QIRT'2000: Quantitative InfraRed Thermography 5

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Infrared thermography and inverse heat conduction problems

by François Papini

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pp. 8 - 21

Infrared imaging and thermomechanical behaviour of solid materials

by André Chrysochoo

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pp. 22 - 27

Abstract:

Infrared thermography gives valuable information useful to observe, understand and model the thermomechanical behaviour of solids. The theoretical framework of standard materials is used to define the different heat sources induced by a deformation process. These sources are estimated from infrared data by using the local heat equation. The image processing involves Fourier techniques and its reliability is studied using spectral methods. An example of thermomechanical analysis of a rubberlike material illustrates the great interest of infrared data for improving behaviour models.

Measurement of Thermal Diffusivity by Lock-in Thermography

by P.G. Bison, S. Marinetti and E. Grinzato

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pp. 30 - 35

Abstract:

Diffusivity is generally measured on small sample under laboratory conditions where each side of the specimen is accessible, but one-side measurement may be necessary in such applications requiring in situ inspection. Experimental results are reported applying a thermoelectric unit in contact with the sample, acting alternatively as heat source and sink and generating thermal waves on the specimen. The read out of temperature is done on the same side, laterally to the source. This allows estimating the diffusivity of the material along the stimulated surface from the peaks displacement velocity or waves phase shifting measurement. Simple formulas coming from an adiabatic model furnish diffusivity values that overestimate the real one with the increase of the harmonic stimulus period. A procedure to extract the real value of diffusivity is proposed.

Photothermal infrared thermography applied to the identification of thin layer thermophysical properties

by N. Horny, J.-F. Henry, S. Offermann, C. Bissieux and J.L. Beaudoin

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pp. 36 - 41

Abstract:

The aim of the present work is the thermal non-destructive characterisation of layers at the surface of metals. The sample is sinusoidally heated by means of an argon ion laser and a focal plane array infrared camera (CEDIP IRC 320-4 LW) is used to measure the temperature variations at the surface of the layer. A numerical lock-in procedure allows the detection of very weak temperature variations at the surface of the sample, down to a few mK when working from the acquisition of hundreds of images, yielding amplitude and absolute phase maps for modulation frequencies ranging from 0.1 Hz to 1000 Hz. An inverse procedure uses the Gauss-Newton parameter estimation method, in order to identify the thermal conductivity and the optical absorption coefficient of the layer.

In-plane Thermal Diffusivity Evaluation by Infrared Thermography

by F. Cernuschi*, A. Russo** and L. Lorenzoni*

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pp. 42 - 47

Abstract:

A new thermographic methodology for measuring the thermal diffusivity of a platelike sample is presented. In particular, the study of the time evolution of the spatial distribution of the surface temperature of the rear face of the plate (after heating its front surface by a flash Gaussian shaped source) enables to determine the in-plane thermal diffusivity. This technique is applied to an AISI3O4 stainless steel plate and the results are compared with literature value and with the value obtained on the same material by using Thermal Wave Interferometry.

Application of two arrays of 32 lR detectors:

The thermal diffusivity measurement on anisotropic materials

by D. Demange, P. Beauchéne and M. Bejet

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pp. 48 - 53

Abstract:

Two arrays of 32 IR detectors are used for the thermal diffusivity measurement on composite materials in thin plate. The method consists of illuminating with a short pulse one of the faces of a square sample heterogeneously, to be able to analyze heat transfers in parallel and perpendicular directions of the faces of the specimen.

Real time processing with low cost uncooled plane array IR camera-Application to flash non-destructive evaluation

by D. Mourand and J.C. Batsale

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E-mail: mourand@lept-ensam. u-bordeaux. fr

pp. 54 - 59

Abstract:

A one-dimensional transient flash method based on infrared thermography device, allows to go back to thermal diffusivity map. However, each pixel of the temperature image presents a very noisy temporal signal. Moreover, in the case of an uncooled plane array camera, each plane array detector presents independent calibration coefficients and independent offset levels. We present in this framework, an identification method based on the estimation of thermal diffusivity variations around a nominal value by an asymptotic gradient expansion. Such method combined with real time processing and computing devices allow to obtain the estimation result at the same time as the evolution of the experiment.

Theoretical approach of the photothermal thermography using array detector system under random excitation and parametric analysis capabilities for thermal system identification

by S. Oblin, F.X. Wagner and J.L. Bodnar

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E-Mail: j;.bodnar@univ-reims.fr

pp. 60 - 65

Abstract:

The subject of the work presented here, is to approach theoretically the thermal system identification capabilities, given by a parametric analysis to the photothermal thermography using array detector system association. We show that the method allows the access to a good approximation of pulse and multifrequencies harmonic duralumin sample responses as well as to a good identification of its thermophysical properties, while submitting it to a lower excitation density.

Estimation of a local ID or 2D thermal conductivity field with infra-red images processing and volume averaging method

by M. Varenne, J.C. Batsale and C. Gobbe

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pp. 66 - 71

Abstract:

The estimation of local therrnophysical properties can be of paramount importance in order to study heterogeneous media. The volume averaging method is used to implement an estimation method of a local thermal conductivity field of a 1 D or 2D heterogeneous medium. The method is tested with experimental transient temperature fields, obtained with a calibrated sample with an infrared camera. A large number of images are processed at transient state. The same intrinsic stationary field is estimated from each image. By repeated estimations, this method reduces the rneas-urement noise influence.

Vectorial Characterisation of Electromagnetic Fields by Infrared Thermography

by P. Levesque, L. Leylekian and D. Balageas

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pp. 72 - 77

Abstract:

EMIR technique is now able to measure the polarisation of EM fields, thanks to highly anisotropic pbotothermal fllms. The films and the numerical model used to evaluate their electromagnetic behaviour are described. Based on the use of a model, a thermal optimisation of the sensor, taking into account the amphtude modulation frequency, is presented. The technique is applied to the analysis of the EM field, at 12 GHz, in the vicinity of the end of a wave-guide. Validation is achieved through comparison of the experimental results to theory.

