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Advances in lock-in amplifier signal processing optimization: Signal-to-noise-ratio, NDE measurement methodologies and case studies with thermal waves

By A. Mandelis

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Abstract

Detailed analytical models of signal-to noise ratios (SNR) of the conventional frequency-domain (FD) and time-domain (TD) dynamic signal processing methodologies are presented based on a generalized communications systems approach. These methodologies are theoretically and experimentally compared to the (hybrid) rate-window (RW) method using thermal-wave signal phenomenology. It is shown that the lock-in amplifier (LIA) rate-window processing mode in general, and the digital LIA mode in particular, exhibits superior SNR to the conventional FD-LIA method, to the transient, time-averaged TD-LIA method, and to time-averaged transient response. Between the pulse-duration-scanned and pulse-repetition-period scanned RW methodologies, the former is shown to exhibit superior SNR due to the fixed noise bandwidth, and excellent agreement between the theory and case-study thermal-wave data, as it does not require knowledge of the instrumental transfer function as a normalizing input.

Keywords: lock-in amplifier, signal-to-noise ratio, optimization, frequency, time, domain, rate-window, photothermal, waves, communication theory.

Deconvolution and multiple elimination to enhance temporal resolution in ultrasonic volume-scan measurements

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Abstract

Traditionally, data obtained with a C-scan only gives one value for each particular point of the target. If the whole time-signal is preserved, it is possible, however, to obtain more information. Since the time-signal resulting from a pulse-echo measurement may be very complex, advanced algorithms are needed. Applying the inverse formulation of the theory describing the interaction of a plane wave with a layered medium can be used in order to obtain the acoustic parameters of the target material.

Keywords: c-scan, ultrasonic, wave theory, deconvolution, multiple elimination, resolution, processing.

Deconvolution and wavelet analysis on ultrasonic reflection tomography

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Abstract

Ultrasonic Reflection Tomography results from a linearization of the Inverse Acoustic Scattering Problem, named Inverse Born Approximation. This is a method of Inverse Problem resolution. But, it allows a reconstruction of small disturbances in a reference medium. These small disturbances generate a small signal and now, the problem is to discriminate this useful weak signal from a parasitical strong signal with background noise. First, we tried to improve the resolution of the URT and we used a deconvolution technic based on the Kalman filter. Secondly, we present a problem of signal discrimination by Wavelet Analysis.

Keywords: Ultrasonic Reflection Tomography, Inverse Born Approximation, Bio-Medical Engineering, Non-Destructive Evaluation, Deconvolution, Wavelet analysis.

Ultrasonic measurements of thickness of thin internal layers in highly absorptive layered polymer composite based on time domain inversion algorithm

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Abstract

A method of investigation of the structure, properties and geometrical parameters of highly absorptive polymer multilayered media using short pulse scanning acoustic microscopy is described. The possibility of successful evaluation and visualization of internal layers having 3% of the total thickness of a sample is demonstrated. A time domain digital algorithm is developed to provide a precise thickness measurement of each layer in the layered polymer.

Keywords: NDE, ultrasonic spectroscopy, thickness gage, date inversion

Reconstruction of thermal conductivity depth profiles from photothermal measurements

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Abstract

Frequency or lateral scans of the surface temperature respond to the material's depth profile of thermal conductivity and thermal density. Based on analytical expressions of surface temperature the unknown profiles can be retrieved by minimization of an appropriately defined merit function. Numerical simulations demonstrate the advantage of applying gradient techniques with regularization. Experimental results for surface hardened steels are presented

Keywords: Thermal waves, photothermal microscopy, depth profiling, inversion, hardness measurement, non destructive evaluation.

Nonlinear inverse scattering methods for thermal wave slice tomography

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Abstract

A wavelet domain, non-linear inverse scattering approach is presented for imaging sub-surface defects in a material sample based on observations of scattered thermal waves. We use newly developed wavelet-based regularization methods to resolve better the edge structures of defects relative to reconstructions obtained with smoothness-type regularizers. A non-linear approximation to the exact forward scattering model is introduced to simplify the inversion with little loss in accuracy. We demonstrate this approach on cross-section imaging problems using synthetically generated scattering data from transmission and backprojection geometries.

Keywords: Thermal wave slice tomography, inverse scattering, wavelet transform, edge preserving regularization.

The source localisation inverse problem and its application to the depth profiling of optical absorption in thin films by photothermal measurements

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Abstract

The depth distribution of low concentration optical absorbers in thin films may be measured using photothermal techniques, in which an irradiating impulse establishes a heat flux source profile below the sample surface due to optical absorption and subsequent non-radiative decay. Inverse scattering techniques are used to reconstruct the initial heat flux profile from experimental data, from which the optical absorption profile is easily determined. The inverse scattering reconstructions may be sensitive to experimental bias errors because of ill conditioning. A body of experimental work in this laboratory has led to a systematic methodology for recovering stable, reliable solutions to this inverse problems.

Keywords: photoacoustic, photothermal, inverse problem, regularisation.

