NASA Thermographic Inspection of Advanced Composite Materials

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Abstract

As the use of advanced composite materials continues to increase in the aerospace community, the need for a quantitative, rapid, *in situ* inspection technology has become a critical concern throughout the industry. In many applications it is necessary to monitor changes in these materials over an extended period of time to determine the effects of various load conditions. Additionally, the detection and characterization of defects such as delaminations, is of great concern. This paper will present the application of infrared thermography to characterize various composite materials and show the advantages of different heat source types. Finally, various analysis methodologies used for quantitative material property characterization will be discussed.

Spatiotemporal Active Thermography

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Abstract

Standard active thermograph techniques such as lockin-thermography or burst-phase-thermography apply only temporal varying patterns to the surface of the object to be investigated. As a consequence, the heat flow is basically directed perpendicularly to the surface. In contrast, spatially varying heat flow applied to surfaces causes also temperature differences parallel to the surface and thus is also sensitive to lateral conductivity changes. Applying spatially and temporally varying heat flow results in a powerful generalized technique for non-destructive and remote investigation of objects, which is called spatiotemporal active thermography (STAT). Some important basic features of this technique are worked out.

So far, active thermographic techniques have mainly been applied to static objects. There are, however, many interesting applications with moving parts to be investigated by active thermographic techniques. Especially demanding are processes with random motions. STAT is a powerful experimental technique even for such complex cases. This is demonstrated by the investigation of heat exchange across the aqueous viscous boundary at the wind-driven and wave-undulated ocean surface.

Published in the QIRT Journal, Volume 1, Issue 1

Analysis of thermoelastic and dissipative effects related to fatigue of aluminium alloys

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Keywords

Aluminium, fatigue, infrared thennography, thennomechanical couplings, dissipation

HIGH SPEED NON CONTACT IMAGING OF STRESS IN MATERIALS APPLICATION ON BLADE VIBRATION ANALYSIS

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Keywords

Thermal Stress Analysis, Lock-in Thermography, Transient loading, Integration time, spectrum of measurement, blade vibration

Abstract

Perfonnances of infrared focal plane array detectors drastically improved in the last decade using advanced detector materials like HgCdTe and InSb. These new technologies provide to the Thermo Elastic Stress Analysis large advance in stress analysis especially in term of understanding and measurement during very fast events.

Thermo-elasticimetry is the unique technique of measurement which measures directly the mechanical energy by temperature measurement. Using infrared cameras it gives a non contact, full field stress measurement on the surface of materials.

This article deals with the measurement of fast transient phenomena, in particular on slam door (2s), Hopkinson tube (100 ~s) and vibration analysis of jet engine blades (10-20KHz).

Published in the QIRT journal, volume 1, issue 1

ADVANCES IN INVESTIGATION OF THE NUCLEATION AND PROPAGATION OF PHASE TRANSITIONS IN A TINI SHAPE MEMORY ALLOY

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Keywords

Shape memory alloy, phase transformation fronts, infrared detection

TECHNOLOGY OF NON DESTRUCTNE CHECK UP IN INDUSTRY

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Keywords

Crack resistance, non destructive check, thermographic approach, entropy

Fault Localisation of ICs by Lock-in Fluorescent Micro-thermal Imaging (Lock-in FMI)

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Abstract

An improved method for high resolution surface temperature acquisition using fluorescent microthermal imaging (FMI) is introduced. In combination with lock-in-thermographic it can be applied for localisation of leakage currents in microelectronic devices with a precision accuracy of about 1IJm. As an example hot spot detection of an

IC failed with a raised current consumption is demonstrated. The physical failure at the detected hot spot position is verified by TEM cross-section analysis.

Lock-in Thermography on Electronic Devices Using Spatial Deconvolution

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Abstract

We show that the "0°/-90°" lock-in thermography signal is very useful to be displayed for microscopic investigation of integrated circuits (ICs). Like the phase signal this signal is independent on the local IR emissivity. But in contrast to it signal components from different heat sources are superpositioning linearly, which holds at least in good approximation. Therefore this signal can be deconvoluted (inverted) numerically for compensating the blurring caused by lateral heat diffusion.

Lock-in IR Thermography for Functional Testing of Electronic Devices

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Abstract

Lock-in thermography (LIT), which is a standard tool in nondestructive testing (NOT), is also very advantageous for electronic device testing (EOT). In this contribution the special points of view of LIT applied in EOT are reviewed. For example, in EOT the power generation is usually not sinusoidal but square-shaped (on I off), and the lock-in correlation is gegerally synchronized to the frame rate of the IR camera. As for NOT the display of the phase image suppresses the emissivity contrast, but in EOT also the display of the 00 image or the -90° image may be advantageous. A novel kind of the realization of synchroneous undersampling is described.

Quantitative Analysis of the Influence of Shunts in Solar Cells by Means of Lock-in Thermography

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Abstract

Infrared lock-in thermography not only allows to image local heat sources like shunts in electronic devices like solar cells, but it also can measure currents flowing in certain regions of the device quantitatively in a non-destructive way. After dealing with the physical basics of quantitative lock-in thermography, two types of measurements are described: 1. The quantitative measurement of the I-V characteristic of a point shunt in a solar cell, and 2. the evaluation of the influence of shunts on the efficiency of the cell as a function of the illumination intensity. The investigation of a typical multicrystalline solar cell shows that the shunts deteriore predominantly the low light level performance of the cell.

Published in the QIRT Journal, Volume 1, Issue 1

Thermographic imaging of free carrier density in silicon for solar cells

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Abstract

The measurement of free carrier density in silicon is a key parameter for the characterisation of silicon solar cell material. Carrier Density Imaging (CDI) is a valuable tool to obtain spatially resolved images of the free carrier density distribution. This article describes the experimental setup of CDI for absorption mode and recently developed emission mode measurements. The theoretical dependence of the absorption and emission of infrared radiation on the free carrier density is discussed. Results of absorption and emission mode measurements are presented and the advantages of the emission mode are elaborated.

Capillary pumped loop for cooling of electronic devices

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Abstract

Capillary pumps are passive, two-phase heat transport systems that use the capillary pressure in a porous material in an evaporator to force circulation of cooling medium flow. The Capillary Pumped Loop (CPL) has been designed, built and investigated. Pump is destined for cooling of electronic component, which work with maximum temperature

about 100°C. Contact surface is 50x50mm. Investigating the static parameters of the pump is the purpose of this paper. The results indicate that a pump takes off 100-200W from the electronic device at 100°C near the surface of the power source.

Modelling and thermography measurements of thermal wake effect in electronic components

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Abstract

In this paper, investigations of thermal wake effect are presented. Two flat heat sources placed one after, another cooled with forced laminar convection were considered. Paper includes numerical simulations of these two flat heat sources cooled by forced convection as well. Real model of heat sources has also been investigated in a wind tunnel.

IR Thermography for Quality Assessment of Microelectronic Devices

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Abstract

This work presents collaboration between electronics industry and University aimed to develop novel power cycling methodology combined with IR thermography for quality and reliability studies of microelectronic assemblies. For this purpose an array of programmable Thermo Electric Converters (TEC) was designed and constructed [1]. The array provides possibility of introduction of controlled anisothermal temperature field as a function of time. Such field is exploited for stimulation for IR thermography and lifetime acceleration experiments. Furthermore, an advanced method, which takes advantage of short stimulations by photon blast was used to perform Time Domain IR Thermography. Combination of such techniques provided information about the weakest points in the assembly, design and optimisation of the manufacturing processes.

Estimation of motion and parameters of heat transport from thermography

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Abstract

In this contribution a technique for measuring motion and parameters of temperature change locally in thermal image sequences will be presented. This leads to the estimation of highly accurate optical flow and parameters of heat transport, such as the constant of diffusivity or the matrix of anisotropic diffusion. Results of the computation are shown on a number of sample applications.

Measurement of physical parameters of laboratory forest fires by bi-spectral infrared imaging

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Keywords

Infrared bi-spectral imaging, infrared remote sensing, forest fires, classification.