Real-time thermal image processing based on DirectX technology

by S. Zwolenik and B. Wiecek

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pp. 80 - 83

Abstract:

In this article we describe new software technology for speciabsed applications, including advanced image processing for thermography. Native architecture of Windows98 and Windows 2000 allows easy to implement small components (called filters) for multimedia processing directly into operating system. This technology may be used in Windows98 and WindowsNT with additional operating system improvement. This technology is optimised for fast multimedia streaming into computer or between computers. We developed software based on this technology, i.e.: operating system's extensions and specialized filters for thermographics application. This system is optimised for real-time processing on thermal images with full metrological data.

Narrow spectral range infrared thermography in the vicinity of 3 μm operating wavelength

by B.G. Vainer

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pp. 84 - 91

Abstract:

An implementation of infrared thermography (IRT) developed for operation in the narrow spectral range (NSR) close to wavelength λ = 3 μm is presented in details. Its applicability to remote sensing, multichannel spectrography, optical defectoscopy, medicine, etc. is substantiated. IRT-assisted investigation of low-energy EM sources is described. Basic physical principles, which define application of IRT in cosmetology are specified. A set of advantages of 3μm-NSR IRT is formulated. System performance of suitable thermograpbs based on the InAs CID FPA is considered; the linkage between radiation temperature, NETD and frame rate is ascertained. IR camera calibration routine is described.

Long-range passive IR sensor

by H. Madura, Z. Sikorski, M. Kastek and H. Polakowski

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pp. 92 - 96

Abstract:

The paper presents the applications and the essential characteristics of IR passive sensors, as well as the principle of their operation. The analysis of radiation signals from a particular target (human being) is described. The preference of selecting a long wavelength detection band of 8/12 μm, in respect to low temperatures contrast of a target and influence of false alarm that result from fluctuations of both background and reflected solar radiation, is motivated. Also, the usefurness of optical filters that eliminate radiation at wavelengths shorter than 8 μm is demonstrated.

Software package for uncertainty calculations of temperature measurements by using thermal cameras

by K. Chrzanowski* and R. Matyszkiel**

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Military Institute of Communication, Zegrze Pld. Poland

pp. 97 - 102

Abstract:

The difficulty of determining measurement uncertainties is an important limitation while using thermal cameras at the industrial plants and the certified laboratories that have implemented the quality systems according to the international standards ISO 9001-9004 and EN 45001-45003. The software that enables calculations of uncertainties of temperature measurements by using thermal cameras has been developed and its description is presented in this paper. The software might help to remove the above-mentioned limitation if the user is able to estimate the possible dispersion of measurement parameters, such as the object effective emissivity, the effective background temperature, the effective transmittance of the atmosphere and some parameters attributed to the thermal camera.

Longwave IR focal-plane binary optics

by Z. Sikorski and H. Polakowski

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pp. 103 - 107

Abstract:

In this paper we compare diffractive and refractive binary micro-lenses for the longwave IR FPA. To investigate diffraction on the micro-lenses we have used a numerical code based-on the rigorous electromagnetic theory, because neither geometrical optics nor thin element approach of scalar diffraction theory can correctly describe waveguide shadowing and interference effects inside the micro-lens surface relief. These effects strongly influence the micro-lens diffraction efficiency when the width of the surface-relief features is close to the wavelength.

Efficient transform coding of IR line-scan images based on spatial adaptivity

by D. Milovanovic, A. Marincic, B. Wiecek*, G. Petrovic and Z. Barbaric

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** Technical University of Lodz, Institute of Electronics, Stefanowskiego 18/22. 90-924, Poland*

pp. 108 - 111

Abstract:

Based on our systematic studies of IRLS (InfraRed Line-Scanner) image statistical properties and comparative anatysis of state-of-the-art transform-based image coders, we propose the coding performance improvements by performing spatial image segmentation and operational rate-distortion optimization. In this paper, we present a new approach to adaptive coding of IRLS images which combines the advantages of the following techniques: hierarchical tree-like image segmentation alongscan direction and Lagrange optimization of a trade-off rate-distortion D(R). The proposed discrete optimization argorithm is based on the fast systematic search for the best possible image segmentation scheme, combined with the best possible bit allocation in the independent coding of each segment. We have implemented the proposed optimization algorithm on computer and obtained a significant signal-to-noise (SNR) improvement by the spatial adaptivity and independent discrete wavelet-transforrn (DWT) coding of each image segment as compared to the standard discrete cosine transform (DCT) coding of non-segmented IRLS test images,

Characterization of a focal plane array (FPA) infrared camera

by H. Pron, W. Menanteau, C. Bissieux and J.L Beaudoin

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pp. 112 - 117

Abstract:

FPA infrared cameras are presently at a fast development stage owing to the rapid increase of the computers performances but, up today, only a few works have dealt with the characterization of such equipments (see (1), (2) or (3) for example): the only information we got about the calibration of such systems come from the FPA sensors manufacturers ((4), (5), (6)).
We present here the results of our first characterization tests, realised with a long wave FPA camera (CEDIP IRC 320-4 LW) Our study was led according to three directions : spatial resolution (in order to point out the correlation between neighbouring pixels), temporal resolution (as a function of the windowing of the matrix) and, finally, thermal resolution.

Automated test-bed for evaluating long-range passive IR sensors

by H. Madura, Z. Sikorski, M. Kastek and H. Polakowski

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pp. 118 - 121

Abstract:

The paper presents measuring possibilities of an automated test-bed intended for measuring parameters of long-range passive IR sensors. The configuration scheme of the set-up for measurements of both frequency and angular characteristics of IR sensors is presented. Some examples of determining parameters of passive IR sensors are given.