Thermal wave diffraction tomographic microscopy

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Abstract

Thermal-wave Slice Diffraction Tomography (TSDT) is a photothermal imaging method for the detection of sub-surface defects in materials by way of mapping cross-sectional slice thermal diffusivity. A mathematical model that represents the behavior of a three dimensional thermal-wave is correlated with a numerical reconstruction technique which utilizes the Tikhonov regularization method to invert almost singular matrices resulting from the ill-posedness of the inverse thermal-wave problem. Experimentally, photothermal-radiometric detection microscopy is used. A focused laser beam and the emitted blackbody radiation are scanned across a material cross-section and the photothermal radiometric signal is recorded in back-scatter or transmission. The numerically reconstructed experimental data constitute a tomogram.

Keywords: thermal-wave slice diffraction tomography, photothermal-radiometric detection microscopy, Tikhonov regularization, ill-posed inverse problem.

Computer simulation of radiographic NDE

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Abstract

A Practical simulation tool producing radiographic images from parts represented by CAD data sets is presented. It allows the setup of a virtual 3D scene including radiation source, detector plane and one or more parts to be inspected. Defect structures can be handled as separated structures. All geometrical objects of the scene are interactive arrangable and different material properties of objects in one scene are allowed. Also it is possible to control the different radiographic parameters. With help of the software tool a variety of practical tasks in radiography can be simulated. The used radiographic model is presented and examples illustrate the application of the simulation tool.

Keywords: radiographic testing, computer simulation, CAD interface, parameter optimization.

Detailed simulation of ultrasonic inspections

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Abstract

Simulations of ultrasonic inspection of engineered components have been performed at Chalk River Laboratories of AECL for over 10 years. The computer model, called EWE for Elastic Wave Equations, solves those equations using a novel finite difference scheme. It simulates the propagation of an ultrasonic wave from the transducer to a flaw, the scatter of waves from the flaw, and measurement of signals at a receive transducer. Regions of different materials, water and steel for example, can be simulated. In addition, regions with slightly different material properties from the parent material can be investigated. The two major types of output are displays of the ultrasonic waves inside the component and the corresponding amplitude or A-scans.

The EWE model has been applied to the inspection of large pipes in a nuclear plant, gas pipeline welds and steam generator tubes. Most recent work has dealt with the ultrasonic inspection of pressure tubes in CANDU reactors. Pressure tube inspections can reliably detect and size defects; however, there are improvements that can be made. For example, knowing the sharpness of a flaw-tip is crucial for effective fitness-for-service assessments. Computer modelling of the ultrasonic inspection of flaws with different root radii has suggested inspection techniques that provide flaw tip radius information. A preliminary investigation of these methods has been made in the laboratory.

The basis for the model will be reviewed at the presentation. Then the results of computer simulations will be displayed on a PC using an interactive program that analyzes simulated A-scans. This software tool gives operators direct access to the results of computer simulations.

Keywords: ultrasonic, simulation, flaw characterization, material properties, visualization.

Parameter estimation techniques for ultrasonic signals analysis and interpretation

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Abstract

Our overall objective is to improve the resolution of the ultrasonic signals by estimating the impulse response of flaws located near to the outer surface in nuclear reactor pressure vessels. Thus, we are addressing the restoration problem, that is, in general, ill-posed and difficult to solve in practice. Our specific objective is to use the information provided by the estimated impulse response, in order to discriminate between crack-like defects that jeopardize the integrity of the piece and volumetric defects that do not.

Keywords: ultrasonic NDE, impulse responses, parameter estimation, model order selection.

Precision measurement of galvanization thickness applicable on-line to steel and derivated products

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Abstract

Using analytical solutions of Maxwell equations and carefully analyzing them, we have shown that an eddy current coil placed near a ferromagnetic conductive substrate coated with a non ferromagnetic layer, can be used to determine two parameters: first, the product of the thickness and electrical conductivity of the coating, and second, the permeability-to-conductivity ratio of the substrate. The method [1] needs no calibration to infer the above quantities. One must know only geometry of the coil and inspected object.

Keywords: zinc thickness measurement, coating thickness measurement, eddy current measurement, on-line measurement, measurement without contact, quality control, galvanized products, non ferromagnetic coating, ferromagnetic substrate, galvanization.

Novel digital pulse pile-up identification and parameter estimation algorithms in nuclear spectrometry

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Abstract

A fast waveform sampling facility has been recently developed and integrated into the VAX-based data acquisition system at the Energy Research Laboratory of KFUPM. The facility can acquire waveform records up to 1024 samples in length, at 10-bit resolution with a sampling rate of 50 MHz. The present study is concerned with nuclear pulse identification and parameter estimation. Modern digital signal processing techniques offer a better alternative to the conventional analog approach, so our aim is to develop algorithms to run in on-line DSP hardware.

