List of Abstracts of QIRT 1996 (Stuttgart, Germany)

In Situ Calibration for Quantitative Infrared Thermography

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Abstract

This paper presents a method to correct temperatures obtained by infrared thermography using thermocouples as reference temperatures. The raw signal values of the infrared detector are compared to the temperature measured with thermocouples. The relation between raw thermal value and body temperature includes three parameters which allow to determine a best-fit approximation between detector signal and body temperature. The resulting non-linear system of equations is solved numerically using the Levenberg-Marquardt procedure. These parameters are then used to calculate the corrected temperatures of the body.

IR detection of thermal waves - effect of imaging conditions on the background fluctuation limit

By J. BOLTE, B.K. BEIN, J. PELZL

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Abstract

Starting from the basic principles of photon detection, a general theoretical description is here given for the incoherent background fluctuation limit of thermal wave detection. Different imaging conditions of IR detection of thermal waves and different detectors are considered. The theoretical limits are compared with measurements obtained for a MCT detector. Good agreement between the observed detection limits and the theoretical prediction is obtained.

Characterization of spatial light distribution of flash lamp systems

By F. CERNUSCHI[1], M. LAMPERTI[2], R. MARCHESI[3], A. RUSSO[3]

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Abstract

In this work results of an experimental activity are reported, where we evaluated the spatial distribution of light intensity for two different flash lamp systems.

Two different methods have been experimented; in the first one a map of the energy distribution was obtained using a lab energy-meter while in the second one the temperature distribution of a homogeneous flat surface few instants after being flashed was imaged using an IR camera.

A comparison between the spatial features of the two flash systems and between the two methods is done.

Influence of the radiation diffraction in image converter of the thermograph upon its metrological parameters

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Abstract

The influence of radiation diffraction upon geometrical resolution of the thermograph with series structure of measuring line has been analysed in the paper. Analysis of thermograph properties in bands of 3-5 μm and 8-10 μm proved that when applying the aperture diaphragms the influence of the radiation diffraction upon geometrical resolution may by significant. This influence is stronger for larger values of the hole numbers in the applied diaphragms. It was shown that the thermal resolution of the thermography system can be improved by reducing the bandwidth of the electronic system of the camera.

Thermography improvements using ultraviolet pyrometry

By P. HERVE[1] and A. MOREL[2]

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Abstract

Thermography in the UV range allows to nearly get rid of the effects of emissivity, which is the main difficulty of quantitative IR thermography. In the UV range, the strong increase of luminance as a function of temperature - it doubles every 20°C around 700°C - hides the effects of emissivity and allows for an exceptional sensitivity from 600°C on. Another important advantage of UV is due to the fact that natural and artificial radiating sources disturb the measurement ten times less than in the IR. Examples of applications to melting phenomena, temperature rises under shock and simultaneous temperature and emissivity cartography are presented.

Application of infrared image restoration to improve the accuracy of surface temperature measurements

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Abstract

Image degradation is regarded as the major limiting factor for accurate evaluation of surface temperatures with infrared thermography, especially if a high spatial resolution in combination with a large depth-of-field is required. The paper discusses the application of an infrared image restoration technique to enhance the accuracy of surface temperature measurements of small three-dimensional objects. The restoration technique applied is based on a Wiener filter which uses the two-dimensional Optical Transfer Function (OTF), characterising the infrared camera. The OTF was determined from the camera response to a perfect thermal step-edge. Infrared thermographs, acquired from small cubical elements subject to well established boundary conditions, are processed with both the restoration filter and *in situ* calibration to arrive at surface temperatures. Surface temperatures, obtained independently with liquid crystal thermography, are in excellent agreement with the restored results, showing both the necessity for image restoration and improvement of accuracy.

Emissivity measurements at room temperature on polymeric and inorganic samples

By F. CERNUSCHI[1], A. RUSSO[2], G. M. PIANA[1], P. MUTTI[3], L. VIVIANI[3]

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Abstract

An evaluation of the emissivity of polymeric and inorganic materials has been carried out in the spectral range 8-12μm using a direct technique. For polymeric samples the study focused on the dependence on the doping level. In the case of the inorganic samples measurements were aimed at the evaluation of the emissivity variations with the temperature Furthermore the effects on the emissivity of temperature differences between the sample and the background on the emissivity evaluation have been studied.

Estimation of thermophysical properties of thin plates with averaging techniques and two temperatures model

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Abstract

Averaging techniques are well suited for infrared image processing because they consider spatially averaged temperature fields related or not to each constitutive phase of heterogeneous media. In the case of simple geometry, such as thin rectangular adjacent plates, one or two dimensional exact analytical relationships can be obtained between averaged temperature related to each plate. These expressions are suitable to estimate thermophysical properties such as thermal diffusivity or thermal resistance at the junction of the plates. The main advantage is to reduce the influence of measurement noise. Experimental results are obtained and some examples of estimation of thermophysical parameters are presented.

Spectral emissivity evaluation for materials used in microelectronics

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[2] Institute of Electronics, Technical University of Lodz, 18-22 Stefanowskiego str. 90-924 Lodz, Poland.