Uncooled photodetectors for infrared thermography

by J. Pawluczyk, M. Grudzien, H. Mucha, Z. Nowak, Z. Orman, M. Romanis

and J. Piotrowski

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e-mail: jpiotr@vigo.com.pI

pp. 122 - 127

Abstract:

An advanced photovoltaic detector is reported, based on monolithic Hg(1-x)Cd(x)Te heterostructure with 3-D architecture. It operates in the MWIR or LWIR range at ambient temperature or under thermoerectrical cooling. Since the device operates at zero bias mode, it does not exhibit low frequency noise. The measurements show the possibility to achieve detectivity of ~l.1*O(9)* cmHz$^{1/2}$/W at the 8-9 μm range. Potentially, the devices can be assembled in large focal plane arrays. This will enable obtaining a NETD of less than 0.1 K for staring thermal imagers operating with f/2 optics and 50/sec frame rate.

Pyrometer for temperature measurement of selective objects of unknown and variable emissivity

by J. Barela and K. Chrzanowski

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kchrza@wat.waw.pl

pp. 130 - 135

Abstract:

An active muttiband pyrometer was developed for non-contact temperature measurement of objects of unknown and spectrally-dependent emissivity. It allows for measurement of object temperatures in the 500°C-1200”C range at a speed of up to 200 Hz. The pyrometer consists of a source of infrared radiation (that emits radiation on the object under measurement) and a receiver to measure the radiation that is reflected and emitted by the object into four narrow spectral bands. Tests show that the developed pyrometer has a standard uncertainty in the temperature measurement of real objects of about 1% of the output temperature.

Evaluation of capabilities of IR passive system for location of air-borne objects

by Z. Bielecki*, K. Chrzanowski*, J. Piotrowski** and Z. Zawadzki*

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***Vigo System Ltd., 11a Wyki St., 01-318 Warsaw, Poland, e-mail: jpiotr@vigo.com.pl*

pp. 136 - 141

Abstract:

A simple and low cost IR surveillance device based on a single, thermoelectrically cooled detector working in 3-5 μm spectral band is presented. Despite its simplicity, preliminary estimations of its detection range show its sufficient effectiveness in detection of airborne objects seeing abeam or aft.

IR reflectivity measurements depending on carbon film thickness

by C. Desgranges, C. Balorin, J. Bucalossi,

D. Garnier, D. Guilhem and P. Messina

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pp. 142 - 147

Abstract

In thermonuclear controlled fusion machines using magnetic confinement, carbonisations are realised to prevent metal impurities to enter into the fusion plasma made with hydrogen elements; it consists in helium glows In which methane gas is injected. The methane motecure is broken and the carbon deposits on all inside vesset surtaces: inner walls as well as optic e!ements like windows and mirrors. We studied the dependence of the reflectivity of infrared thermography stainless steel mirrors with carbon films thickness in the 3-5 μm bandwidth. The presented results show a decrease of less than 10% of the temperature announced by the camera.

Analysis of dynamic thermal processes in cement kilns by using the 2D and 3D numerical models

by V.G. Torgunakov, M.N. Sukhanov, V.P. Vavilov

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Tel. +7(3822)418712, Fax +7(3822)417281, Email: vavilov @introscopy.tpu.ru

pp. 150 - 155

Abstract:

The 3D heat conduction numerical model is proposed for analyzing the operation of rotary kilns used in the production of cememt. The usefulness of this model in solving an inverse diagnostic problem and compiling a map of significant defects is demonstrated.

Defect Depth Estimation Using Neuro-Fuzzy System in TNDE

by A. Darabi and X. Maldague

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pp. 156 - 161

Abstract:

Recently, supervised arlificial neural networks have obtained success to reveal and provide quantitative information concerning defects in TNDE (Thermographic NonDestructive Evaluation). Supervised neural networks may converge to local minimum and their training procedure are usually long. In this study, a neuro-fuzzy approach is applied to characterize subsurface defects in TNDE. Similar to neural networks, fuzzy systems are model-free estimator systems which can learn from experience with numerical or linguistic data. In this paper, the concept of a fuzzy set and fuzzy reasoning mechanisms are first discussed. Then, a neuro-fuzzy defect depth estimator based on the Takagi-Sugeno-Kang (TSK) system modeling method is proposed. Finally, the neuro-fuzzy depth estimator is tested wLth both simulated and experimental TNDE data.

Thermal Modulation Transfer Function (TMTF)

by J-C. Krapez

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pp. 162 - 167

Abstract:

the TMTF is a tool for thermal NDE (pulsed thermography). It gives a synthetic view of the thermal contrast degradation that is inherent with a reduction of the defect size. It was built, like the MTF in visual or IR imaging, by using a target with a periodic patlern. The TMTF was numerically simulated with a model having a cluster of parallel slots on the rear side. The class of slots having a low relative depth is aimed to simulate corrosion at its onset. For this class, the TMTF is expressed as a unique curve that moves with the time of observation. An inversion method based on the TMTF was proposed: it clears, to some extent, the observed temperature field from the detrimental effect of lateral diffusion.

Depth profiling in inhomogeneous materials by Photothermal Radiometry: Use of Thermal Wave Backscattering Theory and Genetic Algorithms

by R. Li Voti, M.C. Larciprete, G.L. Liakhou, C. Melchiorri,

S. Paoloni, C. Sibilia and M. Bertolotti

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pp. 168 - 173

Abstract:

In this paper we introduce two different approaches to retrieve the thermal effusivity and conductivity depth profiles in inhomogeneous materials. We recall the general idea, discuss the different potentiallities, and show sorne numerical results of reconstruction.

Modelling of Buried Object Detection Using Thermography

by I. Boras, M. Malinovec, J. Stepanic jr. and S. Svaic

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pp. 176 - 181

Abstract:

In order to evaluate a possibility for buried object detection using active IR the laboratory set-up was made. The experimental system consists of a box containing two different soil types. In soils, objects of different dimensions are buried. The surface temperature distribution is measured using thermography. Additionally, the soil temperature depth profile and soil humidity are measured. Using the developed mathematical modet and measured temperature distribution the possibility for buried object detection and identification are discussed.
The objective of the work is to try to develop applicable method for precise buried object position determination. Results obtained are discussed from the point of view of possible application of the method for buried antipersonnel landmines detection in the humanitarian demining.