We consider three algorithms, using both real and simulated data. Firstly, we develop a window based pulse classification technique depending on a predefined pulse model. Then 3-point and 4-point deconvolution and curve fitting techniques are presented and the results compared. The study includes noise analysis which is especially important when deconvolution is used.

Keywords: pulse pile-up, deconvolution, parameter estimation, DSP hardware, filter, impulse response.

Signal processing for the extraction of damping rates for a multi-mode vibration in metallic structures

By H. Gasquet

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Abstract

In this paper, several signal processing techniques are evaluated for their effectiveness in extracting high resolution time-frequency information from the impulse response functions of structures. The intent is to extract damping rates and mode frequencies for the case of strong damping. Both real and synthetic data are used to demonstrate common problems with window distortion, spectral leakage, and sensitivity to phase in common approaches to signal analysis. Processing techniques will be compared on the basis of their strengths and weaknesses. A discussion of future research directions will be presented along with recommendations for promising approaches for this analysis problem.

Keywords: time-frequency decomposition, signal processing, evaluation, distortion, spectral leakage, damping rate, spectrogram, matched filtering, wavelet, Gabor.

Entropy - like regularisation applied to ultrasonic non-destructive evaluation

By D. J. Battle[1], R. P. Harrison[1], M. Hedley[2]

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Abstract

Of the non-linear regularisation approaches which have been applied to image reconstruction, the Maximum Entropy (ME) approach has met with some outstanding successes, and continues to be an active area of research in many fields. Ultrasonic images are however, generally complex valued, and the positivity constraint inherent in ME formulations is therefore inappropriate. This paper seeks to demonstrate the utility of entropy-like regularisation of acoustic images reconstructed form both synthesised and real arrays in the absence of any positivity constraint. Rather, the complex image amplitudes are regularised with respect to a homogeneous background amplitude according to a cross-entropy measure. Comparisons are drawn between the performance of the conventional Synthetic Aperture Focussing Technique (SAFT), and the ME approach in B-scan deconvolution, and preliminary three-dimensional (3-D) imaging results form a prototype polyvinylidene fluoride (PVDF) array transducer are presented.

Keywords: ultrasonic imaging, array processing, regularisation, maximum entropy.

Synthetic aperture focusing technique data processing applied to laser-ultrasonics

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Abstract

Laser-ultrasonics is an emerging nondestructive technique using lasers for the generation and detection of ultrasound which presents numerous advantages for industrial inspection. In this paper, the problem of the detection by laser-ultrasonics of small defects within a material is addressed. Experimental results obtained with laser-ultrasonics are reported and processed using the Synthetic Aperture Focusing Technique (SAFT), yielding improved flaw detectability and spatial resolution. Experiments have been performed on an aluminum sample with a contoured back surface and two flat-bottom holes. Practical interest of coupling SAFT to laser-ultrasonics is also discussed.

Keywords: laser-ultrasonics, laser-ultrasound, SAFT, signal processing.

Nonlinear image restoration methods for eddy current nondestructive evaluation

By B. Wang[1], J. P. Basart[1], and J. C. Moulder[2]

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Abstract

In this paper we present two nonlinear image restoration methods for improving the resolution of two-dimensional eddy current testing data. The two methods are based on simulated annealing and genetic algorithms, respectively. The basic idea of the nonlinear methods is to formulate the image restoration problem as a nonlinear combinatorial optimization problem by using proper error criteria and regularization functions. To deal with the slow speed of the combinatorial optimization methods, a fast nonlinear forward model based on radial basis function networks was developed. Our test results showed that the nonlinear methods are superior to linear methods such as the Wiener filter and maximum entropy method in terms of resolution, noise reduction, and reliability. However, they also require longer execution times than the linear methods.

Keywords: eddy current testing, image restoration, simulated annealing, genetic algorithms, radial basis function networks.

Development of automated analysis of eddy current signals

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[2]National Research Council

Abstract

Steam generators of nuclear power plants typically contain a total of about 15000 thin-wall tubes which are held in place by support structures. At the points of contact, the tubes may wear, be deformed by accumulated corrosion products, or be subject to stress while being exposed to a corrosive environment. These and other conditions can lead to tube degradation and eventual failure. Vigorous and expensive inspection programs are necessary to monitor tube degradation and identify incipient failures. The only proven NDE method for inspection of thousands of tubes in a reasonable time is eddy current testing (ET). However, the eddy current test technique can suffer from poor discrimination between defects and background noise. Another problem is the vast amount of data that human analysts have to cope with efficiently.

The need for automated analysis systems is well recognized. For CANDU® nuclear power plants, an advisory system is being developed as a first step to enhance analyst productivity. However, many conceptual problems must be overcome before any analysis algorithms may be defined. They generally fall into two areas:

- human factors such as performance expectation and verification, the analyst's special knowledge and his or her effective by typically unstructured approach to problem solving, and
- technical obstacles such as signal variability, incomplete training sets and the difficulty in translating human feature recognition methodology into a mathematical procedure.

This presentation describes the nature of some typical signals, how they are manually analyzed and how they might be automatically interpreted.