Abstract

This paper presents emissivity (ε) measurements for some materials used in microelectronics, eg.: aluminium, silicon, germanium and diamond-like structures. In this work we emphasise emissivity evaluation for semitransparent and multilayer dielectric materials. The measurement was performed with the use of IR Spectrometer. For every sample we measured the reflected and transmitted energy, and evaluated material constants for various spectral ranges. The results of this work may be useful in calculating heat removal by radiation in microelectronic devices.

Radiative and convective heat transfer in microelectronics

By B. WIECEK[1], H. MADURA[2]

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[2] Institute of Optoelectronics, Military Academy of Technology, 2 Kaliski str. 01-489 Warsaw, Poland.

Abstract

This paper presents numerical and experimental results of heat transfer by radiation, convection and conduction in hybrid microelectronic circuits. We chose a heat source with a non-uniform temperature distribution, which agrees with typical cases frequently met in electronics. In this work we evaluate a complex heat transfer coefficient including the non-linear phenomenon for radiative and convective heat dissipation. We apply thermography to confirm the correctness of the simulation.

Infrared imaging techniques for the measurement of complex near-field antenna patterns

By J. WILL[1,2], J. NORGARD[1,3], C. STUBENRAUCH[4], M. SEIFERT[5]

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Abstract

This paper describes the application of "plane-to-plane" (PTP) iterative Fourier processing to infrared thermographic images of microwave fields to calculate the near-field and far-field patterns of radiating antennas. The PTP technique allows recovery of the phase by combining intensity (magnitude) measurements made on two planes, both in the radiating near field of the antenna under test. Starting with an estimate of the phase and the measured magnitudes, Fourier processing techniques are used to iteratively "propagate" between the planes to determine the correct phase distribution at each plane. We describe the technique and show excellent comparisons made between predicted and measured results.

Microwaves holography revealed by photothermal films and lock-in IR thermography: Application to NDE of dielectric and radar absorbing materials

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Abstract

The amplitude and phase space distributions of EM (electromagnetic) fields (X- and Ku bands) are imaged and measured using microwaves interferometry revealed by photothermal films and lock-in infrared thermography. Such EM fields imaging is a powerful tool for NDE (non Destructive Evaluation) of dielectric and radar absorbing materials.

Quantitative stress analysis by means of standard infrared thermographic equipment

By S. OFFERMANN[1], C. BISSIEUX[1], J.L. BEAUDOIN[1], H. FRICK[2]

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Abstract

In dynamic fatigue testing experiments, the thermoelastic effect links the local stress level and the local temperature variation in a material. Though quite minute, this effect can be readily measured by standard infrared thermography. Since neglecting the heat conduction is not relevant in the case of good conductors at high excitation frequencies, an adiabaticity criterion is established. An inverse technique to restore the thermally attenuated contrasts is proposed, using the finite element method for the direct heat conduction modelling. This technique has successfully be applied to an academical test sample. Measurements performed on some automotive parts under cyclic loading are presented. Besides, the influence of highly emissive coatings will be shortly discussed.

Dynamical strain measurement by IRT

By J. JOUGLAR, M. MERGUI, P. L. VUILLERMOZ

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Abstract

We have developed a signal processing technique allowing to measure by IRT the strain distribution on the surface of a sample submitted to a sinusoidal bending stress. Line mode operation of the scanner allows time and memory saving. A sliding-average filtering gives a thermal resolution of about 1 m °C. The dynamic signal is extracted from the frequency spectrum by the averaged periodogram technique, without any lock-in system. The precision of the result is discussed by comparison with strain gauge measurements.

Predicting crack resistance by infrared thermography

By G. KURILENKO

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Abstract

For the last years, the problem of predicting crack resistance found increasing interest. This could be explained by insufficient accuracy of traditional techniques. The proposed method is based on the information coming from kinetics of temperature distributions appearing on the surface of tested specimens. As the method involves the use of IR thermographic equipment, it offers some advantages compared with traditional techniques.

Determination of time dependent crack contact behaviour by thermoelastic stress analysis

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Abstract

Using the Thermoelastic Stress Analysis the time history of the sum of principal stresses (SPS) along the faces of through-thickness cracks in sinusoidally loaded plates is examined. The influence of crack closure on the local stresses is shown and thus the exact moment of local crack opening and closure as well as the local crack opening load are determined. The effect of static preloads on the plate - due to remote loading or residual stresses - is also monitored. Differences between the contact behaviour of cracks in plates made of linear-elastic or elastic-plastic material are shown.

Photothermal investigations on advanced ceramics

By J. GEERKENS[1], B. SCHMITZ[1] and G. GOCH[1,2]

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Abstract

Mechanical or thermal impacts on surfaces and near-surface layers during manufacturing processes often result in structural changes. They become detectable by photothermal techniques, when they correlate with alterations of thermal properties. We apply this approach on the detection of variations in ceramic surfaces. Vickers indentations model the mechanical load during grinding and a thermal surface treatment was performed by pulsed laser illumination. From the photothermal signals the depths and profiles of thermal conductivity variations depending on the different loading strengths could be reconstructed.

Experimental and numerical investigations of thermo-mechanical field coupling effects during crack evolution

By J. VOGEL[1], J. AUERSPERG[2], M. DOST[2], W. FAUST[3], and B. MICHEL[2,3]

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Abstract

A hybrid method combining infrared metrology and numerical simulation enables the investigation of thermo-mechanical field coupling effects in the vicinity of the crack tip. The temperature fields are analysed as a function of the loading rate, the specimen geometry and the crack evolution using infrared thermography. The experimental results are used for adjusting and verifying FE-calculations.