Thermal signature of the buried mine — model and experiment

by P. Pregowski*, W. Swiderski**, R.T. Walczak*** and K. Lamorski***

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****lnstitute of Agrophysics, Polish Academy of Sciences, st. Doswiadczalna 4, 20-236 Lublin, Poland*

pp. 182 - 187

Abstract:

The main disadvantage of applying IR tbernal images for deteclion of buried mines, is the presence ol various false indications in therrnograrns. Selected results of research works tor using infrared thermography for buried mines detection are presented in the paper. Developed numerical model describing heat and water transfer phenomenon in the soil has been verified by laboratory experiment. The *aim* ol presented models was to help in recognising the peculiarities *of* signal and noises depending on such parameters as: time and space variability of moisture and density of soil, buried mine and soir features and environmental conditions.

Data reduction in flash method thermography

by P.G. Berardi and G. Cuccurullo

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pp. 188 - 193

Abstract:

An infrared thermography equipment has been used to measure the temperature rise on the rear surface of the sample submitted to pulse (flash) irradiation, in order to derive simultaneously two thermal properties of the sample. The Levenberg Marquadt best-fit has been used to match the experimental data to the analytical model. The care was taken to tune properly the sample features and the experimental set-up. Since the acquisition time was found to be a critical parameter, its influence on the final results was atso analysed.

Depth defect retrieval using the wavelet pulsed phased thermography

by F. Galmiche and X. Maldague

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email: maldagx@gel.ulaval.ca

pp. 194 - 199

Abstract:

Pulsed Phase Thermography (PPT) is a known method to process thermograms in pulsed thermography through a Fourier frequency analysis. However, the Fourier transform is still limited to a qualitative analysis. This paper shows that the wavelet transform enables to perform both a qualitative and a quantitative analysis. Both experimental and modeling results are presented.

Thermographic non destructive control of joint of ceramic matrix composite tubes

by F. Cernushci and L. Lorenzoni

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pp. 200 - 205

Abstract:

A thermographic technique for the assessment of the quality of joints of ceramic matrix composite tubes is presented: this method is based on the time resolved analysis of the surface temperature rise when a stepwise heating is produced within the pipe. Statrrting from experimental data, a figure of merit for joint thermal resistance was defined and successfully applied to jointed pipes, to a single pipe (perfect joint) and to a pair of pipes inserted one inside the other one but without any joining material (worst joint).

Photothermal infrared thermography applied to the characterisation of thermal resistances at metal—metal interfaces

by P. Laloue*, F. Nigon*, S. Offermann", J.- F. Henry" and C. Bissieux**

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pp. 206 - 211

Abstract:

The quantitative validation of the non-destructive testing method begins by comparing the experimental results with a unidimensional multilayer analytical thermal model. Then, the development of an inverse procedure using the Gauss-Newton parameter estimation method, allows the identification of the thermal resistance or the equivalent air layer thickness at the metal-metal interface. Confidence intervals on these parameters are estimated by this inverse procedure. A unidimensional finite difference numerical thermal model as welt as a tridimensional numerical finite element model have been tested. Finally, thermal resistance estimations are presented.

Ultrasound Lockin Thermography — an NDT Method for the Inspection of Aerospace Structures

by Th. Zweschper, A. Dillenz and G. Busse

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Email: zweschper©ikp.uni-stuttgart.de

pp. 212 - 217

Abstract:

Elastic waves launched into a component by an ultrasonic transducer propagate inside the sample until they are converted into heat. A defect causes locally enhanced losses and consequently selective heating. Therefore amplitude modulation of the injected elastic wave turns a defect into a thermal wave transmitter whose signal is detected at the surface by lockin thermography that is synchronised to the frequency of amplitude modulation. This way ultrasound lockin thermography (ULT) allows for selective defect detection which enhances the probability of defect detection even in the presence of complicated intact structures.
In this paper we report about investigations which are relevant e.g. for maintenance and inspection of aircraft and other safety-relevant areas. Using the phase angle images provided by ULT one can detect hidden corrosion, cracks in rows of rivets, disbonds, impacts, and delaminalions.

Highly-Sensitive Lock-in Thermography of Local Heat Sources Using 2-Dimensional Spatial Deconvolution

by O. Breitenstein, I. Konovalov and M. Langenkamp

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email:breitn@mpi-halle.de

pp. 218 - 223

Abstract:

A lock-in thermography system is introduced, which allows temperature modulations In the 10 μK range to be detected. Under certain conditions (homogeneous infrared emissivity and thermal properties, good signal-to-noise ratio), the spatial resolution of lock-in thermographic investigations of local heat sources in electronic devices can be improved by spatial deconvolution. An iteratively working vectorial deconvolution procedure is presented, which takes into account the wave nature of the oscillating temperature field. Both heat sources lying at the surface and sources buried at a certain depth can be evaluated. The possibilities of this procedure are demonstrated by simulations and by the deconvolution of experimental lock-in thermograms.

Round Robin comparison II of the capabilities of various thermographic techniques in the detection of defects in carbon fibre composites.

by D.P. Almond*, R.J. Ball*, A. Dillenz**, G. Busse**,

J.-C. Krapez***, F. Galmiche**** and X. Maldague****

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***IKP, Universtät Stuttgart, Pfaffenwaldring 32, D-70569 Stuttgart, Germany*
****Structure and Damage Mechanics Department, ONERA, BP 72. 92322 Châtillon, France*
*****Université Laval, Cite Universitaire, Quebec, Canada, GIK 7P4.*

pp. 224 - 229

Abstract:

Four samples of carbon fibre reinforced composite which contained impact damage sites, vehfied by ultrasonic C-scans, have been studied independently by the groups participating in this second QIRT Round Robin exercise. The samples were selected from a much larger collection because long pulse heating transient thermography (Bath) had failed to detect the presence of the defects at the front (impact) faces. The other techniques employed were: optical lock-in thermography and ultrasound lock-in thermography (Stuttgart); pulsed thermography using the emerging contrast technique (ONERA) and pulsed phase thermography (Laval). Only ultrasound lock-in thermography *was* successful in detecting the defects at the front faces.