Keywords: Eddy current, inspection, steam generator, automated analysis, signal analysis, data handling.

Eddy current tomography: A Bayesian approach with a compound weak membrane-Beta prior model

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Abstract

This work deals with an Eddy current imaging system. The solution of the associated inverse problem is regularized in a Bayesian estimation framework. The proposed approach combines the following a priori information: the function to be reconstructed had to be piecewise continuous and is bounded between 0 and 1. This compound *a priori* knowledge allows us to enhance reconstruction results with respect to the shape precision and the size resolution of the objects to be reconstructed in this kind of application.

Keywords: Eddy current tomography, inverse problem, regularization, Bayesian estimation, Beta law, weak membrane, Markov random field.

Modified Fourier descriptors: a new parametrization of eddy current signatures applied to the rail defect classification

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Abstract

The work presented in this paper deals with the problem of parametrization of eddy current signals. In a defect recognition process, it is important to extract a reduced and relevant set of features that owns both a great descriptive potential of defects and a strong insensitivity to some transformations (offset, homothetic transformation and reverse description). An original parametrization procedure called Modified Fourier Descriptors is presented and compared to an autoregressive modeling. The last section considers the application of rail head inspection and some considerations about the parameter selection and the classification problem are detailed. The classification performances will be given for the two parametrization procedures and it will be shown the superiority of the Modified Fourier Descriptors for our application.

Keywords: parametrization, Fourier Descriptors, AutoRegressive process, eddy current, rail head inspection, selection, classification.

Visualization of surface defects using acoustic emission - Data acquisition and data processing

By Th. Benziger and G. Brüggemann

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Abstract

The laser induced acoustic emission (AE) testing is a new developed method for the assessment of surfaces of different materials. It is possible to obtain information about the state of the surface and the regions near below the surface of the material in test. Therefore the m by n measurement points at the surface of the sample are irradiated by a laser beam. This causes the appearance of mechanical stresses. Their reduction can lead to acoustic emission.

The acquired AE signals are filtered and processed using an AE workstation. The control of the measurement and the postprocessing of the data set obtained form the AE device is performed using special developed hardware and software running on personal computer. These components and their advantages are described in the paper.

Keywords: acoustic emission, solid-state laser, data acquisition, data processing.

Statistical method applied to very low thermal signatures in NDT and thermoelastic stress analysis

By Y. Largouët, S. Offermann, C. Bissieux, J. L. Beaudoin

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Abstract

Very small temperature variations are quantified by a statistical treatment of standard thermographic images. This procedure determines the signal amplitude value, comparing the noise and the noisy signal dispersions characterized by their variances. This reliable and simple method has the advantage of needing no link to the reference signal and of treating any kind of signal shape. It is applied here to thermoelastic analysis of applied and residual stresses and to the non-destructive testing by means of photothermal radiometry.

Keywords: infrared thermography, signal processing, thermoelastic stress analysis, applied stress, residual stress, non destructive testing.

An adaptive technique for background removal in D2D

By A. Braggiotti[1] and S. Marinetti[2]

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Abstract

In a Thermal Non Destructive test, carried out according to the reflection scheme, all the information is extracted from the temperature of the heated surface. In a not controlled environment, the signal is affected by contribution of external sources of parasitic signal such as reflections, heater unevenness, etc. To reduce the effects of this kind of noise, three techniques are presented, one in space and two in time. The first one is strictly related to the use of heaters with one-dimensional spatial unevenness, as it is for D2D technique. The other two can be more generally used in case of global heating by means of lamps and flashes.

Keywords: infrared thermography, multiplicative noise, background removal, adaptive technique.

Optical correlator for real-time industrial inspection

By A. Bergeron[1], M. Bruynooghe[2], M. Doucet[1]

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Abstract

In this contribution, an optical correlator is proposed for real-time quality control inspection. The quality control technique is based on the moiré analysis of image. The correlator based on liquid crystal display technology can process images at a rate and a format compatible with both video camera standard and computer display standard. As such, the proposed system can be used for industrial applications requiring real-time monitoring of manufactured objects. Experimental results have shown that supervised detection of defects can be performed accurately.

Keywords: optical correlation, real-time defect detection, phase-shifting moiré, industrial inspection, optical processing, industrial quality control.

The application of wavelets and fuzzy logic to eddy current flaw detection of steam generator tubes

By S.-F. Chuang[1,2], J. P. Basart[1,2] and J. C. Moulder[1]

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Abstract

Based upon the concepts of wavelets and fuzzy logic, we developed an automatic eddy-current data analysis system for detecting flaws in steam generator tubes. The system consists of three major processing stages: 1) preprocessing for calibrating the data and removing the background 2) wavelet transformation for reducing noise and identifing possible flaw indications, and 3) fuzzy logic for testing the wavelet results in order to discriminate between true positives and false positives. Results from tests thus far indicate that the overall procedure has a good potential for automatic flaw detection in steam generator tubes.

