QIRT - Quantitative InfraRed Thermography

FEUP-QIRT-2020/2021-A

QIRT2020 - Quantitative InfraRed Thermography Conference

Porto City Tourism Videos and Photos

Welcome to QIRT 2020 Virtual Conference

21-30 September, 2020

Faculdade de Engenharia, University of Porto, Porto, Portugal

Local Chairs: Joaquim Gabriel Mendes (FEUP) & Ricardo Vardasca (ISLA-Santarém)

email: qirt2020@fe.up.pt

QIRT - Quantitative InfraRed Thermography Association

Quantitative InfraRed Thermography Journal - Taylor & Francis

NEWS

QIRT2020 is officially open

>>>> LIVE - don't miss tomorrow <<<<

Near-infrared imaging for heat and mass transfer studies on aqueous solutions

by **Naoto Kakuta**, **September 23th, 17h00 TOKYO TIME**, **please see the details bellow in the respective section**

https://zoom.us/j/93519283825?pwd=bjMrVVFWSllQRHlvb2swb1lhbVB3UT09
Meeting ID: 935 1928 3825
Pass code: 173033

- 85 videos from the participants' work are available!
- QIRT2020 - 164 participants, 147 communications, 59 full papers
- This platform is also available on mobile Android play store, and Apple Store as "Moodle". After installing, just write https://moodle.up.pt/ ; in the site field
- The videos will be available only until September 30th
- To protect the authors' copyrights, video download is blocked

Video Upload

Those who have produced the video using this platform and the embedded Panopton **don't need** to performe this task.

If you have produced a video using other software, you may upload it here (if < 100Mb), otherwise, send an email to qirt@fe.up.pt with the link for download (you may use https://wetransfer.com/ or google drive).

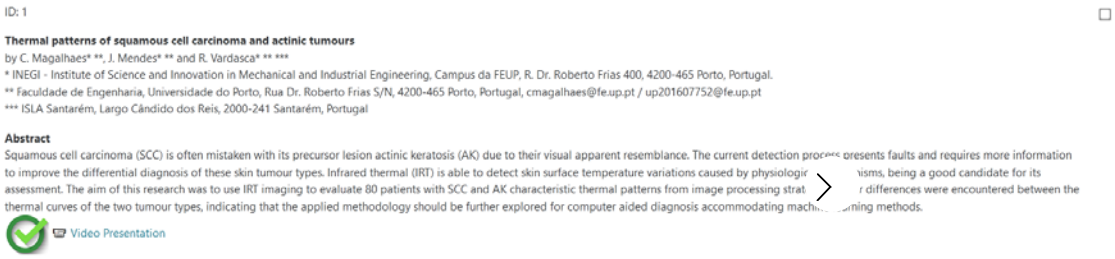
Announcements

World Time Clock

Instructions

QIRT2020 Instructions

1. The QIRT conference is mainly asynchronous, meaning that participants are not all together at the same time. Thus, videos of the presentations are available for visioning, just press in the link bellow the abstract. You may use the check boxes on the right to mark the abstracts of your interest.


ID: 1

Thermal patterns of squamous cell carcinoma and actinic tumours

by C. Magalhaes* **, J. Mendes* ** and R. Vardasca* ** ***

* INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering, Campus da FEUP, R. Dr. Roberto Frias 400, 4200-465 Porto, Portugal.

** Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias S/N, 4200-465 Porto, Portugal, cmagalhaes@fe.up.pt / up201607752@fe.up.pt

*** ISLA Santarém, Largo Cândido dos Reis, 2000-241 Santarém, Portugal

Abstract

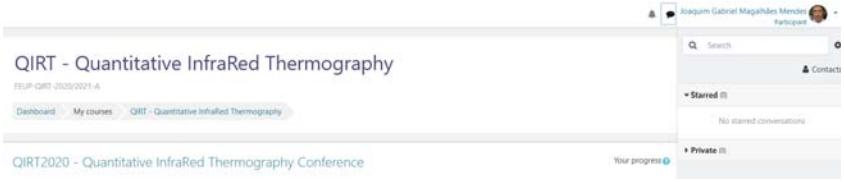
Squamous cell carcinoma (SCC) is often mistaken with its precursor lesion actinic keratosis (AK) due to their visual apparent resemblance. The current detection proc... presents faults and requires more information to improve the differential diagnosis of these skin tumour types. Infrared thermal (IRT) is able to detect skin surface temperature variations caused by physiologic... isms, being a good candidate for its assessment. The aim of this research was to use IRT imaging to evaluate 80 patients with SCC and AK characteristic thermal patterns from image processing strat... r differences were encountered between the thermal curves of the two tumour types, indicating that the applied methodology should be further explored for computer aided diagnosis accommodating machi... rning methods.

Video Presentation

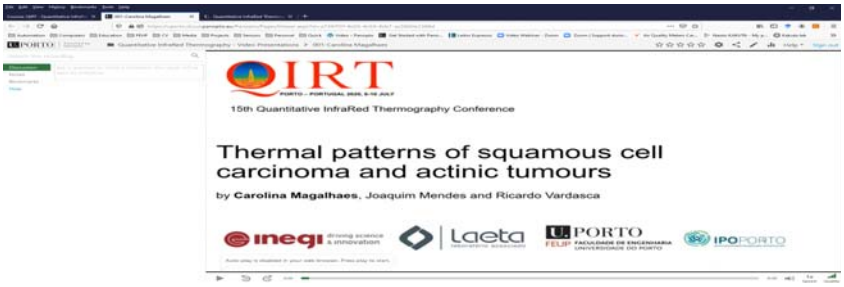
2. However, there will be several **LIVE** Keynote presentations, Companies presentations, as well as, LIVE Topic Discussions. Live events will be announced in the NEWS sections and communicated to participants.

3. Conferences have the purpose of connecting people interested in the same topic. Thus, you can use different ways to place **Q&A** and interact with other participants:

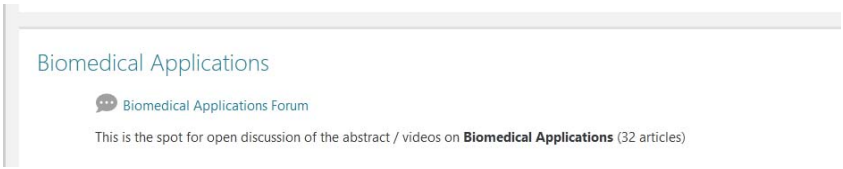
a) You can text anyone in the conference using the chat balloon on the top of the page. This is a real-time conversation; no log is recorded.



b) When visioning the video, you can use the text box on the left, called DISCUSSION to leave a message. This is the best way to comment a specific video, or ask the author. Q&A are viewed by everyone.



c) In the begin of each set of articles, there is an open forum that you can use to start a discussion topic, ask a question, leave a comment, etc.



Message in Video from QIRT Council Representative

Message from QIRT Council Representative

Xavier Maldague <Xavier.Maldague@gel.ulaval.ca>

Keynote Speaker - Prof. Naoto Kakuta

23rd September, 2020, Tokyo time: 17:00

TOKYO METROPOLITAN UNIVERSITY 東京都立大学

Near-infrared imaging for heat and mass transfer studies on aqueous solutions

by **Naoto Kakuta (角田 直人)**, **Kukuta Lab**, Heat and mass transfer lab, Tokyo Metropolitan University, Japan; Email: kakuta-n@tmu.ac.jp

Abstract: This keynote presents a near-infrared (NIR) imaging method that can be used for heat and mass transfer studies on aqueous solutions. This method is a simple and straightforward method in the transmission mode, based on the spectral characteristics of water absorption bands. Temperature and concentrations of solute molecules/ions can be measured simultaneously, enabling the quantitative investigation of local heat production, mixing processes, and chemical reactions. Imaging results on acid–base reactions in microfluidic channels and free convection from a small heat source are mainly introduced, and future directions are discussed.

Link to the presentation

>>>>> IT IS ALREADY TOMORROW, please check the time wordwide

Join the LIVE keynote Presentation using ZOOM:

https://zoom.us/j/93519283825?pwd=bjMrVVFWSllQRHlvb2swb1lhbVB3UT09
Meeting ID: 935 1928 3825
Pass code: 173033

Keynote Speaker - Prof. Graham Machin

24th September, 2020, UK time: 12:00

The relevance and importance of quantitative temperature measurement

by Graham Machin, NPL Temperature and Humidity Measurement Group, UK;

Abstract:

William Thomson (Lord Kelvin), Professor of Natural Philosophy at the University of Glasgow, one of the founders of the UK's National Physical Laboratory and one of the greatest Natural Scientists of the 19th Century said "if you cannot measure it, then it is not science" and "can you measure it? Can you express it in figures? Can you make a model if it? If not, your theory is apt to be based more upon imagination than upon knowledge". Those words are just as relevant today as when he uttered them over 120 years ago.

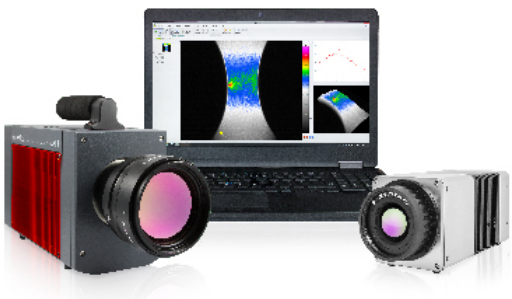
The measurement of reliable truly quantitative temperatures is enduringly difficult. There are a number of reasons for this. Firstly temperature in itself is an intensive quantity not extensive so is quite different from other quantities like mass or length; secondly there is lack of understanding as to the importance of the zeroth law of thermodynamics and the necessity of thermal equilibrium of the sensor with the object being measured; thirdly there is widespread misunderstanding as to how temperature sensors work, be they contact thermometers such as thermocouples or infra-red based devices; and fourthly there is widespread disregard for the necessity of periodic calibration to traceable standards to obviate sensor drift. Without taking these things either explicitly or at least implicitly into account reliable temperature measurement is next to impossible.

Here these four points are discussed; in particular:
• Address the difference between an intensive and extensive quantity and explain why its important in the context of reliable temperature measurement
• Discuss how the zeroth law needs to be taken into account if reliable thermometry is to be performed
• Two common thermometer types will be described and how they operate; namely the thermocouple and the infra-red thermometer, and common sources of uncertainty, which are often neglected, highlighted
• How to attain reliable temperature measurement will be described through the path of periodic calibration attaining traceability to the internationally agreed temperature scale the ITS-90 by an ISO17025 accredited calibration laboratory
The talk will end with a short description of future possible approaches to realising temperature traceability in the measurement setting; especially through the mitigation of the crippling effect of emissivity in IR temperature measurement through its in-situ determination (by an adjunct technique); the mise-en-pratique for the definition of the kelvin and its role in supervising global temperature traceability and the rise of direct in-situ temperature traceability through the development of practical thermodynamic thermometry approaches and self-validating sensors.

~~Link to the presentation (copy)~~

Hidden from students

Exhibition Hall



For any questions regarding the thermographic solutions by InfraTec please send a message to web@infratec.de or call InfraTec +49.351.82876.610.

LIVE Presentation to be schedule here

~~**HGH Systèmes Infrarouges**~~

~~**LIVE Presentation to be schedule here**~~

Hidden from students

LIVE Presentation to be schedule here

Biomedical Applications

~~Link to the Biomedical Application Forum (ZOOM)~~

Hidden from students

~~To be available on~~

~~Session Chair:~~

Biomedical Applications Forum

This is the spot for open discussion of the abstract / videos on **Biomedical Applications** (32 articles)

ID: 1

Thermal patterns of squamous cell carcinoma and actinic tumours

by C. Magalhaes* **, J. Mendes* ** and R. Vardasca* ** ***
* INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering, Campus da FEUP, R. Dr. Roberto Frias 400, 4200-465 Porto, Portugal.
** Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias S/N, 4200-465 Porto, Portugal, cmagalhaes@fe.up.pt / up201607752@fe.up.pt
*** ISLA Santarém, Largo Cândido dos Reis, 2000-241 Santarém, Portugal

Abstract
Squamous cell carcinoma (SCC) is often mistaken with its precursor lesion actinic keratosis (AK) due to their visual apparent resemblance. The current detection process presents faults and requires more information to improve the differential diagnosis of these skin tumour types. Infrared thermal (IRT) is able to detect skin surface temperature variations caused by physiological mechanisms, being a good candidate for its assessment. The aim of this research was to use IRT imaging to evaluate 80 patients with SCC and AK characteristic thermal patterns from image processing strategies. Clear differences were encountered between the thermal curves of the two tumour types, indicating that the

applied methodology should be further explored for computer aided diagnosis accommodating machine learning methods.

Video Presentation

ID: 14

Structure of operating room to avoid perioperative complication

Hisashi Usuki
Surgical Center, Kagawa University Hospital

Abstract There are many requirements for the operating room (OR). Its structure should secure the efficacy for surgical therapy. Purification is the most important requirement for avoiding surgical infections. Simultaneously the environment should be comfortable not only for the patient but also for surgeons. Cleanliness of the OR is comfort for all people. But, the comfortable temperature for the surgeons is lower than that for patient. Then, the patients have intraoperative hypothermia in the OR which temperature is suitable for surgeons. For avoiding surgical complications concerned intraoperative hypothermia the new air conditioning system (ACS) was introduced in the new operating theater. The basic research was performed in the experiment room before the construction of new ORs. The result shows the effectiveness of new ACS which can controlled the temperatures of the air flow for patients and surgeons independently. After the construction of new ORs the temperatures of the surgeons' shoulder and that of the operating table were measured. In the result the temperature of the surgeon's shoulder was 21.8±1.1°C and that of the operating table was 23.7±1.0°C when the temperature of central air flow was 25°C and that of lateral air flow was 21°C. Then, the clinical study was performed after the recognition of the ethics committee. The subject of the clinical study was 316 patients with colorectal cancer. 206 of them underwent laparoscopic surgery in the old ORs with conventional ACS and 110 of them underwent it in new ORs with new ACS. The body temperatures were compared with the temperature before starting surgery and the changes of the patients underwent the surgery in new ORs were compared with those of the patients in old ORs. In the result the temperature changes of the patients in old ORs were -0.40±0.34 °C, -0.40±0.41 °C and -0.32 ±0.42 °C at 30, 60 and 90 minutes after starting surgery respectively, and those of the patients in new ORs were -0.19±0.25 °C, -0.40±0.41°C and +0.05±0.39 °C at the same times. In conclusion the new ACS is useful to avoid the patients' hypothermia.

Video Presentation

ID: 30

Thermoguided Lipolysis and Skin Tightening Technique with 980nm Diode Laser

by F. Kamamoto*, O. Ferrari-Neto*, J. O. G. Reis*, C. Chineze** and Thomas Miliou***
* Hospital da Plástica, Plastic Surgery Department, 905, Bom Pastor Str, 04203-050 São Paulo, SP, fabio.kamamoto@gmail.com, orlandoferrari@gmail.com, jureis@gmail.com
**Kamamoto Clinic, 306, Mato Grosso Str., 01239-040, São Paulo, SP, Brasil, carla@clinicakamamoto.com.br
***Poliscan Medical Technologies, 180, Guapuruvu Str., 13098-324 São Paulo, SP, Brasil diretoria@poliscanbrasil.com.br

Abstract
INTRODUCTION: Liposuction is a well-established procedure to improve body contour through the use of laser in order to reach lipolysis and skin retraction. The current parameters in the devices allow an indirect inference of skin temperature changes. This article presents the authors' experience with laser lipolysis, though an Infrared Camera guidance, providing a secure measurement method for optimal results of the procedure and its effect on tissues.
METHODS: This study included 83 female patients who underwent laser lipolysis.
RESULTS: No skin burn wounds were registered.
CONCLUSIONS: Laser lipolysis performed according to the described technique was safe and reproducible.