Control of drying by means of IR detection of thermal waves

by I. Delgadillo-Holtfort[1], J. Pelzl and B.K. Bein

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pp. 230 - 235

Abstract:

Frequency-dependent thermal wave measurements based on IR detection have been used to study drying processes in different types of materials, namely foodstuff, construction materials and textiles. It has been found thai this technique can give information on the total moisture content, on the moisture depth distribution and on the progress of drying with time.

Modulated photothermal measurements applied to multi-layer superinsulation foils

by A. Haj-Daoud* ** (1), DelgadiIlo-Holtfort* (2), V. John***, B.K. Bein*, N. Marquardt*** and J. PeIzl*

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****Accelerator Physics and Synchrotron Radiation (IBS). University of Dortmund, D-44221 Dortmund, Germany*

pp. 236 - 241

Abstract :

Photothermal measurements based on modulated heating in the visible spectral range and IR detection of the thermal response are used to determine the effective thermal transport properties and the shielding properties of multi-layer superinsulation foils consisting of different numbers of aluminized mylar layers and spacer layers. The measurements have been run at ambient temperature, both at ambient pressure and at reduced pressures between 1 mbar and 300 mbar.

Example of use of numerical simulation to help NDT experimental procedure

by I. Boras and S. Svaic

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pp. 242 - 246

Abstract:

The paper presents the results of the research carried out by means of transient thermography on two samples made of phenoxy resin and phenoxy resin containing copper fibers.
The experiment has been done together with numerical simulation. The goal of the research was to find the possibility of *using* numerical simulation for prediction of the results before starting with real experiment. Namely numerical analysis enable one to sirnulate a set of experiments on the computer, and to select the proper parameters for real one. The further advantage of the numerical approach is a possibility for observing the temperature fields on various planes inside the sample.

Phase angle thermography with ultrasound burst excitation

by A. DilIenz, Th. Zweschper and C. Busse

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pp. 247 - 252

Abstract:

Elastic wave phase thermography with ultrasound burst excitation is a technique derived from the well known Ultrasound-Lock-In thermography and pulse phase thermography thereby resulting in robust and fast measuring method. The advantage of multifrequency thermal waves is combined with the defect-selectivity provided by ultrasound elastic wave phase thermography where phase evaluation of temperature irnages suppresses inhornogenieties in material emissivity. At the same time it avoids the disadvantages of Ultrasound Lock-In Thermography with respect to measuring time, reproducibility, and applicability.

Assessment of knitting process dynamics using computer thermovision method

by Z. Mikolajczyk*, B. Wiecek** and S. Zwolenik**

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pp. 254 - 259

Abstract:

In this paper, the application of thermography to the assessment of knitting processes is presented. This approach jncludes temperature measurement of the textile material in the kntting zone as well as image processing using spectral analysis methods. Frequency components of the temperature characteristics correspond directly to the components of force and tension variation in the textile fabrics. The procedure presented in the paper can be used to monitor *in-situ* the production quality of textile rnachines and to react to potential failures early enough (predictive maintenance).

Rate of energy storage during consecutive deformation of steel

by E.A. Pieczyska, S.P. Gadaj and W.K. Nowacki

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email: epiecz@ippt.gov.pl

pp. 260 - 264

Abstract:

We present results ot investigatons related to the energy storage process in stain!ess steel subjected to continuous and subsequent tensile deformation. The instantaneous rate of energy storage was determined and interpreted in terms of the evolution of material structure. The results found for subsequent cycles of straining confirm that energy stored does not vanish, but it cumulates during the whole material history.

Infrared thermography of the damage of natural gut string

by M.P. Luong

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pp. 265 - 270

Abstract:

The paper aims to illustrate three advantages of infrared thermography as a non-destructive, non-contact and in real time technique (a) to detect the occurrence or intrinsic dissipation localisation, (b) to observe the progressive damage processes and mechanisms of gut string failure, and to determine the optimal tensions for each type of tennis strings. Experimental results evidence a limit of acceptable damage beyond which string will fail due to coalescence of defects and/or weakness zones. In addition this useful technique has been used for a quantitative evaluation of fretting fatigue of tennis strings.

Infrared and speckle image processing applied to heterogeneous thermomechanical behaviour of polymers

by B. Wattrisse, J.-M. Muracciole and A. Chrysochoos

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E-mail: wattriss@lmgc.univ-montp2.fr

pp. 271 - 276

Abstract:

This paper presents an application of quantitative infrared thermography in the field *of* solid mechanics. The process-ing of thermal images of a sample, recorded during tensile tests performed on a semi-crystalline polymer under its glass transition temperature, gives the distribution of the heat sources responsible for the temperature variations. These energetic data are associated to other mechanical information (strain, strain-rate, stress distribution) by means of a speckle image processing technique.
These tests show the early and progressive development of the mechanical, and the resulting calorimetric manifesta-tions of necking.

Lock-in thermography and fatigue limit of metals

by J.C. Krapez, D. Pacou and G. Gardette

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pp. 277 - 282

Abstract:

Thermography was performed on stainless steel 316L and aluminium alloy 7010 samples as they were submitted to a sinusoïdal mechanical stress (traction/compression). For each stress amplitude value the temperature data were recorded in 5 s. A specific signal demodulation procedure was used to extract the first two Fourier components and the mean temperature rise. From their particular dependence on the stress amplitude, characteristic stress values could be derived. In some instances, these values are very close to the fatigue limit of the considered material.

Application of thermography for slow and fast varying processes in textile reasearch

by M. Michalak*, I. Krucinska* and B. Wiecek**

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***Computer Thermography Group, lnstitute of Electronics, Technical University of Lodz, Poland*

pp. 283 - 288

Abstract:

Aiming at replacement of the traditional destructive investigations of texlile materials with nondestructive, contactless methods, textile composite materials were studied in the process of drawing on a tensile testing machine. It was shown that there is a relation between temperature of the samples during breakage and tensile strength of composite material. On the basis of results of studies of a ring spinning frame twisting system, it was shown that thermovision can be used for diagnosing of textile machines work. A correlation between dynamic state of traveller-ring-yarn friction trio and its thermographic image was shown.