Keywords: eddy current, signal processing, wavelets, fuzzy logic, steam generator tubes, flaw detection.

A self-adaptive neural network for on-line blind separation of convolved sources

By A. Cichocki and J. Cao

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Abstract

In this paper, we investigate a new approach for improving the convergence property and performance of blind convolved sources separation under stationary and nonstationary environments. We propose a simple modification Jutten-Herault algorithm by introducing auxiliary additive and multiplicative noise and self-adaptive local on-line algorithm for learning rates. Simulation results are presented to illustrate the effectiveness and performance of the proposed method.

Keywords: blind source separation, convolved mixture, additive and multiplicative artificial noise, convergence property, self-adaptive learning rate, stationary and nonstationary environment, neural network, on-line learning algorithm.

A neural network based method for the in depth reconstruction of material properties: theory and application

By C. Glorieux, J. Caerels and J. Thoen

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Abstract

A neural network method to solve inverse problems is explained in general. The method is applied to reconstruct thermal conductivity profiles of one-dimensionally inhomogenous materials from a photopyroelectric frequency spectrum. The performance of the profile recognition algorithm is tested by simulated examples and illustrated in the experimental case of an inhomogeneously aligned liquid crystal.

Keywords: neural network, photopyroelectric, thermal conductivity, inhomogeneous alignment, liquid crystal.

Improvement of neural network performances in thermal NDE

By P.G. Bison[1], S. Marinetti[1], G. Manduchi[2], E. Grinzato[1]

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Abstract

Neural networks (NNs) have been applied successfully in thermal NDE to detect and classify faults inside opaque materials.

The obtained results show how NNs are very useful tool for solving NDE problems when the experimental conditions do not allow the use of analytical inversion formulae. The main purpose of our previous papers about this topic was proving the effectiveness of NNs in the NDE field. In this paper we go more into details about the structure of NNs. For instance, by changing the output layer layout according to the problem being solved, it is possible to improve significantly the performances of the NN.

The classical "1 of N" approach, that clamp to 1 the output corresponding to the correct class and to 0 all the other class during the training, is not the most suitable for classification in case of overlapping or fuzzy class boundaries. In TNDE, the estimation problem may be fuzzy due to 3D effect in heat diffusion. The source of overlapping classes behaves like a noise whose statistical description is assumed gaussian for the sake of simplicity. The intrepolation capability of NN was also tested using a reduced set of examples. Some NNs with different output structures were trained using experimental data.

Experimental results are reported and classified according to the estimation capability.

Keywords: infrared thermography, thermal non destructive testing, neural network.

Ultrasonic guided wave system for fast assessment of disbonds in large multilayered structures

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Abstract

Standard ultrasonics make use of bulk waves to point-by-point evaluate materials in the proximate location under (or near) the inspection probe. Moreover, bulk waves represent three-dimensional waves which attenuate very rapidly along distances and also have some difficulty inspecting thin bonded, non uniform and hidden structures; since with a conventional C-scan, the inspection transducer probe needs an access to each point of the inspected area. This paper describes a UT system based on ultrasonic guided waves for fast assessment of disbonds in large multilayered metallic structures.

The inspection approach is based on the use of Lamb waves or, generally, the resonant modes of propagation in a plate-like structures. While the system represent a digital PC-based manual scanner driven by a state-of-the-art guidewave software, which comprises of a vast list of features and capabilities for defect assessment and graphical interpretation and imaging.

In this work, we experimentally elaborate the guided wave testing technique to determine quickly, cost-effectively and reliably where these multilayered structurally significant parts are in need of repair (to locate defects such as corrosion and disbonds). To demonstrate the efficiency and sensitivity of guided wave system, experiments were performed on 1.0-1.6 mm thick aluminum plates. These tests were carried on real and simulated types of common of adhesive joint designs. A lap splice joint sample, a sample with a tear strap or doubler reinforcement and a simulated repair patch. When testing with simulated samples, various sizes, shapes and locations of programmed disbonds in the interface of aluminum plate were introduced by leaving the programmed areas free of epoxy (air gaps) when the plates were bonded.

Keywords: corrosion, ultrasonics, Lamb waves, adhesive joints inspection.

Detection of flaws in radiographic images by hypothesis generation and testing approach

By R. M. Palenichka*, and U. Zscherpel**

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Abstract

Detection and binary segmentation of low-contrast flaws in noisy radiographic images is considered with an application to non-destructive evaluation of materials and industrial articles. The known approaches, like the edge detection or unsharp masking with a consecutive thresholding, yield poor results for such images. In the presented method of object (flaw) detection, a model-based approach is adopted which relies on shape constraints of the objects to be detected. For detection of local objects, the maximum likelihood principle and statistical hypothesis testing is used with the confidence control during all stages of the image analysis. The proposed novel procedure of estimation of the image intensity from noisy pixels ensures a robust evaluation of basic model parameters in the presence of outliers which are considered as impulsive noise.

Keywords: flaw detection, radiographic image, primitive pattern, hypothesis testing, robust estimate.