Abstract

During the last decade, infrared (IR) sensors have proved to be a useful tool in forest fire fighting. The first applications came from satellite sensors originally devised for meteorological applications, like the Advanced Very High Resolution Radiometer (AVHRR) onboard the NOAA satellites[1,2]. Now, a new generation of specific fire satellites is planned that promises early fire outbreak detection and monitoring[3]. The success of satellite IR sensors has encouraged many forest services to use ground-based IR sensors for fire detection, typical devices being IR cameras placed on rotary platforms on lookout towers. These ground-based applications have been confined nearly always to fire detection, but IR sensors can provide much more information on fires. This information may be very useful to get a better understanding of fire properties and behaviour, in particular by providing inputs and experimental validation for the theoretical models of fire spread. This paper focuses on the problem of how to get quantitative information on relevant physical parameters of forest fires by using IR cameras.

Traditionally, physical information on forest fires is obtained laboratory fires with thermocouples and by measuring the fuel mass loss. This is a very labour-demanding task, that requires to deploy previously a grid of sensors in the fire regions, as well as to perform pre- and post-fire fuel inventories in order to derive heat release from mass loss and heat of combustion of the fuel. In contrast, IR cameras provide fast, spatially resolved measurements of radiated power, without any pre-fire of after-fire work. If camera measurements of other fire parameters proved feasible, it would greatly simplify the experimental study of fires and improve or knowledge of them, by making possible large-scale field studies that now are impractical.

However, quantitative measurements of fires using IR cameras face important difficulties, related mainly to the complex spectral structure of fires. In this work it is shown that some of these difficulties can be overcome by using bi-spectral images of fires (i.e., images in two different spectral bands that are simultaneous and co-registered) and applying them classification techniques, a standard tool for the analysis of satellite multispectral images.

Images of laboratory forest fires were acquired by a bi-spectral imaging system made up by two cameras that operate in the medium infrared (MIR) and thermal infrared (TIR) bands. The cameras are computer controlled so that they provide simultaneous images calibrated in brightness temperatures, that can be co-registered with subsequent processing. The MIR-TIR scatterplot of these images can be used to classify the scene into different fire regions (background, ashes, and several ember and flame regions). This region identification is useful to locate the fire front, to point out places of reignition and to determine the rate of spread. Geo-referencing makes possible to measure areas of the classes and to calculate the power emitted in the MIR and TIR bands by the different classes in a field fire (see an example of results in Figure 1). Additional geometric and spectral corrections make possible to estimate the total power radiated by the fire in the whole spectrum. Time integration provides total energy radiated per unit area. Estimated values for both magnitudes are compared to those for total power and total energy release derived from heat of combustion and fuel consumption. Fires with several different fuel loads have been studied, to check the consistency of the method.

A new experimental techniques for inspection of operating furnaces by use of IR radiometers

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Abstract

The main special feature of elaborated techniques is the dynamic IR thermography, which bases on forming single images which consist of pixels of chosen statistical value, minimum and maximum, noted during adequately long sequence of thermograms with total independence to the moment of its capture. Arrays of these data can be used directly, or as inputs to other artificial images. This paper presents elements of the measuring set which consists from contact and non-contact devices and specialised software. Due to this method, the final "artificial thermogram" offers quality impossible to achieve with a classic "one shot" or "mean thermogram" methods. Many other applications could take advantage of presented idea, algorithm and tools.

Terrain-adaptive infrared line-scan coding: A new image segmentation scheme

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Abstract

IR remote sensing and reconnaissance applications require transmission and/or store of line-scan thermal (IRLS) images in real-time. IRLS images exhibit a high degree of spatial redundancy that a codec reduces optimizing trade-off between bit-rate and image distortion. In this paper, we propose adaptive coding based on joint optimization of image segmentation scheme and operational codec parameters. In computer implementation, we achieved significant coding gain using a new image segmentation scheme and advanced JPEG2000 codec.

Combining Video and Thermal Imagery for Robust Pedestrian Tracking

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Abstract

In the current context of increased surveillance and security, more sophisticated and robust surveillance systems are needed. One idea relies on the use of pairs of video (visible spectrum) and thermal infrared (IR) cameras located around premises of interest. To automate the system, a robust tracking algorithm and the development of an efficent technique enabling the merging of the information provided by the two sensors becomes

necessary and these are described in this paper. Results are presented for a few typical situations.

Thermal tomography on the basis of an information method

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Abstract

A unified (information) approach to the development of an optimum algorithm of thermal tomography on the basis of the available prior information has been designed. The essence of the new criterion is the minimization of the complexity of the description of experimental results. It increases a resolution of thermal monitoring by several folds. The problem of the testing of delamination in a multilayer object is considered as an example of usage. The capability of detection and determination of delamination borders is shown; if its size is much smaller than the depth and thermal resistance is small.

A bias error effect of sub-pixel edge location measurement by means of thermal camera

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Keywords

Subpixel edge location, spatial resolution, optic transfer function, uncertainty of measurement, infrared radiation

Infrared homing head for rotating missiles

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Abstract

A simple infrared system operating without any mechanic-optical scanners that can be used in homing heads of rotating missiles is reported. Space scanning is achieved by missile rotation for the tangential direction scan and an electronic scan of linear array in a dedicated IR focal plane as shown in Fig. 1. Full space scanning is achieved at each rotation of the missile.

The scanning velocity is proportional to the distance of each array element to the optical axis of the system. This results in increased bandwidth, deteriorating of SIN ratio, and in consequence, in reduced thermal resolution for the outer detectors.

Fig. 2 shows more advanced solutions in which the negative consequences of increased scanning velocity are compensated by an appropriate increase of number of detector elements operating in the TDI mode.

The probability of low temperature target detection is evaluated basing on the Johnson method as a function of detector detectivity, array geometry, optics parameters, target range and other parameters.

We have shown that useful performance of the simple homing heads can be obtained using LWIR and MWIR $Hg_{1-x}Cd_x$ Te photodetectors operating at near room temperatures. Such devices have been developed at VIGO SYSTEM SA. They are manufactured using complex $Hg_{1-x}Cd_x$ Te heterostructures grown by the low temperature epitaxial techniques. The performance of the devices has been improved using immersion microlenses, optical resonant cavities and other solutions.

Heat flux characterisation in hot jet and flame I wall interaction by IHCP resolution coupled with infrared measurements

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Abstract

The aim of this work is to identify the heat fluxes between turbulent flames and 3D solids in order to improve the conception of aeronautic structures designed to comply with aircraft certification requirement on fire events. The transient temperature rise prediction inside the impinged structure will be representative if the convective and radiative heat fluxes used as boundary conditions of the numerical model are accurately known. To do so, we need to separate these two different heat transfer contributions from the total heat flux information, obtained by solving an IHCP (Inverse Heat Conduction Problem). The inverse technique that was implemented for this study is based on adding back-face

infrared measurements data as observation equation, thus closing this ill-posed problem. To improve our flame to wall heat transfer knowledge, a dedicated test bench composed of a propane/air burner and a 14 kW air heater was built and studied. In the scope of this study, we present the comparison between propane/air flame and hot round isothermal air jet impinging perpendicularly on a titanium plate.

Rear Infrared Thermography in Heat Fluxes Determination on Hypersonics Vehicles

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Abstract

Due to agressive external conditions during an hypersonic flight, parameters such as external wall temperature are not easily measurable with the usual approach. Hence this study develops a promising in flight measurements methodology to estimate heat fluxes on space vehicle external surface, in order to improve the aerodynamic models. One important application will be the design of the thermal protections. THEFA technique consists in using rear infrared thermography measurements and an unsteady inverse heat transfer model ([1]). The aim is to determine the heat fluxes received by the external surface of the vehicle by using the temporal evolution of its internal face thermal map.