Video Presentation

ID: 49

Automated convolutional neural network approach for discriminating systemic sclerosis on the basis of hand thermal pattern

by C. Filippini*, D. Cardone*, A.M. Chiarelli*, D. Perpetuini*, P. Amerio**, A. Merla*
* Department of Neurosciences, Imaging and Clinical Sciences, University G. d'Annunzio of Chieti-Pescara, Italy
** Department of Medicine and Aging Science, Dermatologic Clinic, G. D'Annunzio University, Chieti, Italy

Abstract
Systemic sclerosis (SSc) is a disorder of microvessels and connective tissue, characterized by fibrosis and vascular obliteration. Limbs extremities, including hands, are majorly involved, and they present inhomogeneous patterns of injury. The diagnosis of the disease can be performed using infrared (IR) imaging. Standard procedure includes the recording of IR images of the hands before and after exposure to cold stress, and evaluation of temperature recovery in

manually selected regions of interest. A completely automated methodology based on convolutional neural network is here introduced with the purpose of classifying SSc relying uniquely on resting condition images of the hands.

Video Presentation

ID: 60

Study of pattern of feet skin temperature distribution during continuous post-operative epidural analgesia

Dmitry Kruglov, Randall Stricker and Kevin Howell

Abstract

An epidural infusion of local anaesthetic via a catheter provides analgesia during and after major surgery. If pain relief is not adequate an underperforming epidural will require troubleshooting, resiting or removal. Physical examination (sensory level and evidence of motor block), vital signs (blood pressure and heart rate), pain scores and epidural performance during the surgery might help to identify the reason for catheter failure. An epidurogram (imaging with contrast study) will confirm epidural catheter position, but this investigation is not routinely used.

Injection of local anaesthetic into the epidural space produces sympathetic blockade with a vasodilation effect and predictive increase of skin temperature in distal lower limbs. Infrared thermography of patients with effective epidural blockade shows increased temperature of the feet. We studied five post-operative epidural infusions on the day of placement and the following two days.

Analysis of thermal imaging obtained with a calibrated PTi120 Fluke camera suggested that the skin temperature distribution is continuous. We have noticed patterns with a positive temperature gradient toward toes (presence of sympathetic block), and with significant negative temperature gradient toward toes (absence of sympathetic block). Also, the shape of the area covered by the highest isotherms could be of diagnostic value.

Video Presentation

ID: 63

Perfusion and thermal conductivity parameter extraction, from thermal imaging, for the quantification of the diabetic foot disease

by V. Serantoni*, F. Jourdan*, H. Louche* and A. Sultan**

* LMGC, Univ. Montpellier, CNRS, Rue St-Priest, 34095, Montpellier, France, vincent.serantoni@gmail.com

** PHYMEDEXP, Univ. Montpellier, INSERM, CNRS UMR, CHRU Montpellier, Montpellier, France

Abstract

Diabetes Mellitus (DM) is a huge public health-care chronic disease issue, with about 425 millions of patients worldwide in 2017. DM is a serious pathology, especially through its complications and their severity, as one, called diabetic foot, which can lead to a lower limb amputation. The aim of the present study is to propose a method, based on the use of infrared imaging, to classify the foot state thanks to a bio-heat model. The protocol is based on a global cooling of the feet, the full thermal recording of the skin rewarming and on some parameters extraction.

Video Presentation

ID: 69

Exploring the effect of environmental thermal noise in the contra-lateral thermal asymmetry of the lower limbs

by E.I. Fuentes-Oliver*, C. García-Segundo*, R. Ortiz-Sosa*, R. Solalinde-Vargas** and R. Serrano-Loyola**

* Universidad Nacional Autónoma de México, Institute of Applied Sciences and Technology, Circuito Exterior S/N, Ciudad Universitaria, Coyoacán, CDMX, Mexico, edgarfuentes@ciencias.unam.mx

** Hospital General de México "Dr. Eduardo Liceaga", Dr. Balmis 148, Doctores, Cuauhtémoc, CDMX, Mexico

Abstract

We study the environmental thermal noise effect on biomedical infrared imaging. The approach to discriminate noise from natural metabolic variability, rely on the initial reconsignment of contra-lateral thermal asymmetry between human lower limbs. Then we disambiguate this information from the environmental or background noise, by distinguishing its magnitude and spectral characteristics in the Fourier-space. From the spectral analysis one can unveil this kind of noise characteristics, remove it to correct the radiometric data and improve their true values.

Video Presentation

ID: 78

Quantitative human interpretation for breast thermography

by R. Gonzalez-Leal*, M. Kurban*, F. J. Gonzalez*, and Orquídea Cruz*
* Eva Tech, Diagonal Patriotismo 12 P-3 Col. Hipódromo Condesa, Ciudad de México 06100, Mexico,
raymundo.gonzalez@evacenter.com , kurbanrita@gmail.com , javier.gonzalez@evacenter.com,
orquidea.cruz@evacenter.com

Abstract
Studies that evaluate thermography as a method for breast cancer detection have relied on > .tative evaluation, without a well-defined evaluation technique. Some researchers have proposed systems through which interpreters can quantify their findings in thermographic images. The present work reviews and compares human evaluation methods from the literature in terms of their ability to predict cancer status. Also, additional features that can improve the performance of existing methods are identified and tested.

Video Presentation

ID: 98

Thermoelastic stress analysis of titanium biomedical spinal cages printed in 3D

by A. Quattrocchi*, D. Palumbo**, D. Alizzio*, U. Galietti** and R. Montanini*
* University of Messina, Department of Engineering, 98166, Messina, Italy, {antonino.quattrocchi/damiano.alizzio
/roberto.montanini}@unime.it
** Polytechnic University of Bari, Department of Mechanics, Mathematics and Management, 70125, Bari, Italy,
{davide.palumbo/unberto.galietti}@poliba.it

Abstract
Transforaminal lumbar interbody fusion (TLIF) cages are employed in lumbosacral spine surgery. These implants are made in Titanium and offer biocompatibility, high resistance to corrosion and a good mechanical performance. In the last years, Additive Manufacturing (AM) has been introduced in many biomedical applications, thanks to the possibility of improving complex geometry and customization for specific patient. In this regard, compensation of real mechanical behaviour is a critical issue to be investigated. The present work is focused on the evaluation of stress distribution for a 3D printed TLIF cage by means of non-contact measurements as Thermoelastic Stress Analysis (TSA). A suitable setup has been adopted to guarantee the correct loading application and an optical access to the sample.

Video Presentation

ID: 100

Automatic breast cancer detection on breast thermograms

By R. Gonzalez-Leal*, M. Kurban*, L.D. López-Sánchez*, and F.J. Gonzalez*
* Eva Tech, Diagonal Patriotismo 12 P-3 Col. Hipódromo Condesa, Ciudad de México 06100, México.
raymundo.gonzalez@evacenter.com , kurbanrita@gmail.com , luis.lopez@evacenter.com, javier.gonzalez@evacenter.com

Abstract
Widespread use of thermography as a method for breast cancer detection has been limited due to the lack of standard interpretation methods, relying mostly on subjective analysis. Some studies address this issue by proposing quantitative approaches. Such automated assessment methods have led to promising results, yet these methods have received limited attention. In this study, we propose a computerized system for the interpretation of breast thermograms. Our system consists of an automatic breast segmentation step, an acquisition device-dependent image processing pipeline, and an automated feature extraction pipeline. These features include expert-designed evaluation methods as well as texture and statistical features.

Video Presentation

ID: 101

Effect of exercise on the lower limbs skin temperature of elderly people

by M. Sillero-Quintana*, T. García-Pastor**, G. Morganti*, D. de Mello***
* Sports Department. Physical Activity and Sports Faculty. Technical University of Madrid (UPM, Madrid, Spain).
manuel.sillero@upm.es
** Exercise Physiology Laboratory. Camilo Jose Cela University (UCJC, Madrid, Spain)
***Post-Graduation Department. Physical Education College of Brazilian Army (EsEFEx/EB/RJ/Brazil)

Abstract
The aim of this study was to analyse the lower limb skin temperature (Tsk) of elderly people after a training session. The Tsk of the lower limbs from 66 active elderly was measured by infrared thermography before and after a circuit training session using 28 regions of interest (ROIs) from anterior and posterior areas. Significant differences were observed

between the two sexes and time points. The analysis by sex of the anterior area shows that men had a significantly higher Tsk at both the initial and final time points in several ROIs. Comparing the two time points, only a significant difference was observed Achilles tendon areas.
Video Presentation

ID: 103

Thermal imaging monitoring of local temperature of isolated and transplanted liver and kidneys as a way to diagnose real time transplantation in the clinic

A. Schegolev[1], A. Urakov[2], A. Samorodov[3]
[1]Military medical Academy named after S. M. Kirov
[2]Udmurt Federal Research Center of Ural branch of the RAS
[3]Bashkir State Medical University, AVSamorodov@gmail.com

Abstract
This paper describes a new method to monitor the quality of medical care during organ transplantation. The paper shows extreme temperature difference, demonstrates negative factors affecting the stability of the temperature regime of the transplant, and suggests a variant of intraoperative thermal imaging monitoring.
Video Presentation

ID: 106

ADT in the diagnosis of atopic dermatitis - preliminary tests

by M. Kaczmarek*
* Gdansk Univ. of Technology, 80-233, Narutowicza Str., Gdansk, Poland, mariusz.kaczmarek@eti.pg.edu.pl

Abstract
The article describes the proposal to use Active Dynamic Thermography in the diagnosis and monitoring of the progress of atopic dermatitis treatment. Preliminary studies were performed on a group of 20 volunteers: 10 people affected at various stages and 10 healthy as a reference. The study consisted of recording a sequence of static thermograms, followed by cooling the surface with a fan and recording the thermograms during and after cooling. The results were compared in a group of patients with atopic dermatitis with a group of healthy people.
Video Presentation

ID: 110

Diagnostic accuracy in thermographic imaging for granulation of uninfected diabetic ulcers.

Rodríguez-Alonso D*, Cabrejo-Paredes J** and Benites-Castillo S***
*"Innovaciones pie diabetico" medical Centre, Trujillo, Peru, ortocentro30@gmail.com
**Postgraduate research Unit, National University of Trujillo , Trujillo, Peru, jcabrejop@gmail.com
***Research Institute, University of Cesar Vallejo, Trujillo, Peru, santiagob@ucv.edu.pel

Abstract
The aim was to determine accuracy by sensitivity (Se), specificity (Sp) of thermographic imaging test in the granulation of uninfected diabetic ulcers in medical Center. 29 diabetic type 2 with 41 uninfected diabetic ulcers were transversally design comparing granulation area by thermographic image respect to standard by pathological anatomical study. The results of uninfected diabetic ulcers were in predominance for type 2 and type A by Wagner and University of Texas classification in 70.7% and 51.2% respectively. The diagnostic test had Se in 100%, Sp in 71.4% and accuracy in 90.2%. The accuracy was ideal.
Video Presentation

ID: 111

Predictive diagnosis of peripheral neuropathy and foot deformity in diabetics using plantar thermographic imaging

Rodríguez-Alonso D*, Cabrejo-Paredes J** and Benites-Castillo S***
*"Innovaciones pie diabetico" medical Centre, Trujillo, Peru, ortocentro30@gmail.com
**Postgraduate research Unit, National University of Trujillo , Trujillo, Peru, jcabrejop@gmail.com
***Research Institute, University of Cesar Vallejo, Trujillo, Peru ,santiagob@ucv.edu.pel

Abstract
The aim was to apply a predictive diagnostic model(PDM) using thermographic point measurements(TPM) on sole in diabetics with and without complications such as peripheral neuropathy (PN), peripheral arterial disease(PAD) and foot

deformity(FD).This images study was a cross-sectional design of diabetics with and without complications respect 9 TPM on sole using a FLIR E60 camera. 288 thermographic images were analysed by binary logistic regression model being significant in hallux (p=0.04,OR:1.58) , 1st metatarsus(p=0.03,OR:0.49), 3rd metatarsus (p=0.02,OR:2.26) for FD and 3rd metatarsus (p=0.02, OR:2.47) for PN .In conclusion, PDM were for FD and PN.

 Video Presentation

ID: 112

Infrared Control of Thermal Insulation of Teeth, Dental Crowns and Braces When Inhaling Cold Air with an Open Mouth in the Frosty Day

by A. Urakov*, M. Alies*, A. Reshetnikov*, M. Kopylov*, R. Rozov**,
*Udmurt Federal Research Center of the Ural branch of the Russian Academy of Sciences, Department of Modeling and Synthesis of Technological Processes, T. Baramzina str., 34, 426067, Izhevsk, Russia, email of corresponding author: urakoval@live.ru;
**I.P.Pavlov First St.-Petersburg State Medical University, Department of Prosthetic Dentistry, Leo Tolstoy str., 6-8, 197022, St.-Petersburg, Russia.

Abstract
It is shown that in severe cold, the performance of intensive physical activity is accompanied by intensive inhalation of frosty air with an open mouth, which cools the teeth. Sometimes the frosty air destroys teeth. Especially quickly and strongly cooled metal crowns, dentures and braces. To protect the teeth and soft tissues of the oral cavity from hypothermia and frostbite, it was proposed to cover the teeth with special decorative stickers. It is shown that thermal monitoring of the local temperature of teeth in the cold provides an assessment of the effectiveness of thermal insulation of teeth in real time.
Video Presentation

ID: 116

Detection of Breast Pathology using Thermography as a Screening Tool

by Aayesha Hakim[a], R.N. Awale[b]
[a] Veermata Jijabai Technological Institute, Mumbai, India, aayesha.hakim@gmail.com
[b] Veermata Jijabai Technological Institute, Mumbai, India , rnawale@el.vjti.ac.in

Abstract
Thermal imaging is an emerging, low-risk modality for early breast cancer decision making without injecting any form of energy into the body. To reduce the burden on radiologists, use of automation is suggested to facilitate better interpretation of thermal images. Hotspots are segmented in the thermograms by k-means clustering algorithm. The features of left and right breasts are more correlated for normal cases and are less correlated for abnormal patients. The investigation results reveal that significant difference in feature values of left and right breast of an abnormal patient is depicted by first order statistical features, namely, kurtosis and variance.
 Video Presentation

ID: 125

Differences in knee skin temperature between left and right leg after running on a treadmill measured by infrared thermography

by V. Svaic* and I. Jurak*
* University of Applied Health Sciences, Mlinarska cesta 38, Zagreb, Croatia, vjeran.svaic@skole.hr

Abstract
The main goal of this study was to analyse temperature differences between left and right knees after the graded exercise by running on a treadmill in closed environment. Nine young athletes conducted a submaximal test and thermography was used to determine quantitative measurement of knee skin temperature before and immediately after the exercise. Significant difference was found between left and right leg after the exercise, suggesting that both legs are not used the same way with one leg doing more work, thus showing different temperatures.
 Video Presentation

ID: 126

Multimodal imaging in the evaluation of patch test results

by B. Tomaka*, M. Szwedo* and J. Targosz**
* MONIT SHM Sp. z o.o., ul. Gromadzka 66, 31-719 Kraków, Poland, b.tomaka@gmail.com

**AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Kraków, Poland

Abstract
Contact allergy diagnostics in many cases is based on subjective techniques of evaluation. The clinical evaluation of patch test reaction is achieved by visual impression combined with measurements of the intensity of the reaction on the usual scale of differentiation, and it is likely that some allergic reactions will not be noticed, becau[illegible]f weak or delayed inflammation. Authors are suggesting a new attitude to that problem with the use of infrare[illegible]aging and multimodal imaging methods as a supplementary non-contact technique for more thorough evaluation.
Video Presentation

ID: 127

Comparison of the Fourier-Kirchhoff, Pennes and DPL thermal models of a single layer tissue

by M. Strąkowska*, G. De Mey** and B. Więcek*
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Abstract
This paper deals with comparison of Fourier – Kirchhoff (FK), Pennes and Dual Phase Lag (DPL) heat transfer 1D models of a single-layer tissue. Thermal modelling presented in this paper is based on the concept of thermal impedance by using the Laplace transform for s=jω. In such a case, the models for simple geometry can be solved analytically. Then, the poles of the thermal impedance are identified using e.g. Vector Fitting method which allows calculating the thermal impedance as a sum of partial fractions. It corresponds directly to the Foster Network of a thermal object. Models are compared both in frequency and time domain for wide range of frequencies.
Video Presentation

ID: 128

Thermal infrared imaging reveals that 6-12 month-old babies show different autonomic response to interaction with robot and avatar

by C. Filippini*, D. Cardone*, D. Perpetuini*, A.M. Chiarelli*, L. A. Petitto** and A. Merla*
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Abstract
From birth, infants are immersed in a social environment, often surrounded by artificial intelligent agents (AIAs). However, there is a significant paucity of work on infants' psychophysiological responses, and their related interest, when interacting with AIAs. Here, the psychophysiological responses of infants during interactions with an embodied robot and a virtual human (avatar) presented on a screen are investigated. Understanding infants' psychophysiological/emotional responses to AIAs provides important new knowledge regarding how AIAs impact infants' during the first year of life, which is a period of critical importance for human learning, especially emotional, social, and language learning and higher cognitive growth.
Video Presentation

ID: 129

Dynamics of plantar foot temperature after conductive cold provocation in diabetic patients and healthy controls

by A. Seixas*.**, J. Azevedo*, K. Ammer***, R. Carvalho****, J.P. Vilas-Boas*****, J. Mendes****** and R. Vardasca******
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***** LABIOMEP, CIFI2D, Faculty of Sports, University of Porto, Porto, Portugal
****** LABIOMEP, INEGI-LAETA, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal

Abstract
Cold provocation tests are largely used in clinical and research settings, but conductive cold provocation tests have not been applied in the feet. This study analyses skin temperature dynamics after a conductive cold provocation test in a sample of 30 diabetic patients and 30 healthy controls. The test was easy and practical to apply and induced significant temperature changes immediately after and 5 minutes after the test. Tsk dynamics were similar in both groups. The cooling of the plantar surface was not homogenous with large differences in TSk drops between some regions of interest.

Video Presentation

ID: 130

Towards Dynamic Assessment of Healthy Breast Skin Temperature using Infrared Ther[illegible]raphy

by D. Marques*, J. Moreira* and R. Vardasca*,**,***
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Abstract
Breast skin temperature assessment has been of interest since of the first application of Infrared Thermography in Medicine in 1956. Since it many investigations attempted to appraise the method as a screening tool, although reference data is still lacking and dynamic thermal imaging has proved its value in other clinical applications. It is aim of this research to apply a thermal stimulus to the breasts of 11 healthy participants through thermal conduction and convection to determine, which can be feasible in clinical setup for further research involving breast cancer patients. It was found that the use of a conduction stimuli on the nipple for a 1 minute to be the most adequate method.

Video Presentation

ID: 135

Multimodality imaging in medical diagnostics – challenges and limitations

by A. Nowakowski
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Abstract
This presentation is devoted to discussion of challenges and limitations of selected imaging modalities: IR thermograpy, ADT and TSR, electroimpedance tomography in relation to CT and mammography, MRI and USG. Principle of operation is a key factor for different possible applications of a chosen technology. Practically all modalities are of different limitations resulting in achievable accuracy and resolution of the method. Basic properties of each of the most frequently applied in medical practice modalities are compared showing challenges and limitations in selected medical applications. Matching of chosen modalities allows to overcome some limitations and to improve value and quality of combined diagnostics. The role of IR imaging is underlined.
Video Presentation

ID: 138

Early results for equivalent wavefield transform for active infrared breast thermography

by J. Gershenson*. M. Gershenson **
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Abstract
Dynamic breast thermogram data is collected by recording the breast IR thermograms sequence following cooling of the breast. Equivalent wave field transform (EWFT) was developed as a tomographic nondestructive evaluation method for testing of materials. We obtained human data from the Brazilian 'Database for Mastology'. The data was originally collected for use in artificial intelligence algorithm and not for time series analysis. Method to extract excitation profile using principal component was developed. Inversion reveals clear depth resolved images. The potential for the method in dense breast is very promising both as classification and as low cost non ionizing screening methods.
Video Presentation

ID: 144

Thermography for hyperthermia effects visualisation during magnetic stimulation in Image-Guided Radiation Therapy

by N. Ludwig, P. Arosio, S. Gallo, M. Gargano, J. Melada, and I. Veronese
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Abstract
Gold fiducial markers, implanted into tumors, are commonly used during Image-Guided Radiation Therapy treatments for target localization and patient set up verification. In this study, hyperthermia effects produced by different types of

millimetric gold fiducial markers under the application of an alternating magnetic field in the typical instrumental conditions used in Magnetic Fluid Hyperthermia clinical trials were investigated. Temperature monitoring of the gold fiducial markers into hydrogel-based tissue mimicking phantoms showed temperatures up to 70°C within tens of seconds and local increases to values higher than 45°C-50° C inside the hydrogel volume around fiducials, values able to induce thermal ablation of biological systems.

Video Presentation

ID: 146

Thermal-driven biomarkers for breast cancer screening using dynamic infrared imaging modality

by Bardia Yousefi, Clemente Ibarra Castanedo, Xavier P.V. Maldague
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Abstract

In this study, we delve into the applications of infrared based diagnostic system for early diagnosis of breast cancer or symptomatic patients. We used low-rank sparse Non-negative matrix factorization (NMF) to select the main bases of the thermal images to determine the subsurface thermal heterogeneous patterns in these sets. For that, 55 participants for infrared breast screening selected from Database for Mastology Research (DMR) dataset with symptomatic and healthy participants. We calculate five derived properties of the breast area (contrast, correlation, dissimilarity, homogeneous, and energy) using thermal level co-occurrence matrices (TLCMs) and train a logistic regression to stratify between healthy and symptomatic patients.

We compared the ability of sparse-NMF to the state-of-the-art thermographic approaches such as principal component analysis/thermography (PCT), candid covariance-free incremental principal component thermography (CCIPCT), Sparse PCT, non-negative matrix factorization (NMF). Results indicate significant performance for Sparse-NMF (DMR: 74.1%). The results indicate considerable performance sparse-NMF, which conclusively indicates promising performance in terms of the accuracy and the robustness as a confirmation for the outlined properties.

Video Presentation

ID: 154

Discriminating patients with paediatric idiopathic hyperhidrosis from healthy subjects with infrared thermography and machine learning classifiers

by F. Carvalho*,**, R. Vardasca***,****, C. Magalhaes***,****, J. Mendes***,**** and J. Goncalves*****
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Abstract

Idiopathic hyperhidrosis (IH) is a medical condition characterised by excessive sweating beyond what is physiologically necessary for thermoregulation affecting mainly the axillae and palms. It affects seriously the quality of life of patients and has an incidence at paediatric age of 1.6%. The diagnosis is subjective relying only the the patient claim and physician perception. It is aim of this research to evaluate if dynamic infrared thermography (IRT) along with machine learning classifier on the thermal data are able to discriminate IH paediatric patients from healthy subjects. Using dynamic IRT, through convective provocation, on the views of axillae and palms, it was possible to discriminate IH paediatric patients from healthy subjects using artificial neural networks (ANN) and random forests (RF) in thermal measurements with high accuracy (>99%), the same was not possible only with the thermal data and statistics.

Video Presentation

ID: 155

Thermal profile evaluation in proximal tibial shaft pseudarthrosis diagnosis – a case study

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Abstract
Pseudarthrosis, also known as nonunion, is a serious pathology in bone fractures that present a fault in the healing process. This article presents the thermal analyses of a male patient with a tibia fracture stabilized by a circular (Ilizarov) external fixator. The thermal images were capture along the tibia length, outside and in-between the insertion rings. Significant temperature differences were observed between the three sections of the tibia: th entral zone - medial tibial (25.9°C), between the second and the third ring (26.5°C) and the proximal tibia between the and fourth external fixator ring (25.2°C). The obtained results indicate that thermography might help in the diagnosis and follow up of pseudarthrosis of tibial shaft. The metabolic and vascular alterations at the fracture site encompasses the bone healing process, formation and remodelling produce skin temperature changes that can be monitored by thermography.

Video Presentation

ID: 158

Dynamic infrared thermography for DIEP flap breast reconstruction: initial processing results

by G. Steenackers*, J. Verstockt*, B. Ribbens*, F. Thiessen** and W. Tjalma***
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Abstract
In order to identify the exact location of the useful perforator for DIEP flap breast reconstruction, infrared images can be used. The thermal images will also help to determine which parts of the flap can be safely used for the DIEP flap reconstruction. By means of infrared thermography a blood vessel distribution of the abdominal wall will be visualized. The subjective interpretation of IR images is crucial as the results can generate additional information concerning the hemodynamic properties of the flap. One specific case will be used to explain the state-of-the-art post-processing methods.
Video Presentation

Calibration & Metrology

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ID: 10

Thermal camera calibration with cooled down chessboard

by T. Herrmann*, C. Migniot** and O. Aubreton*
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**ImViA EA 7535, Univ. Bourgogne Franche-Comté, Dijon, France

Abstract
Calibration of a camera have various applications in computer vision. This process is particularly challenging with a thermal camera instead of a standard color one. A calibration target with two layers of different thermal emissivity is commonly used but reflects appear and degrade the corner extraction of the chessboard. While traditional and commonly used methods heat the target chessboard, we cool it down that inverts the distribution of emission of the two layers. The reflects on the reflective layer enhance the contrast instead of decreasing it. Experiments on various configurations and orientations demonstrate the superiority of the proposed method.

Video Presentation

ID: 11

An Experiment Study on Performance Evaluation of Black-Body System by using Infra- ' Camera

by Seoktae. Yoon* and Yongjin. Cho**
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Abstract
The blackbody system is an optical device developed based on the basic concept of blackbody. A blackbody is an ideal object that absorbs all the energy entering the surface from surrounding objects and emits maximum energy at a given temperature and wavelength. Infrared cameras measure the temperature of object in a non-contact method and perform calibration by using a blackbody system. Therefore, it is necessary to evaluate and preserve the performance of the blackbody system itself before using to calibrate other optical equipment. In this study, we used an infrared camera that was calibrated by a high reliability organization for calibration, and conducted an experimental study to check the preservation of system performance by measuring before and after calibration of the blackbody system. The blackbody system uses extended type, and uses the noise equivalent temperature difference and three-dimensional noise of the infrared camera detector as an index for evaluating the performance of the blackbody system.
Video Presentation

ID: 25

A metrology enabled thermal imager for thermal vacuum

by Wesley Bond*, Vivek Panicker*,Jamie McMillian*, Rob Simpson*, Michael Hayes*,
Graham Machin*, Gianluca Casarosa**, James Etchells**
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Abstract
The ground testing of satellites necessitates the validation of their thermal model whilst operational in vacuum. Thermocouples are widely used for this testing, but they are only able to provide a point temperature measurement so a large number are used. A low-cost, in vacuum thermal imaging system however could determine the temperature of a large area. Such an approach can be used to supplement contact temperature measurements, thereby reducing the number of thermocouples required. NPL has completed the de-risking of such a thermal imager that can operate in thermal vacuum from -40 °C to 60°C and has a low instrument uncertainty of ± 1°C (k=2).
Video Presentation

ID: 67

Infrared thermography for defect detection on aluminium-CFRP hybrid 3D structure

by H. C. Fernandes [a,b], S. Quirin [c], M. Schwarz [c, b] and H.-G. Herrmann [b, c]
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Abstract
Advanced materials are widely used in several industries. They play an important role especially in the aeronautic sector where weight reduction is required in order to reduce fuel consumption. Composite materials have a high strength to weight ratio and are applied in airplane construction. In order to ensure the safety of these components during their life cycle, non-destructive testing methods are required. In this work, infrared thermography is used to inspect an aluminium-CFRP hybrid 3D structure. A dual-band infrared camera is used to capture images in two different spectral ranges. Two image-processing techniques are then applied in order to enhance the images: principal component thermography and partial least squares thermography. Finally, a signal-to-noise ratio analysis is performed to assess the quality of the images and detected defects. Results showed that PCT has a slight advantage over PLST in our experiments.
Video Presentation

ID: 82

Thermospectroscopy imaging

by S. Chevalier*, J.-N. Tourvieille**, A. Sommier*, J.-C. Batsale* and C. Pradere*,**
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Abstract

Quantitative understanding of heat and mass transfers during chemical reactions occurring › een different fluids is of prime interest for fundamental chemical physics and applied microtechnologies such as lab-on-a-chip synthesis and fuel cells [1]. To analyse the diffusion and reaction processes, microfluidic chips appear to be powerful tools as the mass transport and the kinetics of reactions can be controlled. These technologies are also well suited to perform imaging studies such as thermal and concentration field measurements in reactive processes using an IR camera associated to spectroscopic measurements with monochromatic IR sources [2,3]. Use in combination with inverse methods based on reaction diffusion equations, imaging methods in microfluidic chips will lead to the characterization of all heat and mass transfer properties in a reactive system. If some work was already done in the field of heat transfer [4], the objectives of the present study are to demonstrate that both heat and mass diffusivities, kinetics parameters, and in particular the standard enthalpy of reaction can be quantified in a hydrochloric acid and hydroxide sodium reaction in a microfluidic channel.
The standard enthalpy of reaction is defined as $\Delta H = \rho Cp T0 \tau RT / (c0 \tau RC)$ [J/mol] where ρ is the density, Cp is the thermal capacity, $T0$ is the ambient temperature, and $c0$ is the initial concentration of the reactants. These data are given by the experimental setup and the fluids used (in general water as solvent). Thus, it remains τRC and τRT which are the characteristic times of the kinetic and heat production during reaction, respectively. To measure them, a microfluidic imaging setup was built as depicted in Figure 1(a). It is made of an FTIR source which generates IR interferograms in each pixel of the camera. Once processed with a fast Fourier transform algorithm, these interferograms leads to the multispectral absorbance of products and reactants (see Figure 1(b)) from which the knowledge of the concentration distribution is obtained. On the mathematical side, the classical diffusion-reaction model of two reactants to one product in a microchannel [5] was used to mimic the chemical reaction as presented in Figure 1(c). Inverse methods were finally used to estimate τT and τC.
First results were obtained using a hydrochloric acid and hydroxide sodium reaction which produces salted water (i.e. HCl + NaOH → NaCl + H2O). A small Y-shape microchannel (5 mm-wide by 30 mm-long) was fabricated and imaged (absorbance and thermal fields). To ensure an accurate measurement of the characteristic time, the reaction-diffusion model was analysed in details, and it was found that τRC can be only measured in the middle of the channel (see Figure 2(a) and (b)) in what it is called the reactive zone. In the diffusive zone, only the transport properties (diffusivity) can be measured using an analytical solution of the reaction diffusion equation in the limiting case of large Damkhöler. In this communication, the complete characterization of τRC and τRT will be presented as well as the heat and mass transport properties. Finally, the standard enthalpy of the reaction will be estimated illustrating the high performances of quantitative contactless measurements using IR imaging techniques.
☎ Video Presentation