Inverse conduction problems and quantitative infrared thermography

By A. ILYINSKY

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Abstract

The efficiency of spectral methods of ICP solution for processing the IRT data has been demonstrated. The statistical analysis of nongaussian IRT noises using nonparametric Kolmogorov-Smirnov statistics has been carried out and consistent estimation of cumulative probability function for the IRT noises has been found.

The nonconsistency of point estimation for optimal regularization parameter selection procedure for the case of nongaussian IRT noises has been shown.

The new selection rule for optimal regularization parameter value using nonparametric statistics of Smirnov-Kramer-von Mises (ω^2 - test) for the case of nongaussian IRT noises has been proposed.

Heat transfer in a 180 deg turn channel

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Abstract

The aims of the present study are to obtain detailed surface flow visualization and convective heat transfer measurements nearby a 180deg sharp turn in a square channel, and to prove that the use of infrared thermography may be appropriate to experimentally study this type of problems. Surface flow visualization and heat transfer measurements are performed by means of the *heated-thin-foil* technique and results are presented in terms of temperature maps and Nusselt number *Nu* distributions. *Nu* is computed by means of the local bulk temperature. The Reynolds number, based on average inlet velocity and hydraulic diameter of the channel, is varied between 1.6×10^4 and 5.5×10^4.

Convective het transfer along slender cylinders

By J-M. BUCHLIN and R. TASSE

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Abstract

An experimental investigation of the forced convection along vertical, slender cylinders aligned in a uniform air flow is performed using quantitative infrared thermography. In the laminar regime, the heat transfer data are correlated in terms of a local dimensionless curvature parameter and validate the thermal boundary layer model for a single slender cylinder. Turbulent heat transfer occurs when the stand-off distance between two parallel, slender cylinders is sufficiently small to affect the axisymmetry of the boundary layer. An enhancement factor of three can be achieved at the transition region. In the turbulent regime, the curvature parameter alone does not describe the thermal exchange.

Heat transfer identification induced by multihole cooling in combustion chambers

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Abstract

This paper deals with the identification of the heat transfer occurring in the combustion chambers of turbomachines. Several test plates, reproducing at different scales the walls of combustion chambers have been used to quantify the effectiveness of a 30° staggered multihole cooling. Using a physical model and temperature measurements made by infrared thermography, the behavior of the convection heat transfer coefficient and the adiabatic wall temperature downstream the hole region have been determined. A modification of the model gave their behavior in the perforated area, then correlations of the effectiveness versus the streamwise distance and the blowing ratio were performed.

Experimental determination of the local heat transfer coefficient on a thermally thick wall downstream of a backward-facing step

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Abstract

A heat transfer measurement technique based on the combination of infrared thermography and numerical computation is presented in the case of a turbulent reattachment downstream of a backward-facing step. The presence of a CaF_2 window and low surface temperatures has led to develop a specific infrared system calibration. Heat transfer measurement technique and infrared system calibration are both presented in this paper.

IR heat transfer measurements in a rotating channel

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Abstract

The main aim of the present study is to develop a new experimental methodology that allows accurate measurements of the local heat transfer distribution nearby a 180deg sharp turn in a rotating square channel to be performed by means of infrared thermography. Another objective is to prove that the use of infrared thermography may be appropriate to experimentally study this type of problems. To perform heat transfer measurements, the *heated-thin-foil* technique is used and the channel is put in rotation in a vacuum tank so as to minimise the convective heat transfer losses at the surface of the foil on the channel outside. Some preliminary results in terms of temperature distributions and averaged Nusselt number *Nu* profiles are presented.

Wall-shear stress measurement with quantitative IR-thermography

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Abstract

Forces are acting on an object immersed in a fluid flow. Next to normal forces, the tangential forces caused by viscous effects in the fluid play a major role in the aerodynamic design of aircraft. The viscous effects generate wall-shear stresses in the fluid flowing over the surface. These wall-shear stresses determine the viscous drag of an aircraft and thus partly determine the fuel consumption.

The most common measurement technique for wall-shear stresses is the hot-film technique. To achieve a more flexible measurement technique it is necessary to provide a fully external heating and temperature measurement. The present paper deals with the development of a measurement technique for local wall-shear stresses using quantitative IR-thermography. After giving a short overview of the theoretical aspects, the experimental set-up and the data processing procedure is described. Finally the results of the performed experiments and conclusions are given.

Infrared thermography study of a confined impinging circular jet

By J.-M. BUCHLIN and M. MEYERS

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Abstract

The convective heat transfer at the impingement of a vertical turbulent circular air jet on a horizontal flat plate is inferred from temperature measurements performed by quantitative infrared thermography. Steady-state experiments are conducted with the heating-thin-foil method. The effects of the jet Reynolds number and the stand-off distance on the thermal exchange coefficient are emphasized. The influence of jet confinements is determined. The IR results agree with published data and are reproduced by numerical simulations performed with the code FLUENT.