Published in the QIRT Journal, Volume 1, Issue 1

Determination of the Conjugate Heat Transfer Performance of a Turbine Blade Cooling Channel

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Abstract

This contribution presents the experimental investigation of the conjugate thermal behaviour of a rib-roughened cooling channel. Previous investigations were mainly focused on the convective aspects of the heat transfer and the channels' models were made out of low conductive materials. To reproduce heat conduction conditions closer to

the ones of a real metallic airfoil, a facility with a metallic ribbed wall was designed. The infrared thermography was used to measure the temperature distribution on the wetted surface. The convection coefficient was calculated as a function of the measured wall temperature and computed wall heat flux. FLUEN® was used to numerically solve the energy conservation equation into the metallic wall, providing the surface heat flux.

FLAME IR THERMOGRAPHY USED FOR COMBUSTION RESEARCH AND TESTING OF FUEL OIL

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Abstract

Infrared thermography (ITH) new application in miniaturized combustion process research has developed an original method for combustion testing of fuel oil droplets, using a simulator The thermal power variation of radiation heat exchange, between the simulator combustion chamber wall and the burning droplet together with sooting high, were estimated. By research and the measurement of apparent temperature (T a) from droplet flame infrared thermograms (IRT), obtained new criteria for gas oil combustion quality determination. A complex graphologyc-thermographyc method resulted, for research and testing of fuel oil droplet combustion, with advantageous industrial applications. As example, combustion with additived air (CWM) of heavy fuel oil (HFO) at boilers, will be detailed.

Thermography measurements of heat transfer distributions for an array of impinging jets - Comparison with numerical results

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Abstract

This paper deals with the cooling of a plate using an array of round gas jets. The study is devoted to a particular configuration in which spent air is ejected through holes placed between the nozzles. The heat transfer coefficient distribution on the plate has been measured using infrared thermography. The effects of jet Reynolds number and nozzle to plate distance have been investigated. The measured values are compared to numerical simulation results obtained by standard CFD simulation tools.

Measurement of Local Heat Transfer Coefficients of Developing Flows Using IR-Thermography

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Abstract

The experimental determination of heat transfer coefficients has been intensively discussed in the literature. Infrared thermography offers an interesting possibility to analyze the heat transfer characteristics of fluid flow due to its high spatial and temporal resolution and non-invasive nature.

The present study describes the application of infrared thermography to determine the heat transfer coefficients of developing flows after a contraction or extension of the cross sectional area. Water and air are used as working fluids and a different experimental setup is employed in each case.

INFLUENCE OF GRAVITATION ON HEAT TRANSFER BY NATURAL CONVECTION

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Keywords

Rotational forces, natural convection, radiation, experimental

Abstract

The objective is to separate natural convection and radiation experimentally. Therefore a heat source is placed inside a closed cavity and the acceleration inside the cavity can be changed. A centrifuge is used to change the acceleration. A flat resistor etched on a printed circuit board of 25.5mm x 25.5mm, is placed in a hermetically sealed cylinder, which hangs under the arm of the centrifuge. The resistor is powered by batteries,

dissipates 1.63W and has a surface temperature of 82°C at 19. Natural convection is maintained inside the cylinder. Convection and radiation are the main modes of heat transfer, but there's also an amount of conduction through the wires that connect the batteries with the resistor. The rotational speed of the centrifuge determines the centrifugal force in the cylinder. When the centrifugal force increases, the temperature of the resistor decreases due to the increase of natural convection. The amount of radiation, conduction and total heat transfer can be determined from the experiment, so the amount of natural convection can also be determined. The experimental results are compared with the governing equations to validate the experiment. The reproducibility of the experiment is also checked.

VALIDATION OF LARGE EDDY SIMULATION OF THE HEAT TRANSFER INDUCED BY AN IMPINGING JET USING QUANTITATIVE INFRARED THERMOGRAPHY

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Keywords

Validation, heat transfer, impinging jet, LES, infrared thermography

Simulation of pipeline gas leakage

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Abstract

This article deals with the problem of simulation of gas leaks in pipelines and development of a prototype simulator. The prototype provides leakage simulation into water and in different kinds of soils without changing the physical properties of them. It is analyzed the behaviour of the system for different sizes of leaks and different pressures. Experimental results of the characterization of pipeline gas leakage are presented. The images of temperature anomaly were received by means of the infrared camera (Infrared camera model Palm IR 250 by Raytheon).

Studies of Roughness Induced Transition at Mach 6 Using IR Thermography

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Abstract

Transition on the boundary layer of a hypersonic vehicle can result from many factors, among which one of the most important is the presence of discontinuities (roughness) on its surface. For experiments performed in ground facilities, not all the in-flight conditions can be reproduced resulting in a mismatch between the data obtained from experimentation and the real flight conditions. This work represents an initial investigation of the parameters for transition in the Mach 6 H3 VKI wind tunnel using infrared thermography and on Kheops model. Three different kinds of discontinuities are considered: distributed roughness, gaps between different sections and isolated roughness elements. Results from the H3 tests are found to be in good agreement with ballistics range results plotted with PANT criterion parameters.

Roughness induced BL transition measurements in hypersonic flow using infrared thermography

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Abstract

Roughness induced boundary layer transition is experimentally investigated in the hypersonic flow regime at M = 9. The primary interest is the possible effect of stepwise geometry imperfections (but also other roughness configurations were studied). Quantitative Infra-Red Thermography (QIRT) is used to measure the surface convective heat transfer and to detect boundary layer laminar-to-turbulent transition. The investigation shows that for a given height of the roughness element, the boundary layer is least sensitive to a step-like disturbance, whereas distributed 3D roughness was found to be effective in triggering transition. The experimental results have been compared to existing hypersonic transition correlations (PANT).

IR HEAT FLUXES MEASUREMENTS IN HYPERSONIC PLASMA FLOW

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Abstract

The most critical area of the reentry vehicle design is evaluation and the measurement, inside any ground facility, of the aerothermodynamic heating (and catalicity) of the material under test. The study of the aerothermodynamic properties in an hypersonic plasma flow represents one of the most important application fields of the optical diagnostic methodologies. The principal feature of the physical process is the non-equilibrium aspect of the plasma constituents. This peculiarity requires a specified development (theoretical and experimental) of the diagnostic techniques in order to take into account the non-equilibrium effects and the different catalicity of the constituent materials. In this paper, we present the preliminary results of the application of the thermography to the Plasma Wind Tunnel Facility named SCIROCCO, located at CIRA, (nozzle exit diameter of 2 m, maximum overall size of the test article of about 80 cm) devoted to test TPS materials of reentry space vehicles in hypersonic high enthalpy flow conditions. A first step to evaluate the applicability of IR thermography to an hypersonic large scale arcjet facility, is the analysis and the evaluation of the radiation emitted and absorbed by the plasma flow impacting the test sample which represent the medium between the IR Thermograph system (detector and window) and the test sample surface. By using ARCSIZ by Aerotherm Co. and H2NS by CIRA codes, we carried out the estimation of all chemical species and relative concentration for the entire set of flow conditions defining the operative map of Scirocco Plasma Wind Tunnel facility. Then, we assume worthy of consideration any chemical species which results to be present with a significant value of concentration in terms of molar fractions. In table 1, the chemical species, present in not negligible amount at the least in one functioning PWT flow condition, are reported.

Coherent thermal structures in a turbulent channel flow

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Abstract

The thermal patterns that arise in a channel flow are analyzed experimentally. The experimental measurements are carried on by means of a non steady application of the Heated Thin Foil technique and by scanning the wall temperature by an infrared camera. The data processing is made by means of algorithms similar to the ones used in Particle Image Velocimetry. Different test conditions were performed and a comparison between them is presented, showing temperature maps, velocity histograms and autocorrelation coefficients.

Thermal Barrier Properties of Nonwovens Multilayer Structures Investigated by Infrared Thermography

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Abstract

Thermal barrier properties of nonwovens multilayer structures manufactured from polypropylene, flax and hemp fibers measured using thermographic method is presented in this paper. We calculated temperature differences between two opposite sides of the sample in the same time using measurement system with infrared mirror in the dynamic conditions.

Local Heat Transfer Coefficient Measurements, Using a Transient Imaging Method With an Inverse Scheme

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Abstract

Local heat transfer coefficient (LHTC) on heat exchangers fin surfaces is usually measured by means of transient or steady methods. Usually, in transient method, it's determined using the assumption of pure convective flux (no lateral conduction in fin).