Determination of the convective heat coefficients by the pulsed photothermal method

by M. Rebay*, J.-F. Henry**, S. Offerrnann**, M. Lachi* and J. Padet*

**Université de Reims, Unité de Thermique et Analyse Physique, Laboratoire de Thermoméca-nique.*
***Université de Reims, Unité de Thermique et Analyse Physique, Laboratoire d'Energétique et d'Optique, UFR Sciences, Moulin de la Housse, BP 1039, 51687 Reims,*
E-mail: mourad.rebay@univ-reims.fr

pp. 290 - 295

Abstract:

We present some elements in order to improve the non-detructive procedure for the measurement of the local heat transfer coefficients between a flat plate and an air flow. We use the pulsed photothermal radiometry method which consists of analysing the transient temperature on the front face of a wail after a sudden deposit of luminous energy by a lamp. The infrared camera measures the temperature evolutlons at difterent abscissa from the leading edge of the plate) in order to deduce the local heat coefflcients for the same experiment. The results of three identilications, based on a one-dimensional model at any abscissa with constant heat transfer coefficients, are compared.

Heat transfer between fluidised bed and moving belt

by M.P. Moschos and J.M. Buchlin

von Karman Institute for Fluid Dynamics, 1640 Rhode St Genèse, Belgique, buchlin@vki.ac.be

pp. 296 - 300

Abstract:

The fine control of the thermal exchange between a continuous moving belt immersed inside a gas-fluidised bed is of great importance in several industrial processes such as powder coating. The determination of the heat transfer coefficient in such a complex flow configuration is tedious and requests the application of non-intrusive technique. Infrared thermography is applied to a thermal sensor moving in a dedicated set-up. The thermal behaviour of the probe is theoretically modelled to provide he local heat transfer coefficient between the fluidised bed and the moving belt. The experiments are performed in various conditions of superficial gas velocity, belt velocity and height of the particle packing.

Convective Heat Transfer in a Channel with Perforated Ribs

by J.M. Buchlin, L. Ceulers and G. Talbot

von Karman Institute for Fluid Dynamics,
Chaussée de Waterloo, 72, 1640 Rhode Saint Genèse, Belgium, E-mail: buchlin@vki.ac.be

pp. 301 - 306

Abstract:

Infrared thermography associated to the steady heated thin foil technique is applied to obtain the convective heat transfer mapping in a channel implemented with perforated ribs immersed in a turbulent boundary layer. Different types of perforations are first compared for a single turbulator configuration. Then, the emphasis is given to the effect of rib-to-rib spacing in the case of chevron type rib arrangement. The influence of the open-area factor and the channel Reynolds number on the thermal enhancement is also shown.

IR-Cyclic Method To Determine Heat Transfer Coefficient

by M.P. Moschos* **, J.M. Buchlin* and A. Papaioannou**

**von Karman Institute for Fluid Dynamics, dept. Environmental & Applied Fluid Dynamics, 1640 Rhode St Genèse, Belgique*
***National Technical University of Athens, School of Chemical Engineering, Dept. Process AnaIysis and Plant Design, 15780-Zografou Campus, Athens, Greece.*

pp. 307 - 312

Abstract:

The knowledge of the heal exchange coefficient by convection is a key parameter for the design and the performance evaluation of thermal systems. The paper deals with the determination of the convective heat transfer coefficient using a cyclic method. It relies upon a theoretical model that is described. The relevancy of the model is validated through experimental tests performed in a wind tunnel specially designed to study thermal boundary layer development over a heated flat plate. Quantitative Infrared Thermography allows the measurement of the wall temperature field that leads to the mapping of the heat transfer coefficient. Sensitivity analysis of the parameter effect yields the range of the expected accuracy.

Application of infrared thermography in natural convection study

by T.S. Wisniewski*, T.A. Kowalewski** and M. Rebow*

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***Center of Mechanics, IPPT PAN Polish Academy of Sciences, Swietokrzyska 21, 00-049 Warsaw, Poland, e-mail: tkowale©ippt.gov.pI*

pp. 313 - 318

Abstract:

The main goal of the study is to test the applicability of Infrared Thermography for verification of Thermal Boundary Conditions at external non-isothermal walls bounding a flow domain. Experimental and numerical studies have been made for transient and steady natural convection in a differentially heated cube filled with water.The analysis is carried out for pure convection of water in the vicinity of the freezing region (cold wall temperature T(c)= 0°C), and for convection of water accompanied by freezing (T(c) < -10°C). The opposite hot wall temperature is always fixed at +10°C.

Convection heat and mass transfers in a vertical duct

by X. Chesneau, L. Pietri, J. Bresson and B. Zeghmati

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UPRES EA 2986
Université de Perpignan, 52 avenue de Villeneuve, 66860 Perpignan cedex, France

pp. 319 - 324

Abstract:

Heat and mass transfers are analysed in a vertical duct where an air flow is established. One of the plates is heated and cooled by a falling water film. Temperatures at the wall and at the water-air interface are measured using thermocouples and an infrared thermography system. It is shown that the infrared camera measures the water surface temperature. From temperature measurements, local Nusselt numbers are calculated for different wall heat flux densities and liquid mass flow rates. From these data, Sherwood numbers are deduced using Lewis function assumption.