Twenty-five years of infrared thermography among other NDE techniques in Poland

By P. Pregowski

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Abstract

There are two NDT associations in Poland. They mainly engage in practical aspects of the defects discovered with utilization of the following methods of testing: ultrasonic, magnetic, eddy-current, radiographic and liquid-penetrant. Since 1990, Polish thermographers worked within its own society. Up today, most of works are directed for more effective search for defects, because the interest in their evaluation grows. Problems of Signal Processing for NDE of materials were not the subject of the separate meetings in Poland but have been scattered among many of them. This paper will try to present a short revue of research teams engaged in this subject with the aim to give the links for potential cooperation between interested parties.

Keywords: infrared thermography, optics, optoelectronics, acousto-optics, neural networks.

Ultrasonic NDE and NDT in China

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Abstract

Under the police of reforming and opening, the national economy of China has been booming, consequently, the ultrasonic technique of non destructive evaluation (UNDE) and testing (UNDT) have been widely used and popularized in China, The rich variety of phases such as application, education, training, research works, manufacturing, and organization as well, of UNDE and UDET in China is reviewed in this paper.

Keywords: ultrasonic NDE and NDT, China.

The combination of thermography and image treatment for monitoring of and quality assurance during laser welding

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Abstract

The efficiency of laser welding strongly depends on the stability of the process. Even small deviations and instabilities of the melt pool cause a strong influence on the process and the weld quality. The goal is to reduce these problems by analyzing infrared images acquired from the laser welding process.

The image acquisition requires a CCD camera and a specific spectral filter combination. A preliminary image treatment is necessary due to interferences and noise in the thermogram. For the recognition of process deviations it is inevitable to establish typical characteristics of the image. Basing on these parameters determined with the thermogram it is possible to classify the defects.

Keywords: laser welding, thermography, process control, quality assurance, image treatment.

A study of delamination in a high silica glass phenolic cylindrical liner by ultrasonic, X-ray radiography and thermography techniques

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Abstract

The delamination in a high silica glass phenolic cylindrical liner made by hand layup has been studied by using Ultrasonic (Drycoupling, Pulse echo), X-ray Radiography and Thermography techniques. These techniques are tried out on the same component at the same location for comparison. Drycoupling showed a wide range of gain points (58 dB to 99 dB) on the liner. Radiography revealed delaminations at higher gain points (above 70 dB) observed in Drycoupling. Thermography manifested these higher gain points as lesser hot/cold regions corresponding to the delaminations observed in Radiography. The data obtained regarding the presence, size and location (depth) of the delamination by Drycoupling, Radiography and Thermography techniques are discussed and correlated. The merits and limitations of these NDT techniques in assessing the delamination are also discussed.

Keywords: drycoupling, pulse-echo technique, radiography, thermography, delamination, liner, gain (dB).

Pulse-echo infrared thermal wave imaging studies for multilayered objects with defects or flaws

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Abstract

Pulse-echo infrared thermal wave imaging has been recognized as a powerful tool for nondestructive evaluation (NDE) of materials. Using eigenfunctions and integration transformations, we present an analytical three-dimensional model of pulse-echo infrared thermal wave imaging that fits multilayered objects with defects or flaws. The simulated images based on our theory are compared with that only valid for a non-laminated object.

Keywords: thermal wave imaging, multilayers, defects and flaws

Pulsed phase thermography (PPT) applied to the inspection of wood panels

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Abstract

Pulsed Phase Thermography or PPT has been recently introduced. This novel technique enhances the probing capabilities of traditional pulsed thermography (sometimes referred to as 'thermal wave imaging'). In this paper, a brief review of PPT principles will be introduced followed by results of investigation on wood specimens. Comparisons with a classical thermographic approach will be done as well.

Advanced multichannel thermal and visual system

By B. Wiecek[1], S. Zwolenik[1] and P. Sawicki[2]

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Abstract

In this paper a new PCI multichannel interface card for thermal and visual images acquisition and processing is presented. Both system architecture and software functions, especially for more advanced image processing are outlined. The presented system is designed to link single thermal and up to four high resolution CCD cameras with powerful computer equipped with PCI bus. The system allows to capture thermal and visual images in parallel in real-time into the operational memory in the computer. A new software dedicated for 3-D operations allows to mix thermal and optical images, reconstruct 3-D scene for measuring a distance or correct directional emissivity. The software in Win'95 and WinNT compatible.

Keywords: thermal and optical image processing, data acquisition, PCI interface.

Digital radiography - State of the art in industrial applications of NDT

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Abstract

An overview is given about the applicability of existing film digitization systems for NDT X-ray films. According to the physical parameters of the X-ray film (optical density range, image sharpness, contrast sensitivity, SNR) an appropriate scanner has to be applied. The scanning accuracy is determined by the application field (wall thickness and radiation energy, type and size of flaws to be detected).