However this assumption is not totally validates since a lateral conduction flux still exists inside the fins. We present in this paper several improvements we brought to this transient method and particularly the use of inverse 2-0 scheme to correct LHTC obtained without taking into account the lateral heat conduction.

The inverse scheme is implemented and then validated using a numerical test case with a specific LHTC variation. Then the method is used in a real experiment to determine LHTC on a single finned tube.

Convective heat transfer from a surface to a slot air jet using infrared thermography: Effect of the temperature on flux measurements

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Abstract

Impinging jet heat transfer is investigated experimentally using the steady heated-thin-foil technique associated to infrared thermography. For low Reynolds numbers the convection heat flux in the stagnation region is very sensitive to the target surface temperature measurements. This is mainly due to the tangential heat conduction term in the local balance equation. This term is also responsible of the measurement uncertainty increase.

Infrared Thermography Study of Heat Transfer in an Array of Round Jets

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Abstract

The paper describes a study of convective heat transfer in a multiple-jet systems composed of round nozzles. The application concerned is the fast cooling of moving strip. The experimental approach involves the application of infrared thermography associated with the steady-state heated foil technique. The study aims to determine the effect on the average heat transfer coefficient of the jet Reynolds number in the range 40000 to 85000, the normalised nozzle to strip standoff distance Z/D from 2 to 10 and the normalised nozzle spacing WID from 2 to 5. The geometrical nozzle arrangements tested include staggered and non-staggered configuration. The experimental findings are compared with an existing correlation; deviations, which are observed at small Z/D-values may reach 30%.

Some Applications of Infrared Thermography for Antenna Characterization in the Polytechnic University of Catalonia

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Abstract

Infrared Thermography has been applied with success to antenna diagnostic and even to power pattern determination of antennas. Some of the experiences carried out at UPC in relation with this technique are presented.

Mine detection using the EMIR@ method - Improved configuration using a mobile detection system

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Abstract

Traditional way of metallic mine detection by magnetic techniques are often efficient; however, many methods have been experimented in order to detect any kind of mine even those made in plastic with no convincing result. We propose to adapt to that issue the EMIR@ method, already used in many other applications. Following preliminary results presented at QIRT 2002, a mobile detection system is evaluated leading to better images of buried mines or mine surrogates.

Compared improvement by time, space and frequency data processing of the performances of IR cameras. Application to electromagnetism

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Abstract

The thermal resolution of a camera can be improved by time, space and frequency processing. In the first part, the efficiency of such processing is compared for a given camera, using an extended blackbody. In the second part, the processing are applied to the improvement of the radiation pattern determination of a X-band horn using the EMIR technique.

Direct IR Diagnostics of Antenna Aperture Distributions

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Keywords

Phased arrays, aperture distributions, field diagnostics, infrared, thermograms

Abstract

A thermal imaging technique has been developed to measure electromagnetic (EM) fields. This technique is applied in this paper to measure the EM fields radiated by large phased array antennas. This thermal technique is based on infrared (IR) measurements of the heating patterns produced in a thin, lossy detector screen made from a carbon loaded polyimide film placed near the antenna in the plane over which the field is to be measured. The temperature rise in the screen material (over the ambient background temperature of the screen) is related to the intensity of the field incident on the screen. An experimental calibration table was developed at NIST/Boulder to convert the temperature rise into equivalent field strength at any point on the screen by irradiating the screen with a plane wave of known intensity. This thermal imaging technique has the advantages of simplicity, speed, and portability over existing hard-wired probe methods and produces a 2D picture (a pseudo-color image) of the field. In general, these images can be used for field diagnostics of the antenna (near-field or far-field patterns) and/or to evaluate the aperture excitation of the array. The aperture distribution can be compared to a standard "test pattern" to determine the operational state of each individual element of the array, which controls the radiation pattern of the antenna. Phase shifters and/or attenuators which produce incorrect element magnitudes or phase shifts can be identified with this technique.

Infrared surface temperature measurements for long pulse operation, and real time feed-back control in Tore-Supra, an actively cooled Tokamak

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Abstract

Tore Supra is a Tokamak (Ip=1.5MA, Bt=4T) aiming at doing researches in the field of controlled nuclear fusion. It has been constructed with a steady-state magnetic field using superconducting magnets and water-cooled plasma facing components (PFC) for high performances long pulse plasma discharges. When not actively cooled, plasma-facing components can only accumulate a limited amount of energy since the temperature increase continuously during the discharge until radiation cooling is equal to the incoming heat flux. Such an environment is found in the JET Tokamak [1] and on TRIAM [3]. In this paper we report the recent results of Tore Supra.

Quantitative infrared thermography applied to blow moulding process: measurement of a heat transfer coefficient

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Abstract

This paper deals with an application of blow moulding process applied to PET bottles forming. The most important stage of this process is the radiative heating step which is realised with infrared ovens using powerful halogen lamps. To validate a 3D thermal control volume software, called Plastirad, developed in our laboratory, temperatures maps were needed on the plastic preforms as well as convective heat transfer coefficient inside the oven. This measurement has been performed with two different methods: IR thermography and hot wire anemometry. These two methods have been investigated and results are compared to focus on the interest of IR thermography.

Quality Control of Invisible Defects in the Laminating Process using a New Thermographic Online System

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Abstract

A new thermographic online system for quality control in the laminating process is presented in this paper. The developed online system allows a 100% control of the laminating process of wood-based panels. Different types of invisible defects can be selected for detection. The system is implemented on a standard PC and tested in an industrial production process of particle boards with a transportation speed of about 50 m/min. A processing speed of 12 images/sec was reached and in the case of a detected fault an alarm message is sent to the operational personnel.

A Resection Method Applied To Infrared Measurements

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Abstract

Heat flux measurements are one of the main purposes of tests carried out in hypersonic wind tunnels. They are performed at Onera mainly with Infrared Thermography (IRT), while sensors as thermocouples enable to check its reliability. Image processing tools are used to recognize the model position in images and to extract information from them. Methods doing these actions are called resection methods. The Onera's method requires markers, which are recognized automatically. The relative position of the camera is identified and the model motion can then be corrected in a 3D manner. The resection method is now widely applied for wind tunnel testing both for infrared or visible applications.

Photothermal infrared thermography applied to the non- destructive characterisation of the interface between liners and engine blocks

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Keywords

Infrared thermography, thermal resistance, metal - metal interface, lock-in procedure, thermal modelling

Abstract

The aim of the present study is to characterize the variations of thermal resistances between liners and engine blocks of cars; a non-destructive evaluation is proposed: photothermal infrared thermography.

The thermal response of the sample submitted to a modulated optical stimulation is measured by means of an infrared camera. Then, a numerical lock-in procedure yields both amplitude and absolute phase maps of the thermal field periodic component.

On the one hand, an analytical modelling, associated with an inverse procedure using the Gauss-Newton parameter estimation method, allows the identification of the thermal

resistance on academic samples, representative of the liner-engine block interface. On the other hand, the implementation of a numerical modelling allows studying two-dimensional defects at the cast iron-aluminium interface.

Finally, the method is applied to liner-engine block interfaces. The measured thermal resistances match the values obtained when a cast iron plate and an aluminium plate are pressed together.

Investigations on active thermographic testing techniques for manufacturing processes

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Abstract

Active thermographic testing techniques based on ultrasonic, inductive or optical heating were analysed and further developed. In case of ultrasonic excitation the interplay of vibration and released heat was studied by comparing thermography and 3D-vibrometry results. Damage due to ultrasound excitation can be avoided. Eddy current induced thermography is comparable in sensitivity for crack detection to ultrasound induced thermography. Analytical and numerical modelling was applied to simulate the effect of position and geometry of various heat sources and the relation of experimental parameters to the thermal contrast. Main applications comprise carbon and glass fibre reinforced polymers, aluminium components and turbine blades with thermal barrier coatings and cooling channels.