ID: 84

IR Camera based system for high speed granulometry measurement on liquid dispersions

by R. Gilblas*, Y. Le Maoult* and N. Lecysyn**
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Abstract

Liquid dispersions by explosion are still partially unexplored because of the brevity and the complexity of the physical phenomena involved. The theoretical models developed need experimental data as inputs or as validation cases. This work presents the development of a high frequency full-field granulometry method based on the measurement of the transmission in the infrared spectral band. The granulometry is obtained inverting a simple Beer-Lambert's law for each time of the explosion. This paper recalls the theoretical background about optical scattering and presents the experimental set up.
☎ Video Presentation

ID: 99

Inverse Method based on Cosine Integral Transforms to Estimate 2-D Heat Flux and Thermal Diffusivity

by A. AOUALI*, S. CHEVALIER*, A. SOMMIER*, J.C. BATSALE* and C. PRADERE*
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Abstract

The estimation of physical properties in complex materials and boundary conditions such as flux or temperature at the interface require the development of inverse method. When used in combination of imaging techniques using an IR camera, such methods can be used to estimate the transient spatial distribution of heat flux, temperature and material

physical properties [1]. The choice of the inverse method directly linked to the parameters that need to be identified. In this work, we report an inverse method based on integral cosine transforms to estimate the spatial distribution and amplitude of heat flux, as well as the in-plane diffusivities in a homogenous copper block.
An imaging experiment was performed were the temperature field at the surface of the copper slab was measured using an IR camera (see Figure 1). To estimate the heat flux at rear face of the copper slab, an inverse method based on an analytical asymptotic solution of heat equation in the Fourier space is developed [2]. By using two cosine integral transforms of the temperature measurement at the surface of a material with known dimensions ($Lx \times Ly \times e$), and known properties, the density (ρ), as well as the calorific capacity (Cp) of the material. The advantages of the inverse methods into the Fourier space are solution to the equation is a product of the initial condition and the exponential of the product of the spatial frequencies, the longitudinal diffusivities and the time, on the other hand, because we obtain a spatial frequency distribution (possibility of spatial filtering). Finally, by applying the logarithm function to the solution obtained, we will have a first order polynomial, with the initial condition as intercept, and the longitudinal diffusivities as slope.
The proposed inverse method has been validated numerically where the spatial distribution of the heat flux was estimated. The next step is to use the method with a temperature field measured by an IR camera. In this communication, the full presentation of the inverse method and the experimental setup will be presented. A discussion about the limitation of the heat flux and diffusivity estimation will be done in particularly concerning the noise in the experimental data.
Video Presentation

ID: 137

Measurement of temperature in a standard flame using multispectral thermography
by J. Meléndez *, J. Talavante *, G. Guarnizo *, and M. J. Martín**
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Abstract
Accurate measurement of temperature in combustion processes is a challenging metrological problem with important practical applications. This paper describes an innovative measurement method of temperature in a standard flame using a multispectral camera with six spectral bands in the medium infrared. The obtained results are compared to measurements with Rayleigh scattering thermometry, a technique traceable to the International Temperature Scale of 1990 (ITS-90), and with temperature maps obtained with a hyperspectral imager. The proposed method provides also measurement of the column density (ppm·m) of CO2 in the flame.
Video Presentation

ID: 159

Effect of unsharpness on the result of thermovision diagnostics of electronic components
by K. DZIARSKI* and A. HULEWICZ**
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Abstract
This work presents the effect of thermogram unsharpness on the result of thermovision temperature measurement. Thermograms have been made using the thermal imaging camera operating in Long-Wave Infrared bandwidth, fitted with macro lens. The element, temperature of which was measured was the 2.3 mm x 2.1 mm temperature sensor placed in a housing for through-hole installation. The sharpness of thermograms was determined using the selected measures. The determined sharpness of thermograms was verified through comparing with responses of one hundred and seven respondents. The relationship was described between the thermogram sharpness and the value of absolute thermovision temperature measurement error.
Video Presentation

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ID: 39

Thermographic analysis of building structures by passive transient measurements

by R. Olbrycht
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Abstract

The investigation of buildings with thermographic cameras often requires certain external conditions, depending on the required effect. When the desired effect is the localisation of thermal bridges, it is advised to carry on the measurements during the night. This paper demonstrates how the results may change depending on the time of day.

Video Presentation

ID: 44

Combination of thermal fundamentals and Deep Learning for infrastructure inspections from thermographic images. Preliminary results

by I. Garrido*, S. Lagüela**, Q. Fang*** and P. Arias*
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Abstract

The application of Deep Learning (DL) models using the measurements acquired by Non-Destructive Testing (NTD) tools as input data stands as a versatile solution for highly automated analysis. However, DL models using thermal images as input data are quite scarce when it comes to analysing defects in medium- and large-scale bodies. Therefore, this paper proposes the application of a thermal criterion and a DL model, Mask R-CNN, in thermal images acquired from different infrastructures with thermal bridges and moisture. The thermal criterion is first applied to the input data, showing its utility to improve DL models performance.

Video Presentation

ID: 52

A Study on the the calculation of the linear thermal transmittance of wall-window joint based on infrared thermography

Jae-sol Choi*, Byung-Ki Jeon*, Seung hoon Park* Eui-Jong Kim*
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Abstract

This paper is a study on a quantitative evaluation of linear thermal transmittance of the thermal bridge through window-wall joint based on infrared thermography. The purpose of the work is to check the possibility of deducing the linear thermal transmittance from the thermal images. Therefore, this study presents a methodology to match measured thermal images and simulation results. By iteratively finding out the adequate joint thermal properties in simulation using the reference thermal images, the obtained simulated case can be used to derive the linear thermal transmittance of wall-window joint under steady-state calculation.

Video Presentation

ID: 77

Multiscale Analysis of Solar loading Thermographic Data for the Inspection of Civil Engineering Structures

by Katherine Tu*, Stefano Sfarra**, Clemente Ibarra-Castanedo***, Xavier P.V. Maldague***, Yuan Yao*†
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Abstract
The concept of multiscale thermographic data processing is proposed in this work for the inspection of civil engineering structures. In the proposed framework, thermograms of buildings collected by solar loading thermography are decomposed into a number of intrinsic mode functions under different scales by multidimen[illegible]nal ensemble empirical mode decomposition (MEEMD). Then, principal component analysis (PCA) is adopted to ext[illegible]ne features at each scale. Compared to the popular principal component thermography (PCT) method that applies PCA to raw thermographic data, multiscale analysis provides an opportunity to zoom in on different types of structural features.

Video Presentation

ID: 92

Influence of Moisture Content on Defect Detection by Active Thermography Method to Concrete Structure

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Abstract
At present, damage due to deterioration of concrete structures is a social problem. In order to prevent this problem, an infrared thermography method has been proposed and verified as a non-destructive inspection method different from conventional methods. Therefore, the infrared thermographic non-destructive testing considering with environmental condition and the weather condition which can happen to existing structure were considered in the present study. In this study, the effect of moisture content in concrete on defect detection was focused. As a result, it was suggested that the moisture content affects the defect detection.

Video Presentation

ID: 96

An attempt to shorten the inspection time of active thermography method

by S. Ishihara*, M. Ishikawa*, H. Nishino*, M. Koyama**, H. Kasano***, H. Hatta**** and S. Utsunomiya****
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Abstract
When inspecting concrete structures or low-thermal-diffusivity materials (such as plastic materials) using active thermography method, a long inspection time is required, and this impairs the efficiency of thermographic non-destructive inspection. In this study, we focused on the use of high-frequency thermal waves which has theoretically fast heat propagation speed, and tried to shorten the inspection time. In order to verify the effectiveness of shortening inspection time, experiments for mortar specimens with an artificial defect were performed.

Pdf Presentation

ID: 108

Developing Quantifiable Defect Record for Tall Building Envelop using Passive Infrared Thermography and Building Information Modelling

by Lydia S. Y. Chiu[1], Wallace W. L. Lai[2], Miranda C. Y. Lui[3]
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Abstract
This ongoing project aims to develop a methodology for imaging and diagnosis of external wall debond of tall building envelop by adopting quantitative infrared thermography (IRT) in as-built building information model (BIM) based on point cloud technology. Thermal images of the building envelop are captured and ortho-correction is performed. The data obtained is then processed and exported as binary images indicating the location of debonds and combined with

point cloud data and imported into BIM for health diagnosis of building envelop. The approach is similar to establishment of a regular track record of building envelop which is currently in vain.

Video Presentation

ID: 140

Active thermal characterization of building wall layers using inverse method

by E. Biteau, F. Brachelet, D. Defer and L. Zalewski
Univ. Artois, ULR 4515, Laboratoire de Génie Civil et géo-Environnement (LGCgE), Béthune, F-62400, France; franck.brachelet@univ-artois.fr

Abstract
This article presents an active method of building walls thermal characterization. A thermal stimulation is applied by a heating blanket on one side of the wall. Temperatures and injected heat flux evolutions are recorded by a data logger on the front face and the temperature by an infrared camera on the back face. Those signals are then processed by an inverse method which allows the determination of the thermal conductivity and the specific heat of each wall layers as well as the Newton's coefficient, knowing their thicknesses. Different types of stimulation waveforms are tested and the associated uncertainties are determined.
Video Presentation

ID: 145

Experimental works based on active and passive thermography for measuring the thermal resistance of building walls

by T.-T HA*, L. IBOS*, V. FEUILLET*, Y. GARCIA**, V. LE SANT**, A. KOENEN**, L. PEIFFER***, R. BOUCHIE****, K. ZIBOUCHE**** and J. WAEYTENS*****
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*****Université Gustave Eiffel, IFSTTAR, Champs-sur-Marne, France

Abstract
This study presents the experimental part of RESBATI project. Several measurements based on active thermography were launched on a real Internal Wall Insulation. Three estimation processes proposed by project partners were applied in order to estimate the thermal resistance of this wall and its uncertainty. Moreover, the influence of some parameters (as applied heat power, convective heat transfer coefficient ...) on estimation capability were also discussed. Besides, a two-week passive measurement was performed to compare with active method.
Video Presentation

Electronics & Semiconductors

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Electronics & Semiconductors Forum

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ID: 21

Near Infrared Single Photon detection using an Avalanche photodiode Operated with a Bipolar gating signal

by B.K. Park, M.K. Woo, S.W. Han, Sung Moon
Center for Quantum Information, Korea Institute of Science and Technology, Seoul 136-791, Korea, s.moon@kist.re.kr

Abstract
Near infrared single photon detection using an InGaAs/InP avalanche photodiode(APD) operated with a bipolar

rectangular gating signal was reported. The use of the bipolar gating pulses enabled us to operate the APD well below the breakdown voltage during the gate-off time. As a result, it permits to decrease the lifetime of the trapped carriers, and then reduces the after-pulse noise of the detector. At a repetition rate of 200 MHz, the after-pulse probability is 8.2% less than conventional gating signal detection.

Video Presentation

ID: 37

Transient Thermographic Heat Path Analysis using Spatially Resolved Thermal Equivalent Networks

by Nils J. Ziegeler*, Peter W. Nolte**, and Stefan Schweizer*,**
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Abstract
In this work, an evaluation method for transient thermal measurements is presented. It is based on a onedimensional heat path analysis technique common for the thermal characterization of electronic components. This technique is generalised to obtain spatially resolved values for thermal resistances as well as thermal capacities via infrared thermography. The analysis of recorded image sequences yields the “time constant spectrum”, which enables for a detailed insight into the physical parameters describing the heat flow dynamic of the device. As a proof of concept, a 4 x 4 LED array is investigated and the experimental results are analysed.

Video Presentation

ID: 121

Inspection of silver-sinter die attaches by pulsed and lock-in infrared thermography with flash lamp and laser excitation

D. R. Wargulski*, D. May**, C. Grosse-Kockert*, E. Boschman***, B. Wunderle** and M. Abo Ras*
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*** Advanced Packaging Center, Duiven, Netherlands

Abstract
In this study we demonstrate the capabilities of the IR thermography for the inspection of silver-sinter die attaches. Sintered specimens such as 15 x 15 mm^2 dummy dies sintered on AMB substrates have been measured by pulsed infrared thermography (PIRT), lock-in infrared thermography (LIT) and as a reference by scanning acoustic microscopy. PIRT and LIT will be compared with the focus on the applicability in production lines. Both methods usually need a sample surface blackening which will be avoided here. This need of a sample preparation by blackening or other coating for sample surfaces with low emissivity and absorptivity is one of the main reasons for the low technology adoption of thermography methods for the inspection of thermal interfaces in electronics in industry.

Video Presentation

ID: 143

Experimental analysis of PCM enhanced electronic devices cooling

by M. Felczak*, B. Więcek*
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Abstract
The paper presents experimental results of PCM (Phase Change Material) enhanced cooling method. Investigations were focused on obtaining the best results of the cooling system during its start-up. Analysis of two heat sinks was done. It was investigated using IR and contact thermal methods. The first one is typical heat sink available on the marked. The second is partially filled with a mixture of PCM capsules and heat conducting paste (fig. 1). Latent heat of PCMs was used to absorb more heat in comparison with typical heat sink. PCM material was a mixture of different kinds of paraffin which are encapsulated in hydrophilic silica microcapsules. Because of that this PCMs acts like a solid state in whole operating range. Nevertheless thay has poor thermal conductivity. In order to increase it PCMs were mixed with heat conducting paste.
It is possible to delay the heat increase during start-up and do not increase device temperature during normal operation state (fig. 2).

Video Presentation

ID: 147

Impact of high emissivity paint layer on thermographic measurements of electronic circuits thermal impedance
by M. Kałuża

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Abstract

The aim of this paper is to present the impact of a paint layer - often added on the surface of integrated circuit due to low emissivity of metallic elements - on the results of thermal impedance measurements made with an infrared camera. A thick film resistor on alumina is used as a test device. Its thermal power step response is measured with a cooled thermographic camera for configurations without any paint and with paint layers of different thickness. Next, the measurement results are compared and the impact of the paint is evaluated.

Video Presentation

ID: 167

Thermal resistance of GaN HEMTs in DC/DC step-down converter measured by IR thermography
by B. Torzyk, B. Więcek
Lodz University of Technology, Institute of Electronics, 211/215 Wólczańska St. 90-924 Łódź, Poland, blazejt@gmail.com, boguslaw.wiecek@p.lodz.pl

Abstract
This paper presents the thermographic measurements of temperature of GaN HEMTs working in the synchronous step-down DC/DC power converter. In order to estimate the power efficiency of the converter, the values of electrical parameters, such as input and output currents and voltages were measured simultaneously. Power losses in the transistors were estimated using the additional parameters of the transistors provided by the manufacturer in the application notes. At last, knowing the power loss in the transistors and temperature surplus over ambient, the thermal resistance was evaluated.

Video Presentation

Environment

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Environment Forum

This is the spot for open discussion of the abstract / videos on **Environment** (3 articles)

ID: 62

Interdisciplinarity in action: Using infrared thermography to teach plants' energy balance in secondary education
by J. Marques da Silva*, P. Correia*, M. Calejo Pires*, J. Soares Augusto**, J. Miguel Costa***
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Abstract
Thermography emerged as a practical tool to teach plant biology in higher education. Indeed, thermography can help to teach basic principles of plants' physiology such as their energy balance. The well-established fact that increased leaf temperature reflects stomatal closure, being therefore a measure of plants' response to drought, supports the relevance of the technique. Nowadays, affordable thermographic cameras allow to extend the use of this technology to secondary education. To achieve this goal, however, training high school science teachers is instrumental. We herein report and

discuss a training action on the principles of thermography and their application to plant biology.