Heat transfer measurements in the near field of a jet in cross-flow

by G. Cardone, G.M. Carlomagno and C. Meola

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pp. 325 - 330

Abstract:

The aim of the present study is to add information in the near field of a jet in cross flow. An experimental investigation is made to measure convective heat transfer coefficients over a plate due to the combined effects of a wind tunnel stream and a jet perpendicularly injected into the cross flow .Tests are carried out for varying the stream velocity and the velocity ratio of the jet to the stream. Heat transfer measurements are made by means of an infrared scanning radiometer applied to the heated th*in-foil* technique. Data is reduced in dimensionless form in terms of the Nusselt number *Nu,* based on the nozzle exit diameter. or better the ratio Nu/Nu_o where Nu_o **is** the Nusseft number relative to the undisturbed plate (without jet injection)

Heat transfer measurement in a 180deg turn with rib turbulators by means of IR thermography

by T. Astarita, G. Cardone and G.M. Carlomagno

DETEC-University of Naples, P.le Tecchio 80, 80125— NapoIi, Italy

pp. 331 - 336

Abstract:

Local measurements of the heat transfer distribution nearby a IB0deg sharp turn in a square channel with rib turbulators are carried out by means of infrared (IR) thermography associated to the heatedthin-foil technique. Ribs are mounted on two opposite walls and are placed at 30deg with respect to the channel axis. Two rib pitches are used during the tests.
The convective heat transfer coefficient is evaluated from the measured temperature maps and the local bulk temperature of the flow which is obtained by making a one-dimensional energy balance along the channel. Results are presented in ternis of local Nusselt number, which is normalised with the classical Dittus and Boelter correlation. The fluid used during the test is air and the Reynolds number, based on the flow average velocity and channel hydraulic diameter, is 60,000

Flame analysis by IR thermography and IR hyperspectral imaging

by J.M. Aranda, S. Briz, J. Meléndez, A.J. de Castro and F. Lopez

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E-mail: melendez@fis.uc3m.es

pp. 337 - 342

Abstract:

Measurements of temperatures in flames are important for many applications. Thermocouples are widely used, but they give only time averaged point measurements, and suffer from calibration problems. Infrared (IR) thermography is a nonintrusive technique that could provide temperature imaging if an effective emissivity could be defined for flames. In this work, medium and thermal JR brightness temperatures of a flame are compared to real temperatures obtained by the emission-transmission (E-T) method, showing that effective emissivities vary spatially in the flame. Although ordinary, single-band thermography is thus unable to provide reliable flame temperatures without a previous E-T calibration, this difficulty is overcome by new hyperspectral imaging techniques. These techniques open the way also to remote sensing compositional analysis of gases.

Qualification and Certification of Thermographers

by H. Heinrich

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Erwin Schrödinger Strasse, 67653 Kaiserslautern, E-mail: hheinrich@rhrk.uni-kl.de

pp. 344 - 346

Abstract:

A new three-step quantificaton and certification system was developed using the European standard EN 473 as a basis. The courses are combined with an examination. The first courses at three different levels were successfully carried out. In future actual standards are needed to perform a high quality education.

Applications of infrared thermography in electronics research

by R. Lehtiniemi, C.M. Fager, A.M. Hynninen, T. Aapro,

P. Tiilikka, V. Kyyhkynen and J. Rantala

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e-mail: reijo.lehtiniemi@nokia.com

pp. 347 - 352

Abstract:

In the course of time, power densities in electronics have been continuously growing. Since excessive dissipated power leads to elevated temperatures affecting on functionality usability, and reliability of electronic devices, interest to thermal phenomena occurring in this specific frame of reference has respectively increased in order to enable enhancing the thermal quality of products. One considerable tool to facilitate this work is infrared thermography. In this paper, some not yet so common applications of infrared imaging in electronics thermal management related research are concisely described with examples.

Application of infrared thermography to the characterization of multicristalline silicon solar cells

by A. Kaminski, 0. Nichiporuk*, J. Jouglar, P.L. Vuillermoz and A. Laugier

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**Radiophysics Department, Kiev University, Volodimirskaya Street, Kiev 01017, Ukraine*

pp. 353 - 357

Abstract:

In this study infrared thermography is used to detect defects in large area (100 cm^2) multicrystalline silicon solar cells. Hot spot observed in biased solar cells are correlated to a critical processing step which needs to be improved. Usually these shunts are due to short circuit of the junction which leads to a local heating. By this way infrared thermography appears as a very useful tool to improve solar cell fabrication and efficiency.

On-line thermography applied to crack detection in steel billets.

by J. Wullink* and Ph. Darses**

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***CEDIP Infrared Systems, 19 Sd Georges Bidault, ZI Paris EST, F-77183 Croissy-Beaubourg, France. e-mail. philippe.darses@wanadoo.fr*

pp. 358 - 362

Abstract:

On-line detection of longitudinal cracks in steel billets and bars is performed by inducflve heating and infrared scanning of the surface under inspection. In collaboration with CEDIP, CORUS Research, Development & Technology designed an inspection system based on four infrared matrix cameras. The infrared images are analysed on-line by computer, searching for transverse temperature gradients, indicating the presence of a crack.
This paper describes the construction of the inspection system, functioning of the crack detection tools and results.

Experimental Study and Numerical Simulation of Preform Infrared Radiative Heating

by S. Monteix*, F. Schmidt*, V. LeMaoult*, G. Denis** and M. Vigny**

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***Perrier-Vittel M. T. BP 43 88805 Vittel Cedex (France)*

pp. 363 - 369

Abstract:

The injection stretch-blow moulding process ot thermoplastic bottles requires an heating step before forming. An amorphous preform is heated above the glass transition temperature (80°C for the PET.) using an infrared oven. This step is fundamental in order to determine the thickness distribution along the preform height and then insure high quality bottles.
Thus, the optimisation of the infrared oven is necessary. Various experiments have been conducted to characterise the heat source and the semi-transparent properties of the PET. Measurements of air temperature inside the infrared oven and air cooling speed have been processed. These parameters have been implemented in control volume software that simulates the heating step. The surface temperature distribution of the preform has been measured using an infrared camera. Comparisons between experimental and numerical results for a rotating preform are presented.

Use of thermography for estimation water flow of the radiators in central heating system

by Z. Rymarczyk

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pp. 370 - 374

Abstract:

In the report, the method of estimation of water flow with use of computer programme and thermography worked out on the basis of mathematical model heat exchange "radiator —accommodation" and thermography is suggested. This program makes possible to estimate the temperature distnbution along height of radiator, thermal power of radiator, average value ol temperature surface on the base of the water flow and the temperature *of* surface in inflow area and others. This temperature has been determined on the basis of thermographic measurements. Next, it is compared to the temperature on the surface in outflow area obtained experimentally by means of thermography with suitable temperature on the basis of program calculations for the given water flows.