Thermographic evaluation of Er-doped silica fiber as IR-to-visible image converter

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Abstract

A novel concept for IR-to-visible converter is based on the up-conversion, upon pumping with the near IR radiation. The theoretical heat transfer predictions were followed by the experimental results whereby the fiber was maintained at a series of temperatures. Currently, an IR camera (2003 CEDIP), sensitive in the spectral range from 8 um to 12 um is being used to ascertain the validity of the temperature measurements.

Application of infrared thermography in investigation of hydrostatic extrusion

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Abstract

Hydrostatic extrusion is a technique based on severe plastic deformation. Characteristic features of this process are very large deformation, high strains, strain rates and considerable thermal effect. Temperature is one of the most important factors which controls the structure and mechanical properties of material during this process. Due to very high extrusion pressure (of the order of magnitude 1 GPa) and high speed of extruded material only the 'contactless' methods of the product temperature measurement during the process are possible. Results of measurements with use of ThermaCAM SC 2000 at recording frequency 50 Hz are presented in the paper for hydrostatic extrusion of aluminium wires with OD between 2-3 mm.

Infrared thermography applied to spontaneous combustion monitoring of coal tips

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Abstract

Spontaneous combustion of coal tips can generate dangerous slips and it is necessary to monitor this phenomena. Aerial IR thermography is one of methods widely used but, in the case of coal tips, it appears costly and not adapted to survey the evolution of reaction. It is for these reasons that the LAMTI in liaison with Charbonnages de France Group

develops a method using topographic, thermographic and atmospheric survey that is intended to be more reliable and less expensive.

Local thermal diffusivity measurement

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Keywords

Thermal diffusivity, Infrared thermography

Abstract

In plane thermal diffusivity is measured using a one-side thermographic technique suitable for on field use. Applying an uneven heating on the sample surface and measuring the time evolution of the Fourier Transform of the temperature leads to a simple identification formula. The technique has been applied on both thermally thin and thick samples. Results achieved for porous materials (construction stones) and stainless steel have been compared with those obtained by the classical two side flash method.

Published in the QIRT Journal, Volume 1, Issue 1

Focal plane array infrared cameras as research tools

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Keywords

Infrared cameras, FP A systems, spatial resolution, thermal resolution, calibration

Abstract

Temporal, thermal and spatial performances of some FPA cameras have been tested. Different disturbing behaviors related to this recent technology have been pointed out, especially with a view to research and development applications.

Published in the QIRT Journal, Volume 1, Issue 1

The statistical approach to the sensitivity analysis of the ThermaCAM PM595 measurement model

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Keywords

Infrared camera, measurement model, uncertainty, random variable, correlation, frequency distribution, probability density

Infrared temperature measurement on solar thermal high temperature receivers

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Abstract

Operation of solar thermal receivers requires an accurate knowledge of the temperature distribution at the absorber. However, concentrated solar radiation makes it difficult to determine the temperature on irradiated surfaces. Contact thermometry is not appropriate for the use under concentrated solar radiation and also pyrometry fails when external light sources interfere significantly. To avoid distortion of the temperature reading the measurement has to be performed in a spectral range where the emitted thermal radiation exceeds the reflected solar radiation by a multiple. The paper describes the methods of solar blind pyrometric temperature measurement on solar thermal high temperature receivers.

Analysis of the impact of surface heat transfer on a new modification of the Angstroem's method

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Abstract

A new modification of the Angstroem's method for thermal diffusivity measurement has been developed. This relies on the propagation of harmonic thermal waves with mean value equal to the ambient temperature. The diffusivity is evaluated by relatively simple processing of temperature data, acquired by infrared thermography.

The evaluation is based on a mathematical model, in which the heat transfer coefficient at the specimen surface is assumed to be constant. This work is aimed at verifying that assumption. In particular, the effects of natural convection in air are investigated theoretically by numerical simulation. A strategy to improve the test procedure is finally outlined.

Tungsten Lamp as Radiation Standard and the Emissivity Effects

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Abstract

The derivative of the detected incidance in a wavelength interval with respect to temperature includes two terms. The first term depends on the change in blackbody emission and the second one on the change of emissivity with temperature. The error of neglecting the second term is analyzed and evaluated for a standard radiation source, a tungsten lamp. In this case, the error changes form a negligible amount of 6% to a significant value of more than 45%.

From Hershel's discovery to the thermal camera calibration

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Keywords

Planck's law, thermal camera calibration, camera spectral range, camera sensitivity

Thermal diffusivity evaluation of Thermal Barrier Coatings by photothermal and thermographic techniques

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Keywords

Thermal diffusivity, thermography, coating, NDE

Abstract

In order to improve the thermal insulation of the gas turbine hot path components, porous thermal barrier coatings (TBCs) are widely applied. The monitoring and the characterisation of the thermal properties of TBC are essential since TBC performances strongly depend on the microstructure as well as on the service conditions. In fact, the prolonged exposure to high temperature can promote shrinkage phenomena within the TBC, which make the coating less strain tolerant and more heat conductive: this leads to a drastic reduction of the functionality of this porous ceramic protective top layer.

To face the problem of estimating non destructively the evolution of the functional effectiveness of TBC deposited onto components like blades and vanes, we have performed the study of the evolution of the thermal diffusivity as a function of operating conditions, as a first step. In particular the thermal diffusivity of free-standing TBCs samples aged at different temperatures and for different times has been measured by using the laser flash technique. Collecting all the data, a curve of normalised thermal diffusivity of TBC as a function of the Larson-Miller parameter -which conglobates time and temperature -has been obtained. This curve describes the evolution of the thermal diffusivity but it gives also indications about the functional life of the TBC. A NDE technique able to measure the TBC thermal diffusivity directly onto the components appears useful for monitoring the evolution of the serviced TBC and getting indications about the residual life of the ceramic coating.

In this work, a thermographic non destructive technique for evaluating the thermal diffusivity of TBC directly onto components is presented. In particular, the results of theoretical modelling and experimental activities are reported in the frame of developing two different single side thermographic techniques for measuring the in-plane and the through-the-thickness thermal diffusivity respectively.

Development and trials of through skin sensing of aircraft fixtures using pulsed thermography

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Abstract

This work evaluates the potential of pulsed -transient thermography for locating fixtures beneath aircraft skins in order to facilitate accurate automated assembly operations. Representative aluminium and carbon fibre aircraft skin-fixture assemblies were modelled using ThermoCalc-3D. The assemblies were also experimentally investigated with the ThermoScope system and a custom built system incorporating a miniature un-cooled camera. Modelling showed that the presence of an air gap between skin and fixture significantly reduced the thermal contrast developed, especially in aluminium. Experimental results from the ThermoScope system show that fixtures can be located to accuracies of 0.5 mm. Preliminary images from the custom system are superior to the ThermoScope, and optimisation is expected to lead to further improvements.

Compact thermal model of a D2Pak case with convection

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Abstract

The paper presents a compact thermal model of an electronic component enclosed in a D2Pak case. The model includes convection cooling and is compared to a linear model with isothermal boundary condition. The model presented is a static model.

Reconstruction and Analysis of Pulsed Thermographic Data

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Keywords

Nondestructive, infrared, thermography

Abstract

Interpretation of pulsed thermographic data sequences has typically been based on contrast analysis, in which regions with subsurface anomalies are visually identified with respect to defect-free areas. Quantitative contrast-based analysis requires that the time history of a defect-free reference point, either real or synthetic, is subtracted from the time history of a given point in order to create a contrast curve. In practice, this approach has been limited by the fact that real samples may be either completely defective or intact, so that no contrast exists within the field of view. Although numerous variants to this approach have been developed, they all require the identification of a defect-free region as a reference.

Thermographic Signal Reconstruction (TSR) is a viable alternative to contrast analysis, as it allows non-visual interrogation of thermographic data sequences. The patented TSR technique recognizes the nearly linear behavior of the logarithmic representation of a pixel's time history, and exploits this characteristic by representing the logarithmic data sequence as a series of functions, e.g. a low order polynomial, obtained through a least squares fit to the data. Once the series representation has been created, a replica the original data set can be reconstructed, identical in every respect except the presence of temporal noise. For a given image in the sequence, it is difficult to discriminate between the original and reconstructed images, as the only difference is the high spatial frequency "salt and pepper" noise in the original image. Thus, the reconstructed image offers improved signal to noise performance, but minimal improvement to the contrast to noise ratio.