Video Presentation

ID: 114

Identification of fire changes using thermal IR images: the case of coal-waste dumps

by A. Abramowicz* and R. Chybiorz*
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Abstract
Coal-waste dumps' fires are a major environmental threat. They are usually subsurface fires, characterized by a long process and flameless combustion. This phenomenon is difficult to predict, locate, and eliminate. Current monitoring methods don't allow sufficient reaction to prevent the fire development
To better understand the phenomenon of dumps' fires, a series of aerial and ground thermal infrared photos were taken. They covered the area of a selected dump with active coal-waste fire. A comparative analysis of the obtained images in time and space was performed. Aerial photographs were compared to the ground ones. Trends in fire variability have been identified.

Video Presentation

ID: 120

Using soil and canopy temperature to support efficient management of irrigated vineyards

by J. M. Costa*, R. Egipto**, C.M. Lopes*, J. Silvestre**
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Abstract
Extreme heat and drought events are becoming more frequent and erratic in Mediterranean Europe. Better comprehension of spatial and temporal dynamics of heat fluxes and thermal microclimate in vineyards can support vineyard's management and minimize the impact of climate variability. Field experiments were carried out in South Portugal with two red cvs. Touriga Nacional and Aragonez (syn. Tempranillo) under deficit irrigation. Canopy temperature (Tc) is a robust predictor of plant water status, especially when measured under more stressful conditions. In parallel, soil temperature (TS) had a positive influence on TC especially at the cluster zone.
Video Presentation

Fluid Dynamics and Energetics

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Fluid Dynamics and Energetics Forum

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ID: 45

Petrochemical furnace precise temperature monitoring aided by thermographic data corrections

by R. Fuente*, J.M. Campillo-Robles**, I. Olaizola***, A. Fernández****, I. Arzua*****, T. Echániz* and G.A. López**
* Applied Mathematics and **Applied Physics II, Univ. of the Basque Country (UPV/EHU), Bilbao, 48080, Spain, raquel.fuente@ehu.eus
***Data Intelligence for Energy and Industrial Processes, Vicomtech, Donostia, Spain, iolaizola@vicomtech.org
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*****Petróleos del Norte, San Martín Nº-5, 48550 Muskiz, Spain, iarzuam@repsol.com

Abstract
This work addresses the thermographic temperature monitoring in a high temperature industrial environment (800-1000 ºC). Specifically, Petronor Innovación aims to monitor the tube surface temperature of a reforming furnace to avoid failures that could result in unplanned plant shutdowns. The main drawback lies in the current absence of algorithms of sufficient precision to determine the temperature of a target body from infrared radiation readings by a camera. In fact, spurious contributions of infrared measurements, amplified in high temperature environmen[illegible]are complex to suppress. In this research work, thermal and optical models are developed to generate precise algorit[illegible].or temperature correction in thermography and are implemented in a monitoring platform.

 Video Presentation

ID: 59

Infrared temperature measurements on 3D objects with surface recession
by A. Fagnani[a,b], B. Helber[a] and O. Chazot[a]
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[b]Vrije Universiteit Brussel, 1050, Brussel, Belgium

Abstract
The VKI Plasmatron is the world's largest inductively coupled plasma facility, which allows to reproduce on ground the high-enthalpy, chemically reacting boundary layer over a re-entry body. Test conditions are suitable for qualification of re-entry thermal protection systems and for material response characterization. Infrared thermography provides a valuable mean of non-intrusive surface temperature measurement on the test sample materials. However, infrared data are available in the form of two-dimensional images, while the test object usually has a three-dimensional shape. Moreover, the test material can undergo significant surface recession when exposed to the plasma flow. In this work, we propose a novel methodology to reconstruct three-dimensional temperature maps on a receding surface. First, an optical calibration technique is used to provide the necessary mapping parameters between the real world coordinates and the IR camera image pixels. Then, an auxiliary measurement of surface recession allows to determine the time evolution of the object shape. The surface temperature is hence reconstructed on the inferred time-varying geometry.

 Video Presentation

ID: 64

Thermal spot velocimetry inside a boundary layer in water
by E. Koroteeva*, I. Znamenskaya*, P. Ryazanov* and A. Shagiyanova*
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Abstract
We propose a new method for quantitative visualization of the flow-velocity fields within a boundary layer of a non-isothermal fluid using seedless velocimetry. The method is based on the high-speed thermal imaging of the dynamics of temperature inhomogeneities through an infrared transparent wall. When the temperature inhomogeneities act as a passive flow tracer, the processing of the thermal-image sequences using a cross-correlation algorithm yields the velocity fields in a near-wall flow. Here, we study the near-wall flow formed in the region of interaction between a submerged impinging water jet and a flat plate. The obtained flow velocities range up to 1 m/s, and the limits of the laminar-turbulent transition inside the boundary layer are determined.
Video Presentation

ID: 152

Comparative experimental and numerical study of the heat transfer from a heated wall to swirling impinging jets
by G. Paolillo*, C.S. Greco*, T. Astarita* and G. Cardone*
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Abstract
This work presents a comparison of the results from an experimental and numerical investigation of impinging swirling jets operating at Reynolds number and swirl number equal to 30'000 and 0.61, respectively. Measurements are carried out via InfraRed Thermography using a heated thin foil as heat flux sensor, varying the impingement distance from 1 to 10 nozzle diameters. Numerical simulations of the same configurations are performed with a commercial software (Ansys Fluent) to test the capability of different Reynolds-Averaged Navier-Stokes (RANS) equations-based turbulence models in predicting the heat transfer rates from wall to the swirling impinging jets.

 Video Presentation

Image & Data Processing

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Image & Data Processing Forum

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ID: 4

Exploratory Factor Analysis of Infrared Thermographic Data for Defect Detection

by Kai-Lun Huang*, Stefano Sfarra**, Yuan Yao*†
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** Department of Industrial and Information Engineering and Economics, University of L'Aquila, Piazzale E. Pontieri no. 1, Monteluco di Roio – L'Aquila (AQ), I-67100, Italy
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Abstract
Active infrared thermography is an important non-destructive testing method used for revealing defect structures in materials. In many applications, thermographic data processing is necessary to extract defect features from a large number of thermal images. In this work, it is proposed to use exploratory factor analysis (EFA) for dimensionality reduction and feature extraction of thermographic data. By means of factor rotation, EFA minimizes the complexity of factor loadings and makes the results more interpretable. Hence, the defect information is highlighted while large signal-to-noise ratios are obtained. The feasibility of proposed method is illustrated with the experiment on a panel painting.

Video Presentation

ID: 5

Thermography in laser powder bed fusion of metals: time over threshold as feasible feature in thermographic data

by S.J. Altenburg*, N. Scheuschner*, C. Maierhofer*, G. Mohr*,** and K. Hilgenberg*,**
* Bundesanstalt für Materialforschung und -prüfung (BAM), Unter den Eichen 87, 12205 Berlin, Germany, simon.altenburg@bam.de
**Technische Universität Berlin, Institute of Machine Tools and Factory Management, Chair of processes and technologies for highly loaded welds, Straße des 17. Juni 135, 10623 Berlin, Germany

Abstract
Thermography is one on the most promising techniques for in-situ monitoring of metal additive manufacturing processes. Especially in laser powder bed fusion processes, the high process dynamics and the strong focus of the laser beam cause a very complex thermal history within the produced specimens, such as multiple heating cycles within single layer expositions. This complicates data interpretation, e.g., in terms of cooling rates. A quantity that is easily calculated is the time a specific area of the specimen is at a temperature above a chosen threshold value (TOT). Here, we discuss variations occurring in time-over-threshold-maps during manufacturing of an almost defect free cuboid specimen.

Video Presentation

ID: 8

Generation of Large-Scale 3D Thermograms in Real-Time Using Depth and Infrared Cameras

by S. Schramm*, P. Osterhold*, R. Schmoll* and A. Kroll*
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Abstract
In recent years, various methods for the generation of 3D thermograms have been developed. A well-stablished approach is the fusion of data from depth and long-wave infrared (LWIR) cameras. However, these models generated in real-time have the limitation that the model size is limited due to inefficient data storage. Newer algorithms from Computer Vision promise to overcome this limitation. Within this work, one of these 3D modelling algorithms is extended by the overlay of thermal data, which allows the creation of large-scale 3D thermograms. The results will show the

advantages over current existing systems.

Video Presentation

ID: 12

Automatic Defects Segmentation and Identification by Deep Learning Algorithm with ed Thermography: Synthetic and Experimental Data

by Q. Fang*, X. Maldague *, I. Garrido**, J. H. Erazo***, C. I. Castanedo*,
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*** Escuela de Ingniería Eléctrica y Electrónica, Universidad del Valle, Cali, VA, 760032, Colombia

Abstract
Infrared thermography is used for evaluating composite materials due to the properties of low cost, fast inspection of large surfaces. The application of deep neural networks tends to be a prominent direction in the Infrared Non-Destructive Testing. During the training of the neural network, the Achilles heel is the database. The collection of huge amounts of training data is the high expense task. In Non-Destructive Testing with deep learning, the synthetic data contributing to training in infrared thermography remains unexplored. In this paper, synthetic data from the standard Finite Element Models is combined with experimental data to build repositories with Mask-RCNN to achieve defect segmentation.

Video Presentation

ID: 13

Wavelet transform applied to pulse thermographic data for detection of subsurface defects in aluminum structures Yoonjae Chung*, Seungju Lee* and Wontae Kim*†

*Department of Mechanical & Automotive Engineering, Kongju National University, 1223-24 Cheonan-daero, Seobuk-gu, Cheonan-si, Chungcheongnam-do, 31080, South Korea

Abstract In this study, we focused on pulse infrared thermography as a non-destructive testing method for detection of subsurface defects in aluminum structures. In the present investigation, a square shaped (180 m * 180 mm) aluminum specimen with 10 mm thickness and artificial defects with circular cutouts of varying depth and diameter at the back side was manufactured. The sample was excited at several modulation frequencies by a sinusoidal heat flux, and a thermal infrared camera was utilized for monitoring of surface temperature of a thermal wave that propagated into the sample. Wavelet transform was applied to compute phase angle data from the temperature-time history of each pixel for the assessment of the defects. A phase image was calculated using a Fourier transform and the Wavelet transform. Image processing software MATLAB and Thermofit Pro were used to compute the phase image. The investigation into the effects of wavelet parameters; scale and shift, modulation frequencies, inclusion sizes, and depths on the phase contrast was conducted and discussed.

Video Presentation

ID: 15

Neural network based automated defect detection using induction thermography for surface cracks in forged parts

by D. Müller[1,2], U. Netzelmann[1], A. Ehlen[1,2], M. Finckbohner[1] and B. Valeske[1,2]
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Abstract
A fully convolutional neural network was used for the detection of crack-type defects and for the defect shape prediction of thermography datasets. The method uses a supervised neural network for sematic segmentation (U-Net). For these tasks, training datasets of forged parts were acquired through induction thermography. Furthermore, modelled thermography sequences from COMSOL Multiphysics were simulated. The approach provides a significant improvement over conventional methods of thermal signal and image processing used in active thermography. Furthermore, the results may lead to new procedures for a quantitative evaluation of flaws and defects in non-destructive testing using infrared thermography.

Video Presentation

ID: 16

Improvement of the contrast-to-noise ratio in pulse-phase thermography by frequency dependent windowing

by U. Netzelmann1 and D. Müller2[1]Fraunhofer Institute for Non-Destructive Testing IZFP, Campus E3 1, 66123 Saarbrücken, Germany, udo.netzelmann@izfp.fraunhofer.de
[2]Hochschule für Technik und Wirtschaft des Saarlandes, htw saar, Goebenstr. 40, 66117 Saarbrücken, Germany, david.mueller@izfp.fraunhofer.de

Abstract
Two modified algorithms for pulsed phase thermography were defined. The principle is to mask out parts of the thermal signal that only add noise but no significant information. The algorithms were tested on synthetic signals from a circular hidden defect and experimentally by flash excited thermography on a steel and a polymer sample. A significant improvement of the contrast-to-noise ratio of defects was obtained for higher analysis frequencies.

Video Presentation

ID: 23

Automated defect detection based on time and frequency domain analysis using Eddy Current Pulsed Thermography in EB and TIG welding inspections

by R. Hidalgo-Gato, E. Gorostegui-Colinas, P. López de Uralde, A. Muniategui, B. Urtasun, I. Silanes
LORTEK Technological Centre, Basque Research and Technology Alliance (BRTA), Arranomendia kalea, 4A, Ordizia, 20240, Spain, rhidalgo@lortek.es

Abstract
On this work an active thermography has been applied to Inconel 718 EBW and TIG samples, continuing previous research on this field [1, 2]. In particular, the objective of this work is to improve and automate the processing part of the automatic defect detection procedure to enhance the results of the detection algorithm, which is the one applied in the last step. The proposed method is based on a time and frequency domain analysis (TFDA), in which, the resulting thermograms contain the most relevant thermal information regarding to the defect thermal evolution. To assess the suitability on each resulting thermogram (including the fused images), an accuracy evaluation based on Tanimoto criterion has been employed. This evaluation leads to an optimate processing procedure that ensures a detection with less false positives or negatives.