A quantitative thermographic investigation of cooling of power electronic sources by forced convection cold plates

By G. CESINI, V. MORO, R. RICCI

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Abstract

Aim of this work is the utilization of thermographic methods to analyse quantitatively the thermal behaviour of a rectangular channel cold-plate cooled by a forced flow of air. The infrared thermography is used to measure the case temperature of the electronic components in order to evaluate the local total thermal resistance of the component-cold plate system and the temperature increase on the unpowered components caused by powered components placed near-by (thermal mutual effects between the components). A method based on the superposition principle is also proposed to calculate the mutual thermal effects between the components.

Heat transfer in separated and reattached flow regions over a circular cylinder

By C. MEOLA, G. CARDONE, G. M. CARLOMAGNO and L. MARINO

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Abstract

The behaviour of a circular cylinder longitudinally oriented to a uniform freestream is analysed by means of infrared thermography applied to the *heated-thin-foil* technique. Two different configurations of the cylinder leading edge are considered: a sharp and round ones. Tests are carried out, in an open circuit wind tunnel with low turbulence intensity, for varying the velocity of the freestream and the angle of attack of the cylinder axis with respect to the oncoming flow. The experimental data are reduced in dimensionless form in terms of the Nusselt number *Nu*; the position of the maximum *Nu*, which is linked to the flow reattachment, depends strongly on the leading edge configuration and on the angle of attack.

Experimental study of natural convection in the melting of PCM in horizontal cylindrical annuli

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Abstract

Heat transfer characteristics, including the convective flow driven by melting of subcooled phase change material (PCM) in the horizontal annulus gap, were experimentally studied. The inner cylinder was heated with a constant surface heat flux and the outer cylinder had a constant temperature. The history of the temperature fields was measured with an infrared scanning system. It is shown in this paper that contribution of natural convection in the melt region becomes significant as the Stefan number increases.

Quantitative approach into the heat transfer by convection in microelectronics

By B. WIECEK

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Abstract

Heat is dissipated to the ambient by convection and radiation in every electronic device. In the long chain of thermal conductors from a heat source (semiconductor) to the ambient (fluid), convection has its significant contribution, especially in steady, long-term conditions. This paper presents 2-D modelling of convective heat dissipation for vertically placed electronic elements with non-uniform temperature distribution. One describes heat removal by convection using the convective transfer coefficient α, which depends upon the temperature and the component size. In this paper we evaluate the transfer coefficient by 2-D natural convection simulation.

Lockin thermography as a measurement technique in heat transfer

By M. WANDELT and W. ROETZEL

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Abstract

An experimental temperature oscillation technique is described for determining local distributions of the heat transfer coefficient or local distributions of the thermal diffusivity of heat transferring walls. By heating uniformly one surface of the wall with sinusoidally modulated energy a temperature oscillation is generated which results in a wavelike propagation behavior of heat flow and temperature within the wall. The characteristic of the temperature oscillations at both faces of the wall depends directly on the local heat transfer conditions and the thermal diffusivity of the wall material. So the local values of the heat transfer coefficient or the thermal diffusivity can be calculated from the measured amplitudes or from the phases of the temperature waves at the surfaces. To demonstrate the applicability of the method first experiments were performed. The measured results agree reasonably well with data obtained from literature.

Photothermal inspections of adhesion strengths and detection of delaminations

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Abstract

For more than a decade, photothermal measurement techniques have been used for the non-destructive and contactless evaluation of coating thicknesses and for the investigation of boundaries between a surface layer and its base material. In the following sections, we aim to describe a few examples whereas the photothermal radiometry has been applied on different interfaces embedded in an optically opaque workpiece. The effect of adhesion defects on photothermal signals will be demonstrated. The obstructed propagation of thermal waves can be explained by thermal contact resistances when delaminations or disbondings are located between a coating and its substrate.

Characterization of tribological protective films and friction wear by IR radiometry of thermal waves

By G. KALUS[1], B.K. BEIN[1], J. PELZL[1], H. BOSSE[2] and A. LINNERBRÜGGER[3]

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Abstract

Photothermal depth profiling based on IR detection of thermal waves has been applied to tribological films, before and after exposure to friction wear. It has been found that it is mainly the thermal conductivity of the protective film, which is reduced owing to friction wear and induced stresses.

Laser irradiated transient thermography inspection of iron-zinc alloy coatings on steel substrates

By L. KEHOE, P. V. KELLY and G. M. CREAN

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Abstract

The potential of static Laser Irradiated Transient Thermography (LITT) as a non-destructive testing (NDT) method for the characterisation of thin binary Fe-Zn alloy coatings on steel substrates is investigated. The ability of static pulsed LITT to non-destructively distinguish the presence of both underalloyed phases at the alloy coating surface, and overalloyed phases at the alloy coating-substrate interface is demonstrated. The sensitivity of static pulsed LITT to the thickness of a buried layer of Γ-phase Fe-Zn alloy is discussed.

The on-line detection of moisture and moist coatings by means of thermal waves

By R. HÜTTNER and E. SCHOLLMEYER

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Abstract

The method of thermal wave detection by infrared radiometry is applied to characterize physical properties of moist fabrics. Especially the determination of moisture content on moving fabrics and the control of layer thicknesses in continuous industrial production processes are investigated systematically. The results show a good correlation between the photothermal signal and the moisture content. The thickness of a thin coating could be determined by frequency scans and the thickness of moist coatings could be controlled in a continuous process.