The more significant aspect of the reconstruction process is the ability to operate on the series representation of the pixel time history. For example, first or second time derivatives of any image in the data sequence can be created nearly instantaneously. The derivative images offer an extremely clear visualization of subsurface features, and in many cases, it is possible to detect features in derivative images that are totally undetectable in normal contrast images. The derivative images offer a high degree of immunity to nonuniform heating, and display less blurring than contrast images, as features may be detected earlier, before significant lateral diffusion occurs. Non-visual interpretation of the reconstructed sequences is readily performed by identifying inflection points in the series. To archive the reconstructed data, only the coefficients of the series are stored, so that a significant degree of data compression occurs. As a result, it is possible to process and analyze multiple sequences simultaneously. For a 400-frame sequence of 320 x 256 pixel, 14-bit data, conversion time is typically less than 10 seconds, and file size is reduced from 46 MB to 4.8 MB.

Published in the QIRT Journal, Volume I, Issue I

Autoregressive algorithms and spatially random flash excitation for 2D non destructive evaluation with infrared cameras

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Abstract

Thermal Non Destructive Evaluation methods to detect cracks perpendicular to the plane of a plate needs to implement in-plane thermal gradients. Instead of a flying spot, a spatially random flash excitation on the front face of a thin plate is here proposed. It allows a very simple and quick experiment. Some processing methods are discussed in a longer text in QIRT journal. Only a biased but simple estimation method based on the application of Laplace operator is here presented. The main advantage is to allow the simultaneous process of a huge amount of data, sensitive all over the plate to the thermal conductivity mapping.

Frequency-Modulated Wave Thermography for Non-Destructive Characterisation

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Indian Institute of Technology, New Delhi, India

Abstract

A new, quantitative, whole field, non-contact and nondestructive technique for sub-surface defect detection is presented based on frequency modulated thermal wave imaging (FMTWI). Electro-thermal modeling and MATLAB-SIMULINK simulation has been carried out for the proposed technique. Experimental results for both lock-in thermography (LT) and frequency modulated thermal wave imaging are reported, and comparisons made.

Ultrasound Excited Thermography -Advances Due To Frequency Modulated Elastic Waves

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Abstract

Ultrasound excited thermography allows for defect selective imaging using thermal waves that are generated by elastic waves. The mechanism involved is local friction or hysteresis which turns a dynamically loaded defect into a heat source which is identified by a thermography system. If the excitation frequency matches to a resonance of the vibrating system, temperature patterns can occur that are caused by standing elastic waves. These undesirable patterns can affect the detection of damage in a negative way. We describe a technique how the defect detectability of ultrasound activated thermography can be improved. With the objective of a preferably diffuse distributed sonic field we applied frequency modulated ultrasound to the material. That way the standing waves can be eliminated or reduced so that the detectability is significantly improved.

Application of Infrared Thermography to the Analysis of Welding processes

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Abstract

Infrared thermography is applied to measure the temperature distribution at the surface of metal sheets during the welding. The knowledge of the temperature field is the basis for the understanding of heat effects on welding, the evaluation of the quality and the analysis of weld defects. The measured temperature distribution can be compared with the results of numerical simulations. Thus the infrared thermography is a powerful method for the parameter identification as well as for the validation of numerical models for the simulation of welding processes. The results for three welding techniques, narrow-gap arc welding in vertical position, laser beam welding and high power welding with rotary arc are presented and discussed.

Published in the QIRT Journal, Volume 1, Issue 1

Thermoinductive Investigations of Magnetic Materials for Surface Cracks

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Abstract

Thermoinductive investigations have been carried out on steel work-pieces with the goal of detecting surface cracks. Experimental results show that the method is well suited to find the position of the cracks. Different finite element simulations are used in order to model the temperature distribution in the work-piece and around the cracks, and the derived analytical equations describe the heat transfer process. Results of the numerical simulations and the analytical calculations are compared with the experimental results, and a very good correspondence found. Additionally, the influence of the crack depth on the temperature increase around the flaw is investigated, and a formula derived, which enables the calculation of the crack depth from the measured excess temperature.

Peculiarities of detecting Teflon defect surrogates in CFRP by transient IR thermography

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Abstract

A new thermal NOT model is proposed to explain a 'non-classical' behavior of temperature signals over Teflon inserts in CFRP. Simulation results are compared to experimental data suggesting that composite properties are modified near inserts.

A Quantitative Investigation of Thermosonics

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Abstract

The objectives of this study were to investigate the relationship between the ultrasonic vibrations of a specimen, with a vertical surface crack, and the thermal response. The heat required to be liberated by the defect to obtain a detectable surface temperature rise was modelled analytically for energy liberated only at the crack tip and over the sides of a crack. Experiments were carried out on a nickel based superalloy plate with a vertical surface crack. The strain around the defect and thermal image were measured

simultaneously. Parameters were varied to change the strain to enable a correlation between the strain and surface temperature rise. From this the energy released from the defect was estimated using an optimisation algorithm.

Published in the QIRT Journal, Volume I, Issue I

Pulsed Phase Thermography Reviewed

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Abstract

In this paper, a general review of Pulsed Phase Thermography is presented. The different types of uncertainties related to data acquisition and processing are identified. Equivalence between discrete and continuous Fourier Transforms when applied to thermographic data is discussed. As will be pointed out, the optimal solution for a Pulsed Phase problem, qualitative or quantitative, arises from a compromise between the available computer power and the acquisition parameters: the sampling rate and the truncation window size.

A thermographic study for the assessment of historic structures

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Abstract

Although, the efficiency of thermography as a non-destructive technique in the literature it is well documented, in the investigation of historic structures, where a restoration or conservation treatment can cause irreversible damage to the structure, it is considered to be of most importance. In the present work, both thermographic approaches, passive and active, were used on two different applications, for the investigation of historic materials and structures. The technique was applied on restoration and traditional-historic materials and structures for the evaluation of conservation interventions (materials and techniques) concerning cleaning of architectural surfaces, as well as for the disclosure of tesserae on a plastered mosaic surface.

Defect Detection Capability of Pulsed Transient Thermography

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Abstract

In this work, investigations have been conducted on a novel technique for enhancing thermographic data, which is known as thermographic signal reconstruction, to assess its defect detection limitation on CFRP composite. For defect greater than 4mm diameter, results have indicated a 60% improvement in detectability.

Automatic Interpolated Differentiated Absolute Contrast Algorithm for the Analysis of Pulsed Thermographic Sequences

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Abstract

An automation of the Differentiated Absolute Contrast (DAC) method, called Interpolated Differentiated Absolute Contrast Algorithm (IDAC), is proposed for pulsed infrared thermography. Based on the previously known method, the new algorithm simplifies the analysis process of thermographic sequences resolving the decisions that the user should normally take when applying the DAC method. The algorithm has been successfully checked experimentally with results obtained using Plexiglas TM, graphite-epoxy and aluminium specimens.

Square pulsed thermography applied to thermal defaults characterization

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Abstract

In this study, we extended the flash method to the more general situation of a finite time excitation of the sample in the presence of thermal losses. The objective is the identification of the diffusivity map of a polymer material sample plate that contains some structural defaults simulated on the rear side by artificial damages of cylindrical shape. A comparative analysis of the diffusivity values on the sound and the default areas may allow computing the default depth.

Micro-cracks detection in Photo-Voltaic Cells by Infrared Thermography

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Abstract

In this paper, a technique is presented to detect micro-cracks on photovoltaic cells by infrared thermography. The originality of the system comes from the thermoelectric stimulation used to generate thermal transients at micro-crack locations. These thermal transient are picked-up by an infrared cameras for further detection.