Video Presentation

ID: 41

Super resolution laser thermography

by S. Ahmadi*, P. Hirsch*, C. Hassenstein*, P. Burgholzer**, P. Jung***, G. Caire***, M. Ziegler*
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** RECENDT, Research Center for Non-Destructive Testing, Linz, Austria
*** Technische Universität Berlin, Berlin, Germany

Abstract
In order to break the thermographic spatial resolution limit (super resolution), the combination of spatially structured heating and numerical methods of compressed sensing can be used. Our studies deal with the influence of experimental parameters such as the pulse length of the laser illumination and the size of the laser spot. Furthermore, we have dealt with the choice of parameters in the reconstruction that have an influence on the underlying minimization problem in terms of compressed sensing. Finally, the results of the super resolution method are compared with the results based on conventional thermographic testing methods.
Video Presentation

ID: 46

Spatial and temporal shaping of diffuse thermal wave fields using high-power lasers

by M. Ziegler*, S. Ahmadi*, P. Hirsch*, C. Hassenstein*, E. Thiel*, N. W. Pech-May*
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Abstract
Although thermography is suitable for a wide range of inhomogeneities and materials, the fundamental limitation is the diffuse nature of thermal waves and the need to measure their effect radiometrically at the sample surface. The crucial difference between diffuse thermal waves and propagating waves is the rapid degradation of spatial resolution with increasing depth. A promising approach to improve the spatial resolution and thus detection sensitivity and

reconstruction quality lies in shaping of these diffuse thermal wave fields. We present the latest results of this technology obtained with lasers, i.e. spatially and temporally structureable heating sources and modern numerical methods.
☞ Video Presentation

ID: 47

Defect characterization in Pulsed Thermography: comparison of quantitative techniq › r simulated and experimental data

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Abstract
A CFRP sample with inserted defects of different sizes and depths was evaluated by Pulsed Thermography. In addition to the experimental analysis, which is relative to defect detection, a computational simulation model was developed to reproduce the thermal behavior in the sample during the test. Simulations were performed with defects of several sizes and depths in order to know the influence of these parameters on the maximum thermal contrast. The performances of three models, exponential, a suitable power law and a neural network, were compared to quantitatively reproduce the data.
☞ Video Presentation

ID: 48

Temporal shaping and pulse-compression in thermography using laser heating

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Abstract
The shaping of the heating radiation in the time domain and the corresponding signal processing, i.e. Pulse-compression Thermography, show promises in combining the advantages of both pulse and lock-in thermography. At the same time, the inherent disadvantage of the often-used thermal-based light sources can be addressed using planar illuminating high-power lasers. Prospectively, pulse-compression can thus become a new modality in infrared thermographic inspection.
☞ Video Presentation

ID: 56

Iterative methods for thermographic reconstruction using the virtual wave concept

by P. Burgholzer*, G. Thummerer**, G. Mayr**, P. Kovacs***, M. Haltmeier****
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Abstract
The achievable spatial resolution in thermography decreases with the imaging depth, which leads to blurred images for deeper lying structures. The resolution limit has its origin in the second law of thermodynamics: heat diffusion on its way from the imaged structure to the sample surface leads to entropy production that is equal to the loss of information. In order to address this issue, additional available information about the sample has to be included in the regularization of the inverse problem, such as positivity or sparsity of the signals. We combine the benefits of acoustic and thermal imaging using non-linear reconstruction algorithms combined with the recently introduced virtual wave conceopt.
☞ Video Presentation

ID: 66

Detection and localization of slag inclusions in weld using IR thermography

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Abstract

Slag inclusions are common welding imperfections, decreasing quality of joint. In the paper [illegible]n-line method of slag detection and localization is proposed for manual electrode welding. Two perpendicularly p[illegible]. IR cameras are used to observe welding. Based on topological analysis of welding arc area and dynamics of weld cooling defects are found and localized in seam. To overcome errors in emissivity setting, relative temperature change were used. Results were confirmed with radiographic examination of joints. It was found that proposed method can be successfully
☏ Video Presentation

ID: 74

Discrete Trigonometric Transform Thermography

by Ivan LASSO-MARTINEZ*, Humberto LOAIZA-CORREA* and Andres RESTREPO-GIRON*
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Abstract

This paper presents a signal processing algorithm as a solution to the problem of detection and characterization of subsurface defects in structures, which uses pulsed thermography. The main algorithms that have also approached this problem are thermographic signal reconstruction (TSR), pulse phase thermography (PPT), principal component thermography (PCT), differential absolute contrast (DAC), high-order statistics (HOS), among others. However, none of these algorithms has focused on use of the principle of conservation of energy between time and frequency domains. This is the orientation given to the presented algorithm. Due to discrete trigonometric transforms (DTTs) properties, it was decided to use some of these transforms as a mathematical tool to carry out the previous approach. For this, choice was made between discrete cosine transforms (DCTs) and discrete sine transforms (DSTs). Because there are eight DCTs and eight DSTs, it was necessary to limit scope of this work to the evaluation of only two types among sixteen possible transforms: the DCT–2 and the DST–4 were chosen; the first for its great capacity for energy compaction. The other types will be evaluated in future work. The results lead to conclusion that the cumulative percentage of energy function, calculated with DCT–2 and DST–4, presents advantages similar to those of the phase signal used in the PPT; for example, it is not affected by non-uniform heating and allows quantifying the depth of defects.
Regarding the materials, nine synthetic thermogram sequences were used, designed and generated with ThermoCalc–6L™ that emulate physical characteristics of a CFRP flat surface with 2 mm thick. All sequences contain five defects located at different positions of the specimen. The locations of these defects do not change from one sequence to another. All defects of a sequence are at the same depth; however, depth increases from sequence to sequence. Table 1 lists depths at which the defects of each sequence are found. All defects have a thickness equal to 0.1 mm.
☏ Video Presentation

ID: 79

Image processing and reconstruction method based on broadband InfraRed to terahertz camera

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Abstract

Terahertz waves have been shown to be an effective contactless, safe, and low-cost technique that allows to investigate nondestructive testing or water diffusion within porous media, such as biomaterial or insulation materials [1, 2]. Few years ago a THz camera based on an infrared camera coupled with a photothermal converter was developed [3] in our group. Here we report recent advances on large image scanning and reconstruction processing. The goal is to realize A4 images from x,y scan (cf. figure 1) composed of ROI (from 0.5 x 0.5 to 5 cm x 5 cm). Here, the purpose of image reconstruction based on stitching algorithm is discussed associated with lock-in technique and Singular Value Decomposition for the acquisition of each single ROI.
In fact, different image processing methods were applied to improve the quality of THz images (cf. figure 2). First of all the 4 images method is applied. Singular Value Decomposition can be used to denoised the picture. Normalization by the beam, averaging on several periods, mean of IR image according to THz wavelength can also increase the image quality. The image quality is very sensitive to the signal to noise ratio of the THz source. A simple way to increase it is to reduce the beam size to increase the power density of initial signal. If the beam is small, more scan should be done to image the same object. In this work, images were obtained with a reduced beam size, to get the best signal to noise ratio. The results obtained on the final THz images are super resolved compared to the ROI size, which is encouraging for further study on the system.

☞ Video Presentation

ID: 85

Absolute Temperature Field Measurements in Flames based on Infrared Thermo-Spectroscopic Imaging

by A. AOUALI*, S. CHEVALIER*, A. SOMMIER*, J.C. BATSALE* and C. PRADERE*
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Abstract
Plasma torches are a type of source that generates very high temperatures. They are mainly used in surface treatment applications and ultimate waste treatment. The knowledge of the temperature field in plasma torches is of prime interest for researchers and industry to model and optimize the torch design. First experiments to measure the plasma torch temperature were reported by J.-L. Gardarein et al. [1] using a probe with a thermocouple directly inserted into the plasma. This first measurement led to the knowledge of plasma heat flux, but it was an intrusive method which gives only a single average value. To move forward, researches at I2M are conducted in collaboration with Europlasma to thermally and chemically characterize plasma torches with the end goal of 3D non-contact heat flux and temperature field measurements.
To ensure the previous objective, radiometric techniques are developed which provide adequate means to measure contactless temperature [2]. This temperature can be deduced from the luminance measured using an IR camera if the emissivity of the body is known [3]. In flame measurements, the assumption of thermal equilibrium is generally done [4] which makes the cartography of the emissivity, ε, to be equal to the absorptivity, α. Thus, by measuring the transmissivity,τ, of an IR beam through the flame, one can deduce the absorptivity, where $\alpha=1-\tau$ in semi-transparent medium, and therefore obtain ε. This methodology is validated at the lab scale using a small flame generated by a burner, an IR source and camera.
In Figure 1, the experimental setup to measure the flame temperature is depicted. Three simultaneous acquisitions are made using a shutter synchronized with the camera: (1) the IR source beam alone, (2) the IR source beam + the proper emission of the flame, and (3) the proper emission of the flame alone. From this 3-images method, the total hemispheric transmissivity τ is measured. This result is presented is Figure 2(a) where the thermo-dependence of the transmittivity in the flame is observed. The transmittivity ranges from 0.16 to 0.4, which leads to an emissivity range between 1 and 0.84 (Figure 2(b)). As expected, the flame differs from the black body (emissivity of 1) which has justified the need of emissivity measurements to obtain the true flame temperature from an IR camera. This thermodependency of emissivity is expected to be strengthened in plasma torches which reach 5000 K (about 4-5 time hotter than the flame used in this experiments). In the oral presentation, this 3-images methodology will be presented in details and results of flame temperature measurements will be reported.
☞ Video Presentation

ID: 88

FFT of analytically described temperature curves – an investigation of phase angles

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Abstract
The Pulsed Phase Thermography (PPT) based on the FFT algorithm is a frequently used method for the evaluation of temperature transients in thermographic investigations, especially for weak and noisy contrasts. However, the applicability of evaluation methods from the field of Lock-in Thermography (LT) is an open issue. Here, this question is considered by means of simple analytical functions for the description of cooling curves. It is shown, that only in case of 2n data points the phase values of both PPT as well as LT are equal.
☞ Video Presentation

ID: 102

On the used of EMIR® method to realize 3D characterization of radio wave fields

by A.Sommier*, M. Ayadi*, F. Prince*, D. Balageas*, J.C. Batsale* and C. Pradere*
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Abstract
Since the pioneering works of Iizuka [1] and Gregoris [2] and thanks to the work of a few research groups, the EMIR® (ElectroMagnetic-InfraRed) technique progressively improves its performances, making possible to visualize in real-time, with a high spatial resolution and a very large bandwidth, Continuous Wave (CW), modulated, or pulsed electromagnetic fields [3-5].
The EMIR method combines the use of an infrared thermography camera and of a screen made of a photothermal film transforming a fraction of the electric or magnetic field into heat, producing a 2-D tomography that is an image of the field intensity.

The observation of CW fields is very sensitive. The photothermal film can be placed in planes perpendicular to the propagation direction. An IR camera records the thermal response of the film during a square-shaped illumination by the studied EM source. Norgard et al. [3] show that this field imaging technique has the advantages of accuracy, simplicity, speed, and portability over existing hard-wired probe methods and produces a 2D picture of the near field or the far field.
In this paper, we extend this technique to realize a 3-D characterization of a UHF (0.3 to 3 GHz) radio wave antenna in an anechoic chamber (up-to-now the technique has been mainly applied to microwaves and recently to millimetric fields). The film (1 m x 1 m) is placed between the antenna and an IR bolometric camera (7-15 µm). The antenna emits (0.5, 0.75, 1 GHz, 20 V/m) during several seconds and the camera records the temperature-time evolution of the film. The experiment is repeated for various source-screen distances (3, 6, 9, 12, 15 and 18 cm) (cf. figure 1). Various data processing of the thermograms are possible, leading to the production of thermographic images of the field intensity. Finally 3-D maps of the electromagnetic field are obtained (confer figure 2). This approach allows to decreasing the influence of the radiato-convective heat losses, which tend to distort the field shape.
These results must be considered as preliminary. In the future the quality and accuracy of the images could be improved by introduction of a modulation of the source and use of a lock-in thermographic system [6]. Finally, calculation and results must be compared.
Video Presentation

ID: 122

Feature extraction for drowsiness detection using facial skin temperature distribution
by A. Masaki*, K. Nagumo*, K. Oiwa* and A. Nozawa*
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Abstract
Level 3 autonomous driving vehicle, the driver needs to drive himself when the system is in an emergency. Therefore, the system to detect the lowering of arousal degree is desired. Commercially available drowsiness detection technologies can be roughly classified into two methods. These include: 1) Vehicle-based methods; 2) Driver behavior-based methods. These two techniques may only work if drivers are fully drowsy and the risk of an accident increases.
So far, there has been proposed the model that detects drowsiness instantaneously on facial skin temperature distribution using convolutional neural network (CNN). However, CNN, a supervised learning algorithm, has difficulty preparing datasets for all drowsiness levels. To solve this problem, we focused on an unsupervised learning algorithm, the variational autoencoder (VAE). In this study, we tried to construct a model to detect drowsiness using VAE by using only the facial skin temperature distribution during arousal. The datasets were prepared by conducting the drowsiness induction and suppression experiment.
Video Presentation

ID: 123

Different methods for calculating Crop Water Stress Index using infrared thermography
Borjan Ranilović*, Alen Cukrov*, Ivanka Boras*, Srećko Švaić*, Monika Zovko**
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**University of Zagreb, Faculty of Agriculture, Svetošimunska cesta 25, Zagreb, Croatia

Abstract
When using infrared thermography in agriculture, the Crop Water Stress Index needs to be calculated. This requires the canopy temperature, as well as the dry and wet reference temperature, to be determined. In this paper, an overview of possible methods for their calculation and/or measurement is given, and an analysis which compares CWSI values obtained using different methods of determining the canopy temperatures, as well as different dry and wet reference temperatures, is presented. The effect of different methods on the statistical significance of the correlations found are presented and analyzed to determine the most promising method.
Video Presentation

ID: 134

A new deep-learning neural network for super-resolution up-scaling of thermal images
by P. Więcek, D. Sankowski
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Abstract
This paper presents a novel architecture of deep learning convolutional neural network for up-sampling of thermal images. The proposed solution is based on Kernel-Sharing Atrous Convolution (KSAC) filtering block. The developed system ensures the high accuracy of the up-sampling with scales up to 6 with much lower algorithm complexity compared to the reference methods widely used for visual image processing. The learning process uses the high

resolution RGB visual images available in the DIV2K database. The examples of up-sampling of thermal images generated by IR cameras with160x120 and 32x24 sensors are presented.

Video Presentation

ID: 136

Study and development of an image synthesis software for the simulation of in-situ 3D scenes monitored by infrared cameras

by T. Toullier*, J. Dumoulin*, L. Mevel**
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** Univ Gustave Eiffel, Inria, COSYS-SII, I4S Team, F-35042 Rennes, France

Abstract
This study addresses the development of a software for the simulation of radiative exchanges in in-situ 3D scenes. By using the progressive radiosity method, implemented on a graphic card to improve the computation speed, a direct solution to the radiative transfer equation is proposed. The software integrates the SMARTS2 atmospheric model to take into account the solar irradiance. Moreover, a camera model has been implemented to simulate the acquisition chain from the camera's irradiance to the digital signal. To validate the software, a comparison between simulated data and actual measurements is proposed. Finally, prospects for extending the software are presented.

Video Presentation

ID: 142

A simulation of the capability of multispectral infrared imaging for thermographic inspection of multi-material systems

by S. Quirin* and H.-G. Herrmann**
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** Fraunhofer Institute for Nondestructive Testing IZFP and Chair for Lightweight Systems, Campus E3 1, Saarbrücken, Germany

Abstract
The usage of multi-material systems is increasing just as the customization of industrial products right inside the fabrication process. As different materials and surfaces have a very characteristic interaction with infrared radiation, implications for the usability of thermography for quality control or monitoring setups are substantial. Multispectral imaging approaches are promising to overcome the constraints of an uncertain or unknown emissivity coefficient. A simulation is presented that can illustrate their capability and emphasize their value for non-destructive testing and monitoring.

Video Presentation

Induction Thermography

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Induction Thermography Forum

This is the spot for open discussion of the abstract / videos on **Induction Thermography** (6 articles)

ID: 22

Automated induction thermography system for surface crack in-line inspection

by W. Guo*, C.Y. Ngo* and V. Kumar*
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Abstract

Compared to other active thermography techniques, induction thermography has the advantages of providing instantaneous results while being not affected by surface conditions such as emissivity or geometry. Hence, this technology has high potential to be applied for automated in-line inspection. This work will study the reflected thermal signals from a titanium sample under different moving speed. The titanium sample comes with various electrical discharge machining (EDM) notches to simulate surface cracks. Normalized temperature will be continuously calculated and plotted to reconstruct the surface condition. The final optimized configuration will be se[illegible]ed after leveraging the signal-to-noise ratio (SNR) and inspection speed.
☎ Video Presentation

ID: 24

Study of the influence of radius and distance between windings of Helmholtz coils for detection of cracks using active thermography in coil link chains

by Pablo López de Uralde*, Eider Gorostegui-Colinas*, Iñaki Silanes*, Beñat Urtasun*, Rafael Hidalgo*, Iratxo Gómez† and Iñaki Fdz de Bastida†.
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Abstract
The detection of surface defects in coil link chains is essential to ensure their correct operation in adverse conditions, such as offshore applications. During the processes of bending and welding of the links, cracks that lead to structural failure under working conditions can be generated. That is why an early detection is necessary, especially for safety, but also for economic reasons.
Traditional Non Destructive Testing methods in industry, such as Dye Penetrant Testing or Magnetic Particles, are in general slow and need an experienced technician both in conducting the tests and in interpreting the results. Furthermore, those methods imply the need of cleaning the test specimen after finishing, increasing times and costs. Consequently, inductive thermography has been identified as an advantageous technique because of its cleanness, fastness and the possibility of automation of the whole inspection procedure [1] [2] [3].
The aim of this work is the optimization of the inspection of offshore chains via inductive thermography. For this reason, a research between different types of coils has been performed, leading to the conclusion that Helmholtz coils fit with the needs of the industrial inspection. Prior to the detection and location of cracks, a complete study of the influence of two parameters has been carried out: coil radius and distance between windings. These parameters are essential for the inspection of chains during production, due to the reduced dimensions and complicated accessibility on industrial environment.
In order to study the influence of these two parameters, an analytical model has been developed and the deduced conclusions have been corroborated by means of experimental measurements with different size coils. Finally, the optimal range of parameters has been extracted and applied for the detection of cracks on a welding part of a link.