Photothermal characterisation of surface hardened steel

By T.T.N. LAN[1], D.T. SON[2] and H.G. WALTHER[1]

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Abstract

Photothermal measurements at varied modulation frequencies allow for the estimation of depth profiles of thermal diffusivity or thermal conductivity k in case of known thermal density. We suggest an inversion algorithm performing a sequence of one-parameter fits in order to estimate thermal conductivity k profiles. Surface problems in photothermal depth profiling and an approach to overcome them are discussed. Experimental results of thermal conductivity depth profiling of laser-hardened steel, based on this inversion algorithm are presented. The photothermally obtained k-profiles are interpreted and compared with results from conventional destructive measuring techniques.

Factors affecting the detectability of voids by infrared thermography

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Abstract

During the manufacturing of laminar plastics, debondings between layers can occur due to bad curing. Two inspection techniques by infrared thermography have to be considered: Impulse or transient thermography and lock-in thermography.

For both techniques, the detectability of a defect and the factors affecting it are major issues. The first investigated material is isotropic polyvinyl chloride, the second is anisotropic unidirectional carbon fiber-reinforced plastic. This article will discuss the above mentioned factors and will derive some practical rules about the detectability of a defect.

For the two base materials analysed, the complex contrast is studied as a function of the defect diameter to depth ratio and the modulation frequency of the heating source. Practical rules will be derived and a comparison between the two techniques will be made.

Experimental investigations of defect sizing by transient thermography

By D. P. ALMOND, R. HAMZAH, P. DELPECH, P. WEN, M.H. BEHESHTY and M. B. SAINTEY

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Abstract

Transient thermography images of back-drilled hole defects in bakelite sheets are shown to have spatial and temporal characteristics that are in good agreement with finite difference modelling. Defect size is found to be accurately related to image FWHM. Studies of artificial and real, impact damage, defects in carbon fibre composite plates are also presented. Good agreement is found between defect size indicated by the transient thermography and the ultrasonic c-scan techniques.

Transient thermographic detection of buried defects: attempting to develop the prototype basic inspection procedure

By V. VAVILOV[1], S. MARINETTI[2], E. GRINZATO[2], P. G. BISON[2], I. ANOSHKIN[1] and T. KAUPPINEN[3]

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Abstract

The transient thermal NDT basic inspection procedure is proposed. The procedure is based on the statistical analysis of NDT results presented as a single IR image or image sequence. A defect map of the sample under a test is created according to the accepted values of correct detection and false alarm. The proposed methodology could serve for comparing different thermal NDT procedures and data processing algorithms.

Separation of the thermal and optical properties and error limits in thermal depth profiling of fibre-reinforced materials

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Abstract

In thermal depth profiling of fibre-reinforced materials, the thermal and the optical properties were determined separately and with low relative errors. This is mainly due to the fact that the thermal and optical properties of the measured samples affect the measured photothermal phase at different modulation frequencies corresponding to different characteristic length of the thermal diffusion and optical absorption. The error limits of the thermal and optical parameters are determined by the root-mean-sqare deviations of the measured phases and by the error of the measurement of the static sample temperature.

Inspection of aircraft structural components using lockin-thermography

By D. WU[1], A. SALERNO[2], U. MALTER[3], R. AOKI[4], R. KOCHENDÖRFER[4], P.K. KÄCHELE[5], K. WOITHE[6], K. PFISTER[6], and G. BUSSE[1]

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Abstract

Lockin thermography with its capability to monitor modulated heat flow in larger areas (several m^2) within a few minutes is applied to the inspection of aircraft. Using up to 6 lamps each with a power of 1 kW, we could inspect subsurface structures (e.g. stringers) and subsurface defects (e.g. impact delaminations) from a distance of several meters. The method is well suited to monitor the structural integrity of aging aircraft in the near-surface area. By using ultrasonic excitation instead of radiation one can display selectively hidden defects that are characterised by a local enhancement of mechanical loss angle (e.g. cracks).

Thermal ellipsometry in steady-state and by lock-in thermography. Application to anisotropic materials characterization

By J.-C. KRAPEZ, G. GARDETTE and D. BALAGEAS

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Abstract

A technique for lock-in thermography that we recently developed was applied for the measurement of the in-plane principal diffusivities of orthotropic materials. The surface is point heated with a modulated laser beam and a 2-D synchronous detection is performed of the elliptical thermal field which develops around it. Diffusivities are inferred from the slope of the phase lag profiles. The approach was first validated with a duralumin (isotropic) sample. It was then applied on a unidirectional C/epoxy sample.

The aspect ratio of the surface isotherms is imposed by the anisotropy of the considered material. Therefore, possible in-depth variations of the anisotropy unavoidably modify the aspect ratio distribution at the surface. Based on this observation, an inversion method was recently proposed to monitor the internal fibre orientation changes in composites. Results obtained with a continuous fibres C/epoxy sample and with an injection moulded short fibres sample are reported.

Shape and uneven heating correction for NDT on cylinders by thermal methods

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Abstract

Use of the 'Shape from heating technique' for the non-destructive detection of delaminations on cylinders made of composite materials is presented. A particular solution of the general technique is described to compensate the thermogram for both effects of non planar shape and non uniformity of the heat source. The processing is relatively fast since symmetry of the target is used. The proposed solution, even if not general, can nevertheless be applied to many industrial problems of interest.