NUMERICAL MODELLING AND m THERMOGRAPHY MEASUREMENTS IN THE HEA T TRANSFER ASSESMENT OF THE SOLAR COLLECTOR

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Keywords

Solar collector, efficiency, heat transfer, absorber plate, numerical computation, themography

Abstract

In a plate type of solar collector having tube banks attached to the absorber plate the collector efficiency (Eq.l) is directly dependent on the heat losses from the absorber plate to surrounding as well as on a goodness of the absorber plate cooling by working media. Convective and radiate heat losses, for a given glazing and its distance from the absorber plate, are lower when the absorber temperature is kept lower as a consequence of a more efficient heat transfer between the working media passing in tubes attached to the

absorber. Therefore, it is a crucial task to ensure a good contact between the tubes and absorber plate. In practice that is normally done by applying different types of welding or, alternatively, by special gluing procedures. The geometry of the contact area can be preliminary evaluated by means of a numerical computation of the heat transfer from the heated absorber to the fluid passing throughout tubes. Such numerical model is developed in the both 2D and 3D domain and provided here together with the results concerning the influence of different geometries, flow conditions and number of the contacts. The resulting efficiency obtained is compared with the performed measurements on the simulated solar collector. The comparison indicates fairly good agreement (within 4%) between the computed and test results (Fig.l). The additional method for inspection of the absorber plate cooling efficiency is based on use of IR camera for recording a temperature field profile over the absorber plate. The recorded IR images (Fig.2) clearly indicate places of the improperly performed contact between tubes and plate as well as inefficiently cooled absorber plate areas due to the position and geometry of the tube bank. The recorded temperature field is compared against the numerically obtained one for the case without glazing.

Defect indications in sono-thermography in relation to defect location and structure

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Abstract

A high power ultrasonic burst excitation technique was used to study the potential of the ultrasound excited thermography (vibro- or sono-thermography) to detect and to estimate the depth position of cracks in ceramics as well as voids in glass fibre reinforced polymer. By verification using high-frequency (50 MHz) ultrasound techniques it was proven that sono-thermography can detect relatively deep defects in ceramics. The depth of the defect can be estimated using a theoretical model based on analytical calculations dealing with friction heat sources equally distributed over the crack flanks stimulated by the ultrasonic vibrations of the specimen. In carbon fibre reinforced polymers, the thermographic indications of defects were correlated with 3D X-ray cross sections of the specimen.

Application of thermogrammetry in panel heating and cooling systems

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Abstract

Simultaneous energy saving and comfort advantages of radiant panels are especially important in green buildings using Hybrid HVAC systems. However, introduction of forced-air convective systems complicates the performance calculations. In this study an analytical algorithm was developed to accurately calculate the radiant panel heat flux using thermogrammetry. This algorithm calculates the actual heat flux on the panel surface and the efficiency. The same technique can also be used to detect leaks in hydronic panels or hot spots in electric panels before the failure occurs or compounds.

Published in the QIRT Journal, Volume I, Issue I

Emissivity Measurements of Road Materials

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Keywords

Emissivity, winter maintenance

Abstract

In the future, roads will have to tell the drivers what they are, whatever the conditions are. The accent is specially put on on-board infrared vision so as to understand how weather phenomena can change the surface of the road (presence of ice, ...). The determination of the emissivity is necessary to reach the road surface temperature. Some research has been undertaken on several conventional materials. Their emissivities were determined by the indirect method considering the conditions to apply Kirchhoffs law were met. An infrared hemispheric and isotropic source was used to create a periodic modulated heat flux to which the considered roads materials were submitted to. Measurements presented in this study have shown differences according to road structure (average particle diameter size) and composition. Emissivity measurements conducted on different salt types used for winter maintenance have shown they can be sorted according to their origin.

Structural Investigation of Concrete and Masonry Structures behind Plaster by means of Pulse Phase Thermography

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Abstract

For non-destructive testing in civil engineering, the application of infrared thermography and especially active approaches as pulse phase thermography have gained more and more importance. Pulse phase thermography is very well suite for he detection of voids and inhomogeneities close to the surface (up to a depth of 10 cm) which will be demonstrated in this paper. This method is based on pulse heating of the object under test and on the observation of the cooling down process with an infrared camera. The transient behaviour is afterwards analysed by Fast Fourier Transformation, yielding phase and amplitude images with enhanced visualisation of the defects. Results of European and National (DFG) funded projects are presented.

Dynamic IRT for the frescoes assessment, the study case of Danza Macabra in Clusone (Italy)

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Keywords

Plaster, stone, lime mortar, acrylic strengthening, IRT dynamic techniques

Abstract

IRT technique has various applications for the detection of the plasters defects in historic buildings, as well documented by the scientific literature in the last decades. Most of the analysis is performed in transient condition, during and after the heating of few cm of the masonry exterior layer. Natural or artificial sources of heating successfully generate the convenient thermal gradient for detecting delaminations, cracks, the masonry texture under beneath the plaster and mapping damp areas. Nevertheless, local non-homogeneities of the surface temperature can be caused by the differences of heating absorption due to the optical and thermal characteristics of the surface and its decay. For example, the chromatic alterations, black crusts, salts, and, on the other hand, the colors of frescoes and decoration, the materials of the tiles of mosaics and their embedding cause localized variation of the temperature pattern.

Previous studies demonstrated the advantages of tomographic techniques for obtaining a quantitative approach of IRT on plaster. In such a way the dynamic measures of IR T, versus time and the maximum value of thermal contrast, allow to locate the delamination and calculate its volume inside the thickness of masonry. The procedures can be applied also in the field, often at boundary condition out of control (for example the without a constant irradiating energy).

Starting from the experiences already set, the authors' goal is to compare the IR T measures obtained at different boundary conditions on a famous fresco of Danza Macabra in Clusone, and to define the link between different kinds of material damages and the expected dynamic thermal results.

The Danza Macabra fresco is one of the most famous medieval external paintings in Europe, regarding the theme of the triumph of the death.

Among 1451 and 1485, the painter Jacopo Borlone, a well know professional in Bergamo area, decorated the interior of the meetinghouse of the Disciplini brotherhood and the external plaster of the northern façade. The building is part of a complex, built nearby the cathedral, in the upper part of the village, over a river. In 1575, the members of Disciplini brotherhood substantially began to change the interior displacement of the rooms: the major damage for the fresco was caused by opening a door at the first floor, and adding an external ladder.

The external ladder lasted until 1868, when some work provided the survival of the fresco: the addition of prominent eaves, to avoid running rainwater over the surface, and a new path to get the first floor.

In 1998 the entire complex got under restoration, starting from the Danza Macabra fresco. IRT has been an important tool for studying the decay and the information kept by the masonry under the plaster.

A complete report of the restorators allows defining exactly the maps of strengthening, water repellent, and others products applied on the surface. For that, it has been achieved the comparison between the results of IR T dynamic tests and the assessment of the surface.

The authors shot the first set of measures in 2000, at steady state condition; the second set consists of five recaptures shot within three hours after the end of direct solar irradiation, in the fall 2003. Preliminary tests on frescoed surfaces, both in laboratory and in the field, showed that the measures during the heating phase are not reliable for the diagnosis of the damage, even using Long Wave thermocameras. In fact, the detectable thermal signal results from the interaction between the most external layer and the irradiation, and it is not enough representative of the heating flux coming from the inner layers of the plaster and masonry.

The effects due to the heat, which flows across these layers, are not prominent if compared with the ones caused by the interaction between surface and irradiation. Moreover these effects are lower than the noise due to the approximation of the spectral coefficient value. The authors already showed that the multispectral evaluation of the reflectance coefficients in the range of visible and near IR contribute to a proper evaluation of the thermograms shot on frescoes, and, generally, surfaces affected by chromatic alterations. In the examined case the evolution of the surface temperature in time allows to quantify the effects of spectral absorption (absorbance) in the thermograms.

Particularly, in temperature evolution, the heating phase permits to identify the effects of optical absorbance and the cooling phase allows visualizing the inner structures, hidden by plaster, and locating the surface decay.

Comparing the thermograms to the maps of the applied restoration products, and the assessment before and after the restoration, it has been possible to correlate the materials and its state of conservation to the evolution of the thermal profile corresponding to each analyzed area.

The superimposing of the map of the time of maximum contrast and decay/interventions allows to map the different times of heating flux from the surface, and connect the cooling time with the different damage.