☎ Video Presentation

ID: 33

Detection of short fatigue cracks by inductive thermography

by B.Oswald-Tranta, C. Tuschl,
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Abstract
Inductive thermography can be used to detect surface cracks in metals. As a crack influences the eddy current distribution and the heat diffusion, it becomes visible in the infrared images. The deeper the crack, the larger disturbance it causes, hence its signal correlates with its depth. This paper investigates, how by short cracks their length influences the signal. Simulation and experimental results are presented for ferro-magnetic and for austenitic steel. The signal along the crack, between the hot spots at the crack tips, corresponds with its depth. It is also investigated how the crack profile affects this pattern.

☎ Video Presentation

ID: 76

Parametric simulation of Induction Thermography for optimal cracks detection and characterization

by O. Ghibaudo*, F. Foucher** and A. Kalai**
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Abstract
In the last few years, induction thermography has been identified as a non-destructive testing method for detecting and characterizing surface cracks in metals. The sample to be inspected is heated with a short induced electrical current pulse, and the infrared camera records the temperature distribution and transient temporal behavior at the surface during and after the heating pulse. In this work, 3D Finite element simulations, performed with the software FLUX©, were carried out to investigate how the thermal contrast depends on parameters such as excitation frequenc lse duration, material parameters, crack depth and length.
Video Presentation

ID: 83

Characterizing complex metal-CFRP-hybrid structures by thermography
by M. Schwarz[a,b], A. Hell[a] and H.-G. Herrmann[a,b]
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[b] Fraunhofer IZFP Institute for Nondestructive Testing, Campus E3 1, 66123 Saarbrücken, Germany

Abstract
In this paper results of non-destructive testing of metal-CFRP-hybrid structures are shown. The hybrid samples vary from 2D to 3D geometry. As NDT-method active thermography with its excitation modes flash and induction through an eddy current coil are used. It is shown that artificial induced defects like pleats in the CFRP-layer and mechanically induced delaminations at the interface CFRP/thermoplastic can be detected. For the latter defect, a different damage behavior can be shown depending on the geometry.
Video Presentation

ID: 132

Automated induction thermography for in-line inspection of CFRP
Andrew C.Y. Ngo[1,*], W. Guo[1] and V. Kumar[1]
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[1]Structural Materials Department, Institute of Materials Research and Engineering (IMRE), Singapore

Abstract
Compared with other active thermography techniques, induction thermography has the advantages of providing instantaneous results yet not affected by surface conditions such as emissivity or geometry. Hence, this technology is promising for applications such as automated in-line inspection. This work will study the feasibility of using automated induction thermography for defect detection on a defective carbon fiber reinforced polymer (CFRP) composite under different moving speed. The final optimized configuration will be presented after considering the signal-to-noise ratio (SNR) and inspection speed.
Video Presentation

Industrial Applications

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Industrial Applications Forum

This is the spot for open discussion of the abstract / videos on **Industrial Applications** (12 articles)

ID: 2

Infrared thermography applied to the validation of thermal simulation of high-luminance LED used in automotive front lighting
by C. Rongier*,**, R. Gilblas*, Y. Le Maoult*, L. Redjem-Saad** and F. Schmidt*
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Abstract
Automotive front lighting is evolving towards digital and adaptive high definition beams. To create such functions, multiple LED designs are replaced with new LED concepts using only one high luminance LED. Light concentration emitted from this optoelectronic component generates a high density of energy which must be thermally managed. Indeed, optical performance and reliability of components are directly linked to the LED temperature. Thus, to optimize cooling system, accurate and efficient numerical models must be developed. The validation of these models are based on comparison with experimental data. In this paper, an infrared camera was used to measure quantitatively the temperature of a high luminance LED emitting area and was then compared to 3D thermal simulations.
Video Presentation

ID: 6

Application of quantitative Termography for detecting contact fatigue anomalies in spur cylindrical gears
by J. M. Oliveira Neto*, J. F. Maribondo** and W. F. Amorin Júnior**
*Federal University of Paraíba, Campus-I – Cidade universitária Lot, João Pessoa, Paraíba, Brasil, joao_engmec@outlook.com
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Abstract
Gear failures arise in most cases due to contact fatigue through cyclic stresses from the tooth contact, setting the temperature rise. The present work aims to verify the feasibility of applying quantitative Thermography in its active and passive modes and in controlled environment to detect the conditions of lack of lubrication and flaws on the surfaces of the teeth of a cylindrical spur gear. The technique was able to detect the absence of lubrication, contrary to what was found for flaws in tooth surfaces.
Video Presentation

ID: 26

Non-destructive characterization of wire arc sprayed cylinder coatings using laser-excited lock-in thermography measurements
by J. Arbogast*,**, R. Schaller*, B. Schilder*, S. Lindemann*, M. Rohde**, H.J. Seifert**
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**Karlsruhe Institute of Technology, Karlsruhe, Germany

Abstract
Laser-excited Lock-In Thermography is used to evaluate the thermal diffusivity of thermally sprayed cylinder bore coatings of passenger car engines. Further, microstructural analysis as well as adhesion testing of the investigated cylinder bore coatings are acquired to evaluate microstructural and mechanical properties. Investigation of the interaction between thermal diffusivity, microstructural and mechanical properties disclose major correlations between the observed quantities. The application of thermal diffusivity measurements as a non-destructive testing method of adhesion strength in thermally sprayed cylinder bore coatings is discussed in this work.
Video Presentation

ID: 73

Development of thermographic module for predictive maintenance system of industrial equipment

by P. Venegas*, E. Ivorra**, M. Ortega**, G. Márquez***, J. Martínez*** and I. Sáez de Ocáriz*
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Abstract
The maintenance of industrial equipment extends its useful life, improves its efficiency, reduces the number of failures and increases the safety use. This study proposes to develop a predictive maintenance tool based on infrared thermographic measures capable of anticipating failures in industrial equipment. The thermal response of selected equipment in normal operation and in controlled induced anomalous operation was analyzed. The characterization of these situations enabled the construction of a machine learning system capable of predicting future malfunctions.

 Video Presentation

ID: 87

AI Flame Detection System by Infrared Thermography

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Abstract
It is a very rapid spread that ends all situations in less than three minutes in many cases of fire, the current flame detector is slow to detect initial fire ,which sometimes has a false alarm rate without general solution in the past decade. Artificial intelligent flame detector was designed using machine learning technology based on infrared thermal sensor, and intelligent flame detection technology was developed to accurately detect fire within few seconds of the initial flame stage. In order to improve reliability of AI flame detection, we minmized false alarm rate by distinguishing between fire and actual fire used by humans, and it is an intelligent fire recognition and response system technology of an architecture. The flame detection range is 50 m and response time is 3~5 sec.
Video Presentation

ID: 90

Thermal analysis of impact damage of prepreg composite materials

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Abstract
Composite materials are employed in industry at a high rate, and the demand is increasing. Recently, prepreg carbon and aramid-carbon composite structures, when compared to carbon fiber reinforced polymer composites, have attracted increasing attention due to their better impact damage resistance. In order to characterize the material, impact test according to EN DIN 6038 was carried out including infrared acquisition of impact. Based on the cooled MW InSb detector IR camera, the spread of damage was observed during impact test.
Video Presentation

ID: 94

Estimation of remaining water in steel pipes using active thermography

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Abstract
The aim of this study is to develop a non-destructive inspection method to estimate the quantity of water remaining in steel pipes by using active thermography. The experimental results showed that variations in the surface temperature of the pipes were dependent on the quantity of the remaining water, which could therefore be estimated by observing the surface temperature. In this study, we propose an effective test setup and a data processing procedure to determine the quantity of remaining water, and present some estimation examples.

Video Presentation

ID: 133

Mixed carbon dioxide and water vapour detection by using LWIR 14-16 µm high-sensi… VOx microbolometer camera – modelling and experimental results

by P. Więcek*, R. Strakowski**, B. Więcek**
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Abstract
This paper describes a simple model and IR measurements showing the possibilities of detecting carbon dioxide in the humid atmosphere. The detection is performed in LWIR 14-16 µm wavelength range using low-cost high sensitive VOx microbolometer camera with the extended spectral characteristic in long wavelength band.

Video Presentation

ID: 139

Quantitative measurements of heat transfer coefficient of impinging round jets at high Reynolds number on a perpendicular and inclined heated plate

by Ph. Planquart*, M. Delsipee*, M. Dubois** and JM Buchlin*
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Abstract
Impinging jets are extensively used in the steel industry for high speed cooling of metal sheet. They can provide a high controlled heat transfer coefficient, which is mandatory for fast cooling applications, like the annealing of metal belts. Values of heat transfer coefficient can be found in the literature for standard conditions [1], but for very high Reynolds number (above 100.000), the data are rather sparse and the standard correlations are not valid anymore. Furthermore, in the literature, most of the results are published for impinging jets perpendicular to the substrate. The impinging jets can be round nozzles or slot nozzles depending on the application. In case of multiple jets, we can have either an Array of Round Nozzles (ARN) or an Array of Slot Nozzles (ASN).
The paper presents a quantitative infrared thermography investigation of the heat transfer obtained with an ARN configuration, consisting of 1 central jet surrounded by six additional as sketched and visualized in Figure 1. The arrangement has the following characteristics: Diameter of the nozzle: D=14 mm, Standoff distance: Z=50, 70 & 85 mm, Nozzle spacing: W=70 mm.

Video Presentation

ID: 153

Pulsed-Phase Thermography for Thin-Film Photovoltaic Inspection

by H. Hoppe*, R. Meitzner*, H. Kruschke**, J.B. Slowik* and U.S. Schubert*
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Abstract
Traditionally, lock-in thermography is used for thermal investigation of photovoltaic devices. While this method provides excellent signal-to-noise ratios, it requires measurement times on the order of minutes. Such a method is therefore not suited for inline inspection of a photovoltaic production. Considerably lower measurement integration times are achieved for pulsed-phase thermography. We decided to test this method and apply it for inline inspection. First results were obtained on resting samples, which where illuminated by a flash light.
Video Presentation

ID: 157

Temperature Calculation of a Steel Plate under Kerosene Flame Attack using Two-Colour Pyrometry

by Serge-Olivier Gnessougou*, Marc-Antoine Langevin**, Clemente Ibarra Castenado*, Alain deChamplain*** and Xavier Maldague*
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Abstract
The temporal change in temperature for the surface of a steel plate under kerosene flame exposure is measured without contact using the two-colour pyrometry technique. The pyrometric temperatures from room temperature to 600°C were obtained with a multispectral infrared camera equipped with a fast rotating wheel (50x8 to 365/8 frames/seconds) with two ''through flame filters'' at 3800 nm and 3950 nm. The calculated pyrometric temperatures were validated with the temperature data of three thermocouples incorporated at three different locations in the back of the steel plate (T1 in the center of the kerosene flame, T2 & T3 are at 5 & 13 cm from center).
Video Presentation

ID: 161

AC temperature estimation of power electronic devices using 1D thermal modeling and IR thermography measurements

by M. Kopeć, B. Więcek
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Abstract
This paper presents the novel method and program for reconstruction of the thermal impedance in the heat source based on the IR radiation measurement on the surface of an electronic device. In this approach, temperature is measured after applying power pulse to the element. The thermal modelling of an electronic device is used. Automatic synchronization of temperature measurement and power excitation is available in developed controller. The results from the program IRTherm are compare with the results obtained from the Finite Element Method in a commercial simulation software. Heat transfer is modelled using thermal-electrical analogy by Foster and Cauer networks consisting of thermal resistances Rth and capacitances Cth. The results are presented as the thermal impedance in the frequency domain (the Nyquist plot) and thermal time constant distribution.
Video Presentation

Microscale Applications

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Microscale Applications Forum

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ID: 51

Absorption coefficient of doped polycrystalline silicon films in infrared spectrum

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Abstract Absorption coefficient of materials depends on their extinction coefficient.Based on the equations derived from electromagnetic theory, utilized the value ofthe measured reflectance and transmittance of the multi-layer films, the extinctioncoefficient in infrared spectrum of the polycrystalline silicon films with differentdoped dosage is obtained by means of using the inverse calculation. Thus, theabsorption coefficient of the polycrystalline silicon films results. The analysisdemonstrates that the absorption coefficient increases with the doped dosagesincreasing for a given wavelength. This method used for determining absorptioncoefficient has the advantage of that the measured samples are fabricated simply.

Video Presentation

Modelling

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Modelling Forum

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ID: 40

Analysis of paint thickness based on flash pulse thermography

by L. Muzika* and M. Švantner*
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Abstract
Coating thickness (thermal barrier coatings, anticorrosion paints, etc.) can influence its properties and therefore the thickness is often measured in industrial application. This contribution describes fast areal thickness estimation based on flash pulse thermography. Specimens sprayed by a black paint on AISI 304 substrates were used for a demonstration of the thickness estimation. Two different types of post-processing and thickness estimation were used: functional calibration with FFT (phase) and analytical model. Both procedures were compared and both provided satisfactory results with maximum error of thickness estimation less than 10 %. Advantages and disadvantages of proposed techniques are discussed.
Video Presentation

ID: 75

Investigation on melt pool characterization in laser surface remelting using simulation approach and VIS-SWIR imaging

by P. Koruba*, P. Jurewicz* and J. Reiner*
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Abstract
The characterization of melt pool in laser surface remelting gives useable data for prediction of the process result as well as it may constitute a basis for the study of more advanced processes such as laser metal deposition. In this study the analysis of melt pool was performed using two approaches: development of simulation model and coaxial measurement within VIS-SWIR bands. Moreover the simulation model contains multispectral radiative heat transfer calculation, which results can be directly compared with images from the cameras. As a result an evaluation of utilized spectral bands in case of laser material processing monitoring is proposed.
Video Presentation

ID: 162

Novel data analysis approach for Raman Scattering-based Distributed Temperature Sensing (DTS) systems

by I. S. M. Shatarah*, B. Więcek*
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Abstract
Distributed Temperature Sensing (DTS) systems based on optical fibers are well known for their ability to provide crucial information relative to temperature changes along the optical fiber, with a respectful temperature and spatial resolutions. Commercial DTS systems are commonly based on the Optical Time Domain Reflectometry (OTDR) and the Optical Frequency Domain Reflectometry (OFDR). This paper presents a novel analyzing method for DTS systems, based on the analysis of the backscattered light in the transition state along the optical fiber.

Video Presentation

NDE - Thermal Non-Destructive Evaluation

~~Link to NDE Forum (ZOOM)~~

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NDE Forum

This is the spot for open discussion of the abstract / videos on **NDE** (28 articles)

ID: 7

Detection of internal defects in CFRP composites by Eddy Current Thermography

by W. Swiderski*, P. Hlosta*
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Abstract
The paper presents selected results of defect detection in a multilayer CFRP composite structure. The tests were carried out on a sample consisting of three plates made of CFRP connected with resin, in which the inner middle layer is made of four non-adherent elements. The method of Eddy Current Thermography (ECT) was used in the experimental testing. The results of these tests were then compared with the results obtained from numerical calculations..