Investigation of resolution in lock-in thermography: theory and experiment

By D. WU[1], C. Y. WU[2], and G. BUSSE[1]

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Abstract

The general formalism of wave propagation and scattering effects is applied to optically generated thermal waves in order to describe imaging of near-surface features. The contrast functions of amplitude and phase calculated for flat bottom holes show good agreement with experimental results obtained with lockin-thermography.

Combustion graphology used to improve emulsions of water-in-heavy fuel oil

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Abstract

Combustion graphology uses the infrared and luminous radiation of the flame and cenosphere of a burning droplet of heavy fuel oil in order to carry out scientific research with technical industrial applications. The rational combustion of the optimal water-heavy fuel oil emulsions in industrial power furnaces determines several advantages of which the most important is the de-pollution of the environment. Graphological testing for water-heavy fuel oil emulsion droplets is performed on a simulator and the result of the experiments is presented for two situations; when the effect of secondary atomisation is partially present and when the secondary atomisation is total, the whole droplet exploding. Experimental results are presented for samples processed in laboratory and in an industrial emulsifying installation.

Thermal imaging and frequency analysis

By M. LÄHDENIEMI, A. EKHOLM and O. SANTAMÄKI

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Abstract

IR based thermology and thermal images can be used in many industrial areas of predictive maintenance. In most cases these applications concentrate on taking single samples from interesting surface temperatures which means loss of possibility for long time data recording. The use of a simple image averaging method creates image data without periodic behavior of the object in interest.

There is a lot of interest to be able to measure wide area temperature profiles from a fast moving surface (e.g. in paper machine) with track velocities like 10-20 m/s. Normal low speed line scanners typically give scanning speed of 50 Hz which in this case corresponds to 20 m/s 50 Hz = 40 cm resolution, and thus obtained resolution is not high enough. To have more accurate vision to the surface, IR camera line scanning with line scanning frequency of 8000 Hz was proposed to be the solution which would provide a resolution of 20 m/s / 8000 = 0.25 cm between surface points.

It is well-known fact that all not desired frequencies in a paper transfer system disturb the uniform paper drying process, which in some cases is the basic reason for low quality coating or even broken paper line. The possibility to detect these drying problems with thermal image frequency analysis will give a new way to control the paper drying process, and this method can be utilized in many other similar industrial processes, too. With modern IR temperature scanning equipment it is possible to have information about the temperature distribution along moving surface and then by using the well established frequency data analysis, the error estimations can be calculated. The careful analysis of this new method is given in the presentation.

Velocity and thermal field thermography for thermoplastic polymers extrusion

By G. CUCCURULLO[1] and L DI MAIO[2]

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Abstract

Cast film production is a common operation in polymer processing: different models have been developed to predict the film behaviour at the die exit. The model presented in this paper takes in to account both the inertia forces and the gravity in the momentum equation; this last is coupled with the energy equation by considering temperature dependent properties. Analytical results, obtained by numerical integration using a shooting method, are compared with experimental ones obtained on a pilot plant: extrusions on thermoplastic polymers, namely PET and PP, at different die to chill roll distances and at different flow conditions (mass rate, drawing and cooling), were performed. The film thermal response, in the region between die exit to chill roll, was detected by means of an AGEMA 870 IR system. First experimental tests showed quite different behaviors for PET and PP, probably due to different crystallization kinetics. Analytical results are presented and compared with experimental data.

Determination of glaze thickness on ceramic substrates using an infrared camera

By J. VARIS[1], A. NURMINEN[2], J. TUOMINEN[2], A. AUTERE[2] and J. RANTALA[3]

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Abstract

The thickness of glaze on a warm ceramic substrate was determined by measuring the surface temperature behaviour of the glaze with an infrared camera. A one-dimensional theoretical model was developed for describing the heat conduction in the glaze. Based on curve fitting of the model into the temperature data, estimates of the glaze thicknesses were obtained. For comparison, the thicknesses were also measured destructively.

Investigation of temperature distribution during plastic deformation of stainless steel

By S. P. GADAJ, W. K. NOWACKI and E.A. PIECZYSKA

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Abstract

The object of the work was to find the temperature fields and their evolution during tensile test and simple shear test of metal in order to use them in the examination of material's behaviour.

In initial stage of metal's elongation, the temperature distribution allows to determine the beginning of plastic deformation. In the homogeneous state of stress temperature measurements enable to investigate a process of energy storage during the plastic deformation. Heterogeneous temperature distribution observed in the subsequent, advanced state of deformation are related to evolution of the localized plastic deformation, leading to necking and damage.

Furthermore, examination of the temperature distribution obtained during static simple shear test enables us to confirm the occurrence of macroscopic shear bands, calculated in theoretical approach.

Automated thermal NDT system applied to internal defects inspection of rolled metal sheets in manufactures

By E. ABRAMOVA, O. BUDADIN and V. PANIN

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Abstract

This paper is devoted to the description of a new thermal NDT of rolled metal sheet (plate) during manufacturing as well as during movement of the plate with speed up to 2 m/s, for an iron and steel industry.

Anomalies of the dynamic temperature field arising on the surface of a product are registered in real time by thermovision equipment and are transmitted to a computer.

