presented structure was excited in 50 – 200 kHz frequency range. In general, the experimental investigation demonstrated regularities similar to obtained using simulation. However, more detailed comparison of the modelling and the experimental results revealed some differences which partially can be explained by uncertainties of the determination of the elastic properties.

Keywords: Ultrasonic Testing (UT), two-dimensional Fourier transform, semi-analytical finite element method, dispersion curve, wind turbine blade testing, guided wave
The signal processing technique for estimation of the phase velocity dispersion of guided waves

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Abstract:
One of the main areas for application of the guided waves is inspection of composite materials, which possess anisotropy of elastic properties. The propagation velocity of the guided waves is the key parameter which is used to estimate the deviation of the properties of the composite materials during inspection. In this work, the measurement method of the phase velocity based the zero-crossing technique are enabling to reconstruct the segment of the dispersion curve. According to this technique the multiple time instances at which the signal crosses the zero amplitude line are determined. This information enables to estimate the durations of each of the half period in the signal and to monitor their variations depending on the distance. The durations of the half periods converted into equivalent frequencies give the distribution of the different frequency components in the signal. On the other hand the same time instances enable to obtain the set of the phase velocity values. These values together with corresponding set of the equivalent frequencies give the estimation of the dispersion curve. The proposed technique was demonstrated on the simulated signals. The simulated signals were obtained by modelling of the A0 and the S0 modes of the guided waves in the 100x40x0.2 mm CFRP plate. The obtained results demonstrated a very good coincidence of the phase velocity values calculated using the proposed method with the dispersion curve obtained by the SAFE technique. The investigations demonstrated also that the distribution of the components of different frequency in the signals of the asymmetric A0 and symmetric S0 Lamb waves modes possess opposite character and can be used for mode identification.

Keywords: Ultrasonic Testing (UT), Zero-crossing technique, Guided Waves, Phase velocity, Dispersion curve
Application of ultrasonic guided waves for investigation of structural components of tidal power plants

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Abstract:
The tidal power is one of the promising sources of the renewable energy to be picked up by the tidal stream generators. During the last decade various types of the tidal power plant prototypes were developed, some of them contain special hydrofoils made from composites. However, due to continuous operation under the harsh marine conditions, such constructions should be periodically tested against the faults. The overall structure of hydrofoil is very complicated as the skin and the main spar are made from glass fibre and carbon fibre composite, filled by foam. Inspection of so complex object is a great challenge for conventional non-destructive testing (NDT) techniques. The objective of the presented work was to determine the most critical regions of hydrofoil to be tested, to select the modes of ultrasonic guided waves to be used and to determine the parameters of their excitation, propagation along the sample and interaction with non-homogeneities. The analysis of the multi-layered structure of the hydrofoil to be inspected using ultrasonic guided waves was performed. The geometry, material type, properties and the critical regions of the hydrofoil that should be tested were identified. The dispersion curves of phase velocity of the guided waves propagating in the multi-layered structure of hydrofoil have been determined using SAFE method. The propagating modes of guided waves in the multi-layered structures of the skin and the main spar were identified using the modelling and the experiments. It was estimated, that in order to use the fundamental modes, the frequency range of operation below 200 kHz should be used for inspection of the skin and even lower for inspection of the main spar. Also, possible excitation places and possible arrangement of the transducers were estimated. The testing of main spar should be performed in longitudinal direction and other parts of hydrofoil - along perpendicular direction due to special orientation of fibres in the composite. It was shown that even in the case of limited number of transducers embedded into recommended positions the necessary coverage of the object can be achieved.

Keywords: NDT-wide, Ultrasonic Testing (UT), civil engineering, offshore, power plant, hydrofoil, ultrasonic guided waves, tidal power plant, multi-layered composite, structure health monitoring
Application of different modelling methods for investigation of ultrasonic guided waves propagation in GFRP and CFRP composites

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Abstract:
The application of composite materials in different areas of industry leads to the need of inspection of such components. One of the inspection techniques which are already used is based on the ultrasonic guided waves. However, modelling of guided waves propagation in composite components meets multiple problems: geometrical and structural complexity of components, anisotropy of materials, not defined strictly elastic properties. This leads to the fact that the modelling task cannot be solved using only one simulation technique. So, the objective of the investigations carried out was to review of modelling methods related to propagation of ultrasonic guided waves and to define which question can be answered by them. The analytical, semi-analytical, finite difference and finite element methods were reviewed. The advantages and limitations of each technique were clarified. The analytical techniques can be used just for very rough estimation in 1D approach and do not take into account the peculiarities of geometry. It was shown that the most suitable for the determination of the dispersion curves of the guided wave propagating in the object under investigation is the semi-analytical finite element method. However, the main problem usually is caused by non-accurate definition of the elastic properties which should be adjusted using the experimental measurements. The other related methods - finite difference and finite element, in general enable overall analysis of the wave propagation in the non-uniform, complex structure of multi-layered composite components, interaction with internal non-homogeneities. These techniques require huge computation recourses and complicated analysis of modelling data. On the other hand this is only technique which enables to investigate guided wave propagation at least in the part of composite component. The performance and the results possible to obtain by each of the reviewed techniques were demonstrated by investigation of guided waves in the multi-layered GFPR and CFRP composites.

Keywords: NDT-wide, Ultrasonic Testing (UT), aerospace, automotive, civil engineering, offshore, power plant, railway, analytical and semi-analytical, multi-layered composite, numerical modelling, Ultrasonic guided waves, finite difference and finite element
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