Infrared thermography combined with geophysical techniques for the cultural heritage conservation

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Keywords

Cultural heritage, nondestructive evaluation, infrared thermography, geophysical methods

Abstract

Infrared thermography, as a remote imaging system, is a powerful tool of nondestructive evaluation. Unfortunately, it has some limitations when dealing with deep and low thermal resistance defects as in the case of thick walls of historic buildings and buried anthropic remains, which are important tasks of the cultural heritage field. Thus, it is evident the need of relatively high-depth inspection techniques such as the geophysical

methodologies. The present study is concerned with the combined use of infrared thermography and geophysical methods in the conservation of architectural structures and art treasures. The main purpose of this study was to characterize the overlapping zone from low-to-high depth with the two different methodological approaches. The investigation was carried out on laboratory specimens, which were two-component structures including a plaster layer over a support of marble, brick, or tuff. Air bubbles were intentionally created inside each specimen to simulate detachments. Measurements were performed with infrared thermography and electric-type geophysical methods. Results prove that an integrated use of the two techniques supply also a detailed evaluation of the structure degradation as well as information about the related causes of degradation.

Transient thermographic evaluation of plastered mosaics

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Abstract

Since there are strict conservation regulations as far as mosaics and/or historical sites are concerned, the use of non-destructive testing and evaluation techniques is considered to be essential. Transient thermography in civil engineering can be used efficiently in a variety of applications. The mosaic beneath the plastered surface due to the different thermal diffusivity that it presents can be realised by different surface temperature. The thermal contrast curves between plain plastered surfaces and plastered mosaics were recorded. Special considerations concerning the applicability and accuracy of the used approach for this specific application are also presented.

PRACTICAL THERMAL TESTING OF BUILDINGS

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Abstract

The general mathematical approach of the solution of inverse problem of nonstationary heat conductivity equation is given. This approach is applied for creating a method of determination of the thermalphysical parameters of an building construction using

experimental data and prospective values of these parameters. Advantages of such approach are discussed. An example of successful implementations of this method for the real building structures examination in practice is given.

Correction the temperature magnitudes from IR camera depending on the angle of aspect and the object distance

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Keywords

Thermal nondestructive testing, IR camera, calibration

Infrared Thermography Applied to Acupuncture

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Abstract

Acupressure is a healing therapy that provides stimulation without needle by applying any pressure to the Traditional Chinese Acupuncture (TCA) Meridians. This article presents an application of the Infrared Thermography (IRT) to the thermal reactivity of Human body skin due to the Acupressure Stimulation (AS). To survey an in vivo human skin surface, we will discuss the different sources of uncertainties and slants bound to the measurement by IRT, such as the skin surface's emissivity, the noise and the drift of the camera as well as the influence of the radiance emitted by the ambient surroundings. The main aim of this work is to highlight an infrared an objective evidence of the acupuncture points by IRT under AS defined by the TCA by refining IRT measuring methods. Twelve healthy acupuncture-naïve volunteers of our University participated to this scientific experimentation: a single blind in vivo trial "formula, placebo and sham" sessions.

Quantitative Thermography in Breast Cancer Detection

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Abstract

This is a research effort that helps to define thermal infrared imaging as a diagnostic tool in breast cancer detection, which can be used as a complementary modality to traditional mammography. Our approach consists in the non-topological and the hybrid methods of computerized thermogram classification. The principle task is to find the most significant thermopathological features.

Comparison of thermal and electrical tomography in medicine

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Abstract

Diagnostic modalities - Thermal Tomography (TT) and Electroimpedance Tomography (EIT) - both new in clinical applications, are challenging for acceptance in medical diagnostics. Basic thermal and electroimpedance tissue properties are compared. Diagnostic importance of both modalities is underlined showing common value in many applications. Advantages and week points are discussed. Basic medical applications, especially the research results of the Department of Biomedical Engineering Gdansk University of Technology (TUG) are shown.

Evaluation of cutaneous flap survival by IR thermography

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Keywords

Cutaneous flap survival, infrared thermography

Abstract

There are plenty of recent studies showing the influence of different drugs on the survival of the cutaneous flap. The effects of a topically applied capsaicin, methylprednisolon, mitomycin and gastric pentadecapeptide BPC-157 in improving skin vitality and preventing distal flap necrosis were tested in a random-pattem dorsal skin flap model.

Wistar rats were randomized into five groups, four experimental groups and a control group. A standardized full thickness dorsal random-pattem skin flap was raised on each rat and sutured back into place. A gelatin sponge was placed before suturing between the flap and its recipient bed, with 0.9% saline in the control group and with capsaicin, methylprednisolon, mitomycin and pentadecapeptide BPC-157 in the experimental groups. The flap survival was judged one week postoperatively, and the extent of skin flap survival was compared between the experimental groups and control. Vitality of the flap and survival area was measured by infrared termography. Infrared termography is non-invasive diagnostic method which offers two-dimensional representation of the surface temperature of the skin. It is useful for the evaluation of cutaneous blood circulation of the skin and superficial temperature can be an indicator for the vitality of the skin flap.

The topically applied methylprednisolon and pentadecapeptide BPC-157 resulted in a statistically significant decrease in skin flap necrosis, compared with the control group ($p< 0.05$), topically applied capsaicin and mitomycin did not show statistically significant decrease in skin flap necrosis. The topically applied methylprednisolon and pentadecapeptide BPC-157 was effective in reducing ischemic necrosis in failing random-pattem skin flaps in this rat model.

The results of this study suggest that such a topical drug application might have significant effects in the reduction of ischemic necrosis in the distal parts of skin flaps, and this treatment might also have applications as prophylactic therapy for risky skin flaps. Thermography of the skin is an easy method for estimating the vitality and survival area of the skin flaps.

Verification of 1 D numerical model for heat conduction in human tissue by means of thermography

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Abstract

The paper presents the results of simulation of the heat transport in the human tissue by means of 1 D numerical model and experimentally obtained data. The model is based on the control volume numerical method with the skin temperature and heat losses to the surrounding as the boundary conditions. The thermodynamical properties of the tissue were taken from the relevant literature. The results obtained by simulation are compared with the data given in lit. The temperature droop in upper arm tissue of the observed subject is presented graphically, while the temperature distribution on the upper arm surface is given by thermograms.

Preliminary model of the thermographic image of the periodontum proposed on the basis of results for healthy subjects-preliminary study.

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Keywords

Thermology, diagnostics, periodontology, gingiva, adolescents

Infrared thermography for the use in facial surgery

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Abstract

Today infrared thermography seems to be a useful and non-invasive tool in medical research as well as in clinical practice [1]. The technique enables precisional control of heat produced by drilling and screwing in surgical management of maxillofacial fractures.

Therapy of midfacial fractures requires accurate reduction and fixation of bones to prevent mobility of fragments during fracture healing. This can be achieved by using titanium miniplates and screws. But drilling and screwing in bones shall be performed

with an integrated cooling device for tissues and materials to avoid necrosis of hard and soft tissues. Even damage of nerval tissue and loss of the implants are possible. However, this can be prevented by the use of infrared thermography to measure temperatures on surfaces intraoperatively. In this study first observations were made during 36 experimental drillings on macerated human skulls. Then intraoperative measurements were done during treatment of 13 midfacial fractures.

Use of IR Thermography for Bioheat Transfer Studies

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Keywords

Bioheat transfer, Blood perfusion, Pathologies, Computer simulation, Infrared thermography

Thermographic assessment of thermal effects during laser sterilisation of pathological periodontal pocket

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Abstract

This article evaluates thermal effects during laser-assisted curettage of pathological gingival pocket. The use of thermal imaging camera and a real time recording software allowed to qualify the maximum increases of tissue's temperature as well as to estimate the safe time of laser irradiation on surgical area for selected laser parameters. The main goal of investigation was to evaluate if there is possibility of hard dental tissue damage during laser sterilization. Two kinds of dental lasers were tested: Er:YAG and Nd:YAG. To ensure conditions similar to those occurring in the patient's mouth the investigations was performed using special experimental stand.