The defects are revealed by the videoimage analysis of the temperature fields in a computer by means of a special software.

Simultaneous in-process control of weld pool geometry and heat affected zone based on thermal-optic imaging for welding of steel materials by concentrated energy fluxes

By G. BRÜGGEMANN[1], J. DEMUS[2] and Th. BENZIGER[1]

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Abstract

Robot welding using high power energy flow processes is widely used in the fabrication industry for increasing productivity and enhancing product quality. The application of infrared thermography to the adaptive control of different welding processes is discussed in this paper.

Because these processes are difficult to control and automate, the quality of the product can vary over a large range. Therefore temperature gradients need to be controlled directly on-line with a high accuracy. This requires twodimensional temperature monitoring. A thermo-optic camera system can be used in order to investigate the cooling process in the weld seam area as well as in the heat affected zone. I was found that reasonable correlations exist between thermo-optical machine vision and weld seam quality, as far as weld pool geometry and thermal cycle interrogation is concerned.

The application of thermal imaging in metals industry

By J. WULLINK and J. VAN DER STEL (*)

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Abstract

For many decades use of infrared equipment has been common practice at Hoogovens, both in process control and research. The development of modern thermal imagers gives new opportunities for the steel and aluminium industries. Thermal imaging has been used in applications for cokemaking, ironmaking and steelmaking, web handling, annealing and high pressure die casting of aluminium. This paper presents some results of these industrial measurements.

Nondestructive characterization of the tendency to chilling in cast iron using pulsed video thermography

By G. WALLE

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Abstract

In this paper two thermal techniques are presented to characterize the tendency to chilling in gray cast iron. One technique uses the fact that the cementite phase of the cast iron material shows a thermal conductivity which is considerably below that of ferritic or pearlitic phases. The second technique is based on inductive heating of the specimen by an alternating magnetic field. In this case differences in the electric conductivity and in the magnetic permeability of the cementite and ferritic phases can be used in order to analyze the tendency to chilling in cast iron components.

Detection of flashing temperature spots of dry friction interface by means of infrared radiometer

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Abstract

An experimental study of detecting a spot temperature of the dry friction interface was conducted by means of infrared radiometry. The radiation temperature distribution of the plastic dry friction interface was displayed on the CRT of the infrared radiometer (IR). The radiation temperature distribution of the reciprocating interface T, and the friction coefficient μ were continuously measured. The thermal behavior of the excess hot-spot temperature area of the friction interface under heavy wear condition showed that the time-dependent fluctuation of the temperature and friction coefficient was caused by the generation process of the deposited wear powder in the interface.

Human body skin surface distribution as measured by infrared thermography in altitude hypoxia conditions

By J. LASZCZYNSKA[1], R. KACZANOWSKI[1], K WOJCIK[1], P. SACHA[2], J. LUKASIEWICZ[2] and W. KOWALSKI[1]

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Abstract

A group of seven males was tested inside a thermobarochamber. Every subject was examined in the same manner in a simulated altitude of: 2500, 3500, 4500 m o.s.I. (control at 115 m o.s.I.). After 20 minutes of adaptation the 25 minutes exposition to altitude hypoxia was performed. Thermovisual measurement (AGEMA Thermovision 900 series) was repeated at 5 min. intervals. The results demonstrated that the range and dynamics of temperature distribution were proportional to the intensity of altitude hypoxia and the exposure time. Observed changes depend on the area of body surface.

Thermovision monitoring of the tuberculin reaction with children

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Abstract

Tuberculin reaction is still one of the basic criteria of diagnosing tuberculosis of children. This test should be performed by trained personnel. Doubtful reactions should be estimated by a doctor. Nevertheless, interpretation of results is often difficult. A test reading consists in estimation of a transversal diameter of infiltration. The character of a reaction is also taken into account (exudation reaction in spite of its size always testifies to an infection). A period of time which has passed since the previous BCG vaccination should be known to differentiate infectious and vaccination reactions. Visual examination of test results is not fully objective in spite of fixed criteria for positive tests. For this reason some other and more precise ways of taking measurements are searched. In case of tuberculin tests such studies are well-founded because recognition of a test as a positive one initiates a long and expensive process of diagnosing of potential tuberculosis infection.

The aim of the presented work was to compare results of tuberculin tests obtained with visual and thermovision (THV) methods.

Lockin thermography for imaging of modulated flow in blood vessels

By D. WU[1], H. HAMANN[2], A. SALERNO[1], and G.BUSSE[1]

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Abstract

While conventional thermographic applications to the human body aim at revealing local temperature changes normally related with the beginning of a pathologic process, this paper shows how lockin thermography can be modified in order to meet medical needs in the visualization of functionality of blood vessels.

A compression cuff is used in connection with the lockin system to create a modulation in the blood flow. The amplitude and phase images thus obtained can provide information about the blood flow in the vessels.

Thermal-Coronary-Angiography (TCA) for intraoperative evaluation of graft patency in coronary artery bypass surgery

By V. FALK, T. WALTHER, A. DIEGELER, T. RAUCH, H. KITZINGER, F. W. MOHR

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Abstract

Despite evolution of surgical techniques, coronary artery bypass graft surgery is complicated by early and late graft failure. Early graft failure occurs in up to 10% of all bypass grafts and is often due to technical mistakes at the anastomoses. Thermal Coronary Angiography as a non-invasive method that requires on ionizing radiation or contrast documents graft patency of venous and arterial grafts, allows evaluation of perfusion after revascularization and can detect distal stenoses in native coronary arteries. By detection graft failure intraoperatively Thermal Coronary Angiography helps to minimize the risk of postoperative complications following myocardial revascularization.