One major advantage of the digital data acquisition is the application of image processing for the enhancement of flaw detection. A new method of digital filtering for the enhancement of longitudinal cracks is presented. The procedure was even successfully to distinguish between cracks and root undercuts. An example from the detection of IGSC cracks in images from radiographs of austenitic tube welds from light water reactors is presented.

Keywords: digital radiography, film digitization, luminescence imaging plates, image processing, crack detection.

Quantitative nondestructive measurement of density differences in ceramic materials using industrial computed tomography

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Abstract

The local density of ceramics is one of the critical parameters of the quality of these materials, as the mechanical properties are highly dependent on this value. The origin of these differences lies in a not uniform distribution of the micro porosity due to the production process. Due to the difficult mechanical preparation of the samples, the traditional density measurement is very time-consuming.

The attenuation of X-radiation is dependent on the density and on the atomic number of the material. The attenuation factor, however, is also dependent on the energy of the radiation. For general applications, the specific activity of monochromatic sources, like Cs-137, is too low and a large source spot will result in a poor spatial resolution. Therefore, a lot of industrial CT scanners use the bremsstrahlung of X-ray tubes.

Under these circumstances, all materials show a so called beam hardening effect, i.e. a non-linear relationship between the materials thickness and the attenuation. The usual photon-counting detection system, therefore, will pretend attenuation differences for varying thickness within the beam path.

To get qualitative results, it is often sufficient to harden the radiation using physical filters that reduce the amount of weak energy photons. This method, however, is also reducing the total photon flux and therefore decreasing the signal-to-noise ratio. For accurate quantitative measurements the beam hardening effect has to be taken into account when reconstructing the CT image.

Keywords: computed tomography, density, ceramics.

Quantitative condition monitoring and data extraction by digital radiography and phosphor plate radiology

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Abstract

The possibilities and the techniques for extraction of data from radiographs and phosphor plates is described and exemplified; emphasizing the critical data processing steps in relation to wall thickness determination of major pipes. Determination of wall thickness by the tangential shot technique allow an accuracy better than 0.5 mm for pipes with nominal thickness in the range 3 to 10 mm. Experience has lead to the conclusion that reproducibility and speed of measurement is considerably improved relative to human manual measurements. A completary technique for attenuation based determination of wall thickness of pipes is described and the present limitations of the technique is discussed on the basis of acquired spectra on isotope exposures of step wedges. It is found that the influence of scattered radiation is significant. It appears, that the build-up factor needs to be determined as function of energy for a given detector. Results obtained on preliminary characterisation and use of a phosphor imaging plate system suggests that special precautions are necessary in order to use such imaging system for radiation attenuation calculations, e.g. of remaining wall thickness.

Keywords: wall thickness measurement, scattered radiation, detector response, quantitative radiography.

Non-invasive 3-D radioactive particle tracking in heterogeneous flows: Principle & applications

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Abstract

In recent years engineers have shown an increasing interest in non-invasive measurement techniques for the investigation of the flow of continuous or particulate phases in heterogeneous reactors; Radioactive Particle Tracking (RPT) is perhaps one of the most promising techniques of this kind. RPT is a 3-D position-sensitive Lagrangian technique able to measure local instantaneous and time-averaged full-field flow information non-destructively, by using an array of strategically positioned scintillation detectors (the γ-ray camera) and a punctual γ-emitter freely wandering within the vessel under study. This paper surveys a number of RPT applications to heterogeneous flows which are of great interest to process industry. Some experimental results from our work highlight RPT potential in studying spouted and circulating fluidized beds, and three-phase fluidized beds.

Keywords: particle tracking, heterogeneous reactors, granular flows, particle velocity, trajectory reconstruction.

Ultrasonic measurement of the remaining thickness of corroded cast iron samples

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Abstract

Ultrasonic waves have been used to evaluate the remaining thickness of corroded cast iron samples. Because of the nature of the corrosion defects investigated, when the ultrasonic beam interrogates a location where such a defect is present, the reflected signal coming from the uncorroded-corroded cast iron interface is very weak. In fact, in order to be able to evaluate the remaining thickness of sound iron, the ultrasonic signal which arrives right after the front surface echo has to be highly amplified and special signal processing must be used.

Keywords: ultrasound, corrosion, graphitization, cast iron.

Elastic property modification in aluminum induced by laser shock processing

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Abstract

The elastic property of aluminum alloy 2024 - T62 shocked by laser is investigated using laser ultrasonics method. The results show that the elastic property modification is distributed. The distribution can be fitted by polynomial regression. The elastic constants C_{11} and Poisson' ratio ν increase within the shocked area. The relative changes of C_{11} and ν can be reached up to 40.6% and 24.8 % respectively. The elastic constants C_{44} and Young' modulu E decrease up to 29% and 25.4 % respectively. The Leme coefficients γ increases near the center, but decreases at the edge. The detailed experimental results, analysis, and discussions are presented at this paper.

Keywords: laser shock processing, laser ultrasonics method, elastic property, distribution, location measurement, epicenter waveform, time-of-flight.