Rating Burn Wounds by Dynamic Thermography

by M. Kaczmarek*, A. Nowakowski* and A. Renkielska**

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***Department of Plastic Surgery and Burns, Medical Academy of Gdansk, M Curie-Sklodowskiej 3A, 80-210 Gdansk, Potand*

pp. 376 - 381

Abstract:

Use of the dynamic thermography (lock-in and pulse) for assessment of burns is discussed. Measurements of burns under medical treatment with different depth of affected tissue (from the first to the third-degree burns) are shown. The thermographic data are correlated with histopathological analysis of lesions. The results show that dynamic thermography might be advice as a simple, noninvasive and non-stressed for patients diagnostic tool. Further analysis of dynamic pictures gives the first estimate of the depth of a lesion.

Emission properties of dental materials and hard dental tissues

by M. Dabrowski*, R DuIski*, S. Zmuda** and P. Zaborowski**

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***Dentistry Institute, Central Clinical Hospital of Military Medical Academy, 78 Koszykowa St. 00-909 Warsaw, Poland*

pp. 382 - 386

Abstract:

This paper deals with calculations of emissivity coefficient of selected dental materials and hard dental tissues, which has decisive meaning to the real temperature measurements using the radiometric equipment e.g. thermovision cameras.

Active Thermography with Microwave Excitation - Phantom Studies

by A. Nowakowski, M. Kaczmarek and P. Debicki*

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pp. 387 - 392

Abstract:

Different sources of irradiation - microwave and optical: infrared and halogen lamps — used for comparison of active thermography experiments are evaluated. The main task is to find if microwave excitation is reasonably better than optical one in terms of its use in breast cancer diagnostics. Gel phantom studies with use of different excitation sources and thermographic measurements of forced temperature changes are related. Final conclusion - in medical experiments optical sources seem to be most handy and safe in use.

Usefulness of thermovision in venous system pathology

by A. Jung*, B. Wiecek**, S. Zwolenik**, J. Zuber*, B. Kalicki* and S.J. Klosowicz***

**Pediatrics and Children Nephrology Department of Clinical Hospital, Military University School of Medicine, Warsaw, Poland.*
***Computer Thermography Group, Institute of Electronics, Technical University of Lodz, Poland.*
****Cnystals Physics and Technology Section of the Institute of Applied Physics MUT, Warsaw, Poland.*

pp. 393 - 398

Abstract:

In this article the possible applications the thermography for venous system pathology are presented. Although the investigations are very preliminary, the results bring hope of the usefulness of thermography in medicine, mainly because of its non-invasive character.

The use of statistical parameters in medical IR-image analysis

by I. Benko*, G.J. Köteles** and G. Németh***

**Budapest University of Technology and Economics (BME), Department of Energy, H-1521 Budapest, Hungary;*
***Frédéric Joliot-Curie National Research Institute for Radiobiology and Radiohygiene, H-1775 Budapest P0B 101, Hungary;*
****Semmelweis University, Dept. of Radiotherapy, H-1389 Budapest, ROB. 112, Hungary*

pp. 399 - 404

Abstract:

A world-wide experience has shown that many of the incidents and accidents caused by radiation sources involve only parlial body irradiation and the extremities are the most frequently injured parts of the body. In the recent decade we have investigated the applicability of various thermographic techniques in diagnosis of radiation injury (I,6,9,11). The present paper is dealing with two general mathematical methods of evaluation. The first is the evaluation of statistical methods for the description of temperature distribution (e.g. histographic processing, distribution curve of the histogram). The second one is the application of the distribution curve of temperature histogram for process monitoring.

Medicine-applicable non-steady-state phenomena inspection through the use of infrared thermography

by B.G. Vainer

Institute of Semiconductor Physics. Russian Academy of Sciences, Siberian Branch, 13, Lavrentyev avenue Novosibirsk. 630090 Russia, E-mail: bgv©isp.nsc.ru

pp. 405 - 408

Abstract:

One of the considered problems is devoted to the appropriateness of interpretation of diffuse thermal focuses in medical infrared thermography diagnostics. It is shown experimentally that some of usual diffuse foci can be arisen not by inflammation, etc., but by the heat lateral dissipation from the superficial blood vessels. A phenomenon of anisotropic lateral heat transport along the surface of a human body is discovered, and its specific parameters are measured. The variance infrared thermography method is presented. It works effectively when thermographic registration of non-stable, or non-steady-state, thermal objects, or their parts, is required.

Evaluation of the thermography of gingival condition in children and adolescents with insulin-dependent diabetes mellitus (IDDM)

by D, Burchardt*, M. Borysewicz-Lewicka* and M. Walczak**

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***Department of Endocrinology and Diabetes, lnstitute of Paediatrics, K. Marcinkowski University of Medical Sciences, Poznan, Poland*

pp. 409 - 412

Abstract:

Patients diagnosed with periodonthopathies were subjected to thermographic study in order to analyse blood circulation in the periodontal region and pattern of temperature changes in the gingival crevices. The aim of the study was to assess the influence of insulin-dependent diabetes mellitus (IDDM) on the status of blood vessels in the periodontal region in children and adolescents. Clinical status of the periodontal region was assessed with CPITN (Community Periodontal Index of Treatment Needs). Thermographic patterns were taken in the vicinity of teeth 11 and 21 at some distance from the gingival margin and frenulum of the upper lip, which permitted elimination of a possible influence of other factors on the parameters studied. The thermographic measurements were a few times repeated for each patient and made before and 1,2,3, and 4 minutes after cooling of a selected surface of gingival mucosa. Interpretation of the thermographic patterns was performed taking into account the minimum and maxjmum temperatures: T(min) and T(max), and T(x) — the weighted mean for the left and right sides. Preliminary observations revealed a difference between the data obtained in the group with IDDM and the control group. The results suggest the suitability of the therniographic study for assessment of vascular changes in IDDM patients.