Thermal imaging of the effects of beta-irradiation on human body surface

By I. BENKO[1], G.J. KÖTELES[2] and G. NÉMETH[3]

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Abstract

It is an experience that ionising radiations produce thermal effects in human organisms. Nevertheless, very few data are available on the quantitative relationship of the dose of ionising radiation and the changes of temperature. The studies were planned, therefore, to reveal the thermal detectability of tissue reactions following radiotherapy treatments. By this way during the radiation treatments the thermal measurements made possible to detect the sequential alterations in the thermal map of the involved body surfaces. The thermal studies were performed in collaboration with the National Institute for Oncology by measurement s of patient irradiated with beta rays. In the paper the results of infrared thermogrammetry investigations are given by histographic method.

Experimental determination of the transmission of the atmosphere - based on thermographic measurements

By P. PREGOWSKI[1], W. SWIDERSKI[2]

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Abstract

The influence of limited transmissivity of atmosphere should be taken into account in many applications of IR thermography (IRT). There are a lot of situations when application of computer simulation programs, e.g. based on the LOWTRAN models or using significantly simpler relations, is impossible or limited due to the investigation conditions.

This paper presents one of the procedures to estimate the total influence of the atmospheric path between the object plane and the IR camera. This influence consist of self-emitted and scattered radiation and is often variable, although it cannot be measured or seen directly. We found higher values of signals from the atmosphere than expected. In the case of short wave (SW) cameras, the application of antisolar long wavelength filter reduces the influence of reflected radiation from the sun and also atmospheric signals.

Statistical analysis techniques for aerial infrared images in wavelets transform domain

By D. MILOVANOVIC[1], B. WIECEK[2], A. MARINCIC[1],
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[2]Technical University of Lodz, Institute of Electronics, Stefanowskiego 18/22, 90-924, Poland.

Abstract

Statistical analysis of airborne IRLS (InfraRed Line-Scanner) images in DWT (Discrete Wavelet Transform) numerical domain is an extension of statistical measurements of computer generated images in our earlier works aimed to finding method for IRLS image coding. The initial results obtained with test images indicate that proposed statistical techniques in the wavelet transform domain are efficient for joint space-frequency 2D anisotropy analysis and adaptive data compression of IRLS images.

Advances in pulsed phase thermography

By X. MALDAGUE[1,2], J.-P. COUTURIER[1], S. MARINETTI[1], A. SALERNO[2], D. WU[2]

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Abstract

A succinct depth analysis of Pulsed Phase Thermography (PPT) is presented in this paper. Some theory is presented as well including some comparisons with modulated (or lockin) thermography (MT).

Lock-in contact thermography on solar cells - comparison with IR-measurements

By O. BREITENSTEIN[1], K. IWIG[1], I. KONOVALOV[2], AND D. WU[3]

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Abstract

Since all internal forward currents flowing during operation of a photovoltaic solar cell represent losses in its light conversion efficiency, local regions of increased forward current (local shunts) are degrading the cell performance. These regions may be detected and investigated by lock-in contact thermography allowing the detection of local current densities as low as 100 $\mu A/cm^2$. This technique is described and experimentally compared with two types of IR-based measurements. We find that the detection sensitivity of the IR-measurements is at least one order of magnitude worse than that of contact thermography, as long as no high-sensitive focal plane array IR-camera and/or longer integration times can be used.

Lock-in thermography with mechanical loss angle heating at ultrasonic frequencies

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2The Academy of Finland, P.O. Box 57, 00551 Helsinki, Finland

Abstract

In this paper the mechanical loss angle heating as an internal thermal wave source is described. Acoustic energy at high frequency (ultrasound) can be coupled into the sample. The high hysteresis loss in the defect region results in increased heating of the defect. When the intensity of the ultrasound is modulated at a low frequency the defect itself emits a thermal wave at this low frequency. The range of this thermal wave is large enough for detection at the surface with lock-in thermography tuned to the intensity modulation. This technique combining ultrasonic waves and lock-in thermography provides a fast imaging of imaginary part of Young's modulus in materials. Results obtained with this selective heating on various real components are presented.

Thermovision control, interferometry and computer modelling for increasing reliability and quality of electronic products

By Y. KOFANOV, S. UVAISOV[1] and B. ARLOV, G. PJATNITSKAJA, A. SEGEN[2]

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Abstract

We present information on an automated system ASONIKA that is designed to mainten reliability and quality of radio-electronic equipment (REE) and to simulate physical processes in REE. Methodological aspects are considered to integrate computation and instrumental diagnostics on the basis of the software ASONIKA and measuring thermovision KRIT_T. Formation of the thermal model-norm, utilized for verification of specimens according to their thermal images and evaluation of electronic device reliability and quality under the destabilising influence is suggested. It is noted that a similar technique utilizing holographic interferometry equipment and the mechanical subsystem ASONIKA-M software will allow to generate the model-norm of devices' condition under load.