Measurement method based on scanning Doppler continuous wave acoustic microscope

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Abstract

It is proposed in this paper to use the Doppler effect in the V(z) mode of the continuous wave reflection scanning acoustic microscope. In this method the acoustic lens is moved perpendicular to sample surface with constant velocity. The reflectance function can be estimated by the processing of the output Doppler signal. To confirm the results of theoretical analyze a Doppler continuous wave scanning microscope with operating frequency 300 MHz was developed. With help of the designed device, the investigation of the reflection functions and surface acoustic waves (SAW) velocity measurements were done on materials with known acoustical parameters.

Keywords: acoustic microscopy, Doppler effect, V(z) method, reflectance function.

Directional emissivity correction in thermal and visual systems

By B. Wiecek[1], P. Sawicki[2] and R. Stein[1]

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Abstract

In this paper a new method of directional emissivity correction by extracting 3D shape of object is described. By taking under consideration the Lambert's law it allows to correct directional emissivity with much higher accuracy. We present both mathematical base for this solution and its technical implementation. The results presented in this paper can be used in various application, e.g. in photogrammetry or robotics.

Keywords: directional emissivity, DLT method, thermal and visual image processing.

Measurement of materials behaviour in microstructures by means of digital holography

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Abstract

Holographic Interferometry is widely used as a contactless method in experimental mechanics and non-destructive testing of materials and engineering components. But measuring the full 3D-deformation of the object's surface requires a complicated optical setup with at least three different illumination directions. Especially if micro-components with lateral extensions less than 10 mm have to be examined the simple use of holography becomes more and more a problem.

Since high resolution CCD cameras are available for reasonable prices, digital holography can be used as a fast, easy and precise method for holographic interferometry. Compact and simple setups can be achieved by the use of fiber optics. Digital holography replaces the holographic plate by a CCD matrix. No additional magnifying optical components are needed to achieve lateral resolutions of about 5µm and a deformation resolution of 15nm.

Some experiments using four illumination direction in an optimized setup are presented. They show the 3D-deformation fields of small objects under a given load. The results are compared with computer simulations to receive material parameters.

Keywords: digital holography, holographic interferometry, materials' properties.

Correlation of enhanced visual inspection image features with corrosion loss measurements

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Abstract

In aircraft, lap joint corrosion can be detected optically due to pillowing caused by inter-layer corrosion. The current first-pass technique of visual inspection has been shown to be unreliable for corrosion detection, and enhanced visual inspection techniques have been developed to address this shortcoming.

D Sight and Edge of Light inspections have been performed on specimens from the Institute for Aerospace Research (IAR) Specimen Library. These specimens are from retired commercial aircraft, with various levels of natural corrosion. Many specimens have been characterized by x-ray, eddy current, and enhanced visual inspection techniques. IAR's NDI Analysis software was used to process enhanced visual inspection images and to extract features which are correlated with corrosion loss.

Keywords: edge of light, D sight, corrosion, aging aircraft, NDI.

Evaluation of semiconductors by acoustoelectric current

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Abstract

Acoustoelectric current (AEC) induced in semiconductors is produced by the interaction of their carriers with surface acoustic waves (SAW) propagated in an adjacent piezoelectric. By use of a pulsed laser beam focused on a spot on the surface of the semiconductor, the photo-generated carriers (PGC) interact also with the SAW's potential waves. As a result, it creates an additional transient AEC adding to a stable AEC. Relying upon both transient and stable AEC, one is able to characterize the localized mobility and lifetime.

Keywords: AE current, semiconductor, transient AE current, PGC, mobility, lifetime.

Thermal conductivity and diffusivity depth profiles by photothermal technique: The direct and inverse problem

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Abstract

The theoretical model of the heat propagation in a medium with thermal parameters variable in depth is here completely reviewed. The direct relationship between the thermal depth profiles and the temperature rise at the surface is found and a way to invert it is also shown. Some crucial points of the inversion procedure are also briefly discussed. The depth profiles reconstructed by numerical simulations are in excellent agreement with the real profiles.

Keywords: depth profiling, hardness, inverse problem, nondestructive evaluation, photothermal techniques, thermal waves.

Measurement of ultrasonic waves attenuation in concrete: The spectral ratio technique

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Abstract

The ultrasonic pulse velocity test is the most frequently used test for the nondestructive evaluation of concrete. However, pulse velocity is a parameter that is not always a good indicator of the quality of concrete. The subject of this paper concerns the use of ultrasonic waves attenuation as a tool for evaluating concrete. A spectral ratio technique is used to determine an non-dimensional parameter called the quality factor. This parameter is a measure of the absence of attenuation in the material. The results of this study show that different values of the quality factor can be associated with different concrete qualities. In addition, the quality factor appears more sensitive to variation of the mechanical properties of concrete, particularly in the case of high performance concretes. Measurement of the quality factor can then be considered an alternative to the pulse velocity test for the evaluation of concrete condition.

Keywords: concrete, degradation, pulse velocity test, attenuation, quality factor.