Video Presentation

ID: 17

Infrared thermospectroscopic 2D and 3D imaging of confined drying process

by M. Lehtihet *, J. Leng * and C. Pradère**
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Abstract
In this work is presented an InfraRed (IR) imaging technique allowing one to retrieve quantitative concentration and temperature maps with relatively fast acquisition times [1]. Dynamic samples can be imaged with micrometric spatial resolution and a complete study of coupled heat and mass transfer phenomena can be realized on the basis of these images. A proof-of-concept of this technique is realized on a model transient problem : the drying of a µL drop of colloidal dispersion in confined geometry [2]. Quantitative maps of concentration and temperature everywhere in the drop inside the cell of the thermospectrometer are retrieved. Transport phenomena like colloids re-distribution inside the droplet due to inhomoegeneous drying can be highlighted by this mean. A numerical inverse method based on the acquired images is also established, allowing one to estimate intrinsic properties of the studied material as the diffusivity coefficient [3]. Also, thermal images of the same drying process are presented and temperature gradients establishing themselves due to the vaporization enthalpy are measured and validated using a thermal model of the confined drop. Finally, to extend the setup sensitivity to the thickness of the sample, an IR tomography technique inspired of confocal

microscopy is applied on the ending result of a confined dying of silica dispersion : a millimetric silica gel. By this method, tomographs of both spectroscopic and thermal signals are realized on the studied sample, providing fruitful informations from within the silica gel. These 2D and 3D imaging techniques could find many applications as new tools for nondestructive control problematics, ranging from material design to living tissue inspection.
☎ Video Presentation

ID: 20

A robust multi-scale gapped smoothing algorithm for baseline-free damage mapping from raw thermal images in flash thermography

by Gaétan Poelman*, Saeid Hedayatrasa*,**, Joost Segers*, Wim Van Paepegem* and Mathias Kersemans*
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Abstract
Flash thermography is a promising non-destructive testing technique for the inspection of composite components. However, non-uniform heating, measurement noise and lateral heat diffusion complicate the interpretation of thermographic measurements. In order to overcome these difficulties, a novel baseline-free processing technique called 'Multi-Scale Gapped Smoothing Algorithm' is presented. This algorithm constructs a damage map directly from the measured data, in which an (almost) zero-reference background is obtained, and where measurement noise and excitation non-uniformity are effectively suppressed. The efficiency of the proposed technique is evaluated and confirmed through synthetic data and experimental results of a carbon fiber reinforced polymer with various artificial defects.

☎ Video Presentation

ID: 27

Scanning thermal testing of subsurface defects in metal – coating structures

by A. Chulkov*, B. Oswald-Tranta**, C.Tuschl**, V. Vavilov*
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Abstract
In this study, two line-scanning thermal non-destructive testing procedures using optical and inductive heating are compared in the inspection of metal-non-metal structures. It is demonstrated that, in the case of inductive stimulation, one-sided test procedure converts into two-sided by heating the metal through non-metal. With such technique, deep interlayer delaminations can be detected more efficiently than by using surface optical heating.
☎ Video Presentation

ID: 28

Application of Active Thermography for mode II delamination detection in CFRP: comparison between modalities of the technique and a numerical modelling study of defect parameters' influence

by M. Grosso*, H. G. Kotik** and G. R. Pereira**
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Abstract
In this study, three modalities of Thermography (Pulsed, Pulsed Phase and Lockin) were used to detect delamination defects in CFRP samples from the 4ENF test. The results obtained for each modality were compared in relation to the real delamination area in these samples. In addition to the experimental analysis, a computational simulation model was also created to evaluate the influence of defect parameters (depth and thickness) on its thermal contrast and thus estimate the detection limit presented by the Pulsed modality.

☎ Video Presentation

ID: 32

Detecting and sizing the width of vertical cracks on moving samples using laser spot thermography

by J. González*,**, A. Mendioroz* and A. Salazar*
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Abstract
We propose a method, based on laser spot thermography, to detect and size the width of vertical cracks on samples moving at constant speed by fitting the temperature profile along the line that contains the centre of the laser spot and is perpendicular to the crack to its analytical expression. This method is useful for in-line inspection in factories, for detecting and characterizing cracks in real time, without stopping the production chain. Experimental measurements on samples containing calibrated vertical cracks confirm the validity of the method to measure the crack width with high accuracy.

Video Presentation

ID: 35

Sizing the width and depth of real cracks using laser spot lock-in thermography

by M. Colom*, J. Rodríguez-Aseguinolaza*, A. Mendioroz* and A. Salazar*
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Abstract
We have calculated the surface temperature of a sample containing a surface breaking crack, when a modulated laser spot is focused close to it. This temperature has been obtained numerically using discontinuous finite elements, which are well adapted to deal with narrow cracks. We have used this model to analyse a metallic sample containing a fatigue crack, which remains invisible by optics means. In this way, we have obtained simultaneously the depth and width of the crack.

Video Presentation

ID: 36

Passive thermography for delamination detection in GFRP of Wind Turbine Blade

by Lucas REOCREUX[a,b], Zhewei YU[b], Sébastien ARNOULD[b], and Hervé PRON[a]
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Abstract
Wind turbine blade (WTB) is a complex composite structure, which is normally composed of coating (gelcoat), glass fibre reinforced polymer (GFRP), and natural fibres like balsa [1]. During its manufacturing and its service, many types of defects can appear, either surficial or internal, such as cracks, voids, wrinkles, corrosion, delamination, etc. These defects not only can affect the energetic efficiency of the wind turbine, but also can create significant damage and reduce its lifetime. Hence, an appropriate regular inspection is often required. Common inspections in the industry are achieved either by rope access or by telescope from the ground. While such visual inspections cannot detect the internal defect within the WTB, non-destructive testing (NDT) is often applied, such as ultrasonic testing [2] or thermography [3], [4].
In this work, the passive thermography method is tested to determine the delamination in the main laminate area of the WTB. Such an inspection can be achieved by using natural heating sources like sunshine. A thermal contrast is created between a defect area and a normal area while exposing to the sun, which becomes detectable in thermograms taken by infrared cameras. In laboratory, the delamination was approached by the flat bottom holes (FBHs) and by the insert of Bubble Wrap (BW) inside the GPRP. Both numerical modelling and experimental test were carried out in order to evaluate this method.
The experimental test was carried out using a cut piece of a blade with 2 BW inserts with 20 mm in diameter 7, 10 mm in depth as well as 4 flat bottom holes (FBHs) with 20 mm in diameter and 3, 5, 8, 10 mm in depth. An impact damage is also presented in the front surface of the sample. At the beginning of the test, this sample was moved from inside (room temperature at 25 °C) to outside under the sun irradiation. The thermograms were taken routinely every 4 minutes from 0 to 32 minutes. The result (Fig. 1) shows that the less deep defects, the 3 mm FBH and the 7 mm BW insert can be observed easily at early time, which is about 5 minutes. The deeper ones, on the other hand, can be only observed afterwards. However, the maximal thermal contrasts for these defects are generally achieved around 15 minutes, despite the nature, the size or the depth of the delamination defect.
The numerical model is built in order to calculate heat transfer within a coating + GFRP composite structure with different delamination depth for both FBHs and BW inserts. A constant heating source of 300 W [5] is added to simulate the sunshine, and a convection (h = 15 W m-2 K-1) is used to simulate the wind blow. The results for FBHs and BW inserts are

presented in Fig. 2 and Fig. 3, respectively. From these figures, it can be seen that the thermal contrast is created once the sun starts heating the sample. The maximum temperature differences as well as the time to reach these differences are presented in Table 1. The maximum temperature difference is reached by some time, and this time is correlated with the defect type and the depth. After these times, the thermal contrasts decrease and become less detectable. It can be concluded that the deeper the defect is, the longer time is required to wait for this maximal temperature difference to appear. Generally, these times are between 5 to 15 minutes, which correspond well the experimental results. These results are also comparable to those reported by Worzewski et al. [6].
Both numerical and experimental results show that the passive thermography inspection for delamination detection can be very useful to detect delamination defect within GFRP. However, this method can be very time dependant, which is also reported in the literature [4], [6].

Video Presentation

ID: 42

Quantitative inspection of thickness of thermally sprayed coatings by flash pulse thermographic method

by M. Švantner[1], L. Muzika[1] and A. Moskovchenko[1,2], Šárka Houdková[1], Petra Frková[3]
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Abstract
Flash-pulse thermography is a method for a detection of discontinuities or inhomogeneities in materials at their surface. It is based on an excitation of an inspected sample by a short pulse and analysis of its thermal response. An application of flash-pulse thermography for a quantitative inspection of thickness differences of thermally sprayed coatings is introduced in this contribution. Requirements for a synchronization of thermal response recording and data smoothing precision are described. Signal derivative, pulse-phase and time power-transformation (P-function) methods for an evaluation of the thermographic records are presented. Procedure and results of the inspection are demonstrated on HVOF, TWAS and flame sprayed coatings. A comparison of the method showed that the P-function method is the most suitable for a quantification of coating thickness differences. Some characteristic of the method are demonstrated by numerical computation.
Video Presentation

ID: 55

Analysis of Ballistic Impacts on Composite materials by Infrared Active Thermography

by Stephane Boubanga Tombet and Eric Guyot
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Abstract
This work focused on the assessment of the damaged area on composites ballistic plates subjected to high velocity impact. Active pulsed thermography technique was used for performing post-mortem analysis of the impacted specimens. The post-mortem analysis was combined with inputs of the velocity of the projectile, the absorbed energy to evaluate how efficient the material is at spreading the absorbed energy to a large area.

Video Presentation

ID: 68

Discontinuous finite element numerical modelling for infrared thermographic crack characterization

by J. Rodríguez-Aseguinolaza*, J. González*,**, R. Celorrio***, A. Mendioroz* and A. Salazar*
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Abstract
A new numerical model based on discontinuous Galerkin Finite Element Methods for laser spot lock-in thermopgraphy has been developed able to characterize very narrow cracks in materials, difficult to quantify by alternative numerical methods. It has also been validated by means of experimental results from a wide variety of cracks in terms of size, width, depth and crack orientation angle. Overall, the obtained results indicate a very good agreement with experiments

maintaining a satisfactory accuracy and improved computational economy.

Video Presentation

ID: 80

Estimation of thermal resistance field in multilayer materials by autoregressive asymp > method calibrated with analytical quadrupole method

by M. Bensalem*, A. Sommier**, E. Abisset**, S. Chevalier**, J.L. Battaglia**, J.C. Batsale** and C. Pradere**
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Abstract
This paper addresses the problem of the quantitative estimation of thermal resistance fields in multilayer material by using a flash excitation and an IR camera for the temperature relative change measurement. The main difficulty that arises with multilayer materials affected by thermal resistances as delamination, crack or rugosity is related to the inverse processing method. Indeed, it is shown that the method has to be based on an iterative algorithm in order to quantitatively retrieve the thermal resistance. Moreover techniques based on Thermal Signal Reconstruction [1, 2] which presents the advantage to easily use the measured field are not especially quantitative and generally only address the detection of such defects in a qualitative way. Some authors [3, 4] have proposed original approaches to retrieve quantitative analysis. In the present study, the main idea is to link a simple method based on an asymptotic development of the thermal contrast with an exact modelling of the heat transfer within the multilayer material. The asymptotic method consists in a first order differential equation between a reference temperature, taken directly in a healthy area of the sample or resulting from the exact analytical solution of the multilayer sample, and a temperature that is assumed to be at a location affected by a thermal resistance problem, as showed by eq (1). The asymptotic development reveals two parameters: the amplitude A and a delay that could be linked to the thermal resistance value and related defect thickness thanks to the analytical model.

Video Presentation

ID: 89

InfraRed NDT for cured prepreg carbon specimens

by P. Bagavac*, L. Krstulović-Opara* and Ž. Domazet*
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Abstract
Prepreg laminated composite plates with Teflon inserts and sandwich panel with damaged Coremat were subjected to InfraRed Non-Destructive Testing. Every sample was recorded by means of reflected thermography and raw data were processed by various algorithms: Thermal Signal Reconstruction, Fast Fourier Transformation and Principal Component Analysis.
Video Presentation

ID: 93

Investigation of wave generation and propagation during ultrasound-excited thermography testing and its effects on defect detection

by S. Kishimoto*, M. Ishikawa*, H. Nishino*, R. Fukui**, Y. Habuka** and Y. Nishitani**
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Abstract
In this study, wave propagation during the ultrasound-excited thermography is examined mainly from the viewpoint of the elastic wave propagation study. When ultrasonic waves are input in a test object, various kinds of waves are excited, and standing waves are often generated depending on the wavelength of the input ultrasound and the shape of the tested object. We investigated the generation process of the standing waves and its influence on defects detection through experiments and numerical calculations.

Pdf Presentation

ID: 95

Consideration of input thermal wave frequency for minimizing inspection time of active thermography

by M. Ishikawa*, S. Ishihara*, H. Nishino*, M. Koyama**, H. Kasano***, H. Hatta****, and S. Utsunomiya****
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Abstract
To shorten the inspection time of active thermographic non-destructive testing is desired to enhance its inspection efficiency. The required inspection time should strongly depend on the frequency of the input thermal wave, as it influences the heat propagation speed. In this study, the relationship between the frequency component of the input thermal wave and the inspection time is discussed through fundamental experiments and numerical calculations. The results showed that the input frequency component was varied by changing heating method, and the inspection time was shortened when using thermal wave with higher frequency components that have higher heat propagation speed.

Video Presentation

ID: 104

Optimized simultaneous Multi-Frequency Lock-in Thermography

by M. Ricci*, S. Laureti*, M.K. Rizwan** and P. Burrascano**
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Abstract
An optimised simultaneous multi-frequency approach is here introduced for the first time as a completely novel active thermography scheme. A low peak-factor multi-frequency signal is designed and employed here for modulating the heat emission, being here a 400 W LED chips system in the visible spectral range. The analysis of the acquired thermograms in the frequency domain shows frequency-selective sensitivity at different depths within a carbon fiber reinforced composite sample containing delamination, meaning that multi-frequency lock-in can be performed at a set of desired frequencies with only a single measurement.
Video Presentation

ID: 105

Complementary Barker Code excitation for Pulse-compression Thermography

by S. Laureti*, M. Ricci*, P. Burrascano**, D.A. Hutchins***, G.Y. Tian**** and B. Gao*****
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Abstract
In Pulse-compression thermography, the impulse response of the sample under test is retrieved by exciting the specimen via a modulated-heating stimulus, and then by pixelwise-convolving the collected thermograms via a matched filter. This paper introduces the application of a Barker Code modulating signal to Pulse-compression Thermography in a way that was not explored so far. In particular, the Barker code' features are here fully exploited by actively considering both its negative and positive bits, leading to the retrieval of two distinct thermal contributions. Those are then algebraically summed up and then convolved, leading to a faithful reconstruction of the impulse response. This novel procedure has been demonstrated on an additive manufactured PMMA sample containing artificial defects, heated-up by a single low power 50 W LED chip in the visible spectral range.
Video Presentation

ID: 113

Thermography-based approaches for multi-scale damage assessment in woven composite materials

by JM. Roche*, L. Muller, G. Celeste, A. Mavel, F. Passilly and F.-H. Leroy

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Abstract
The complexity of the non-destructive evaluation of the damage of woven composite materials, induced by mechanical loading, is mainly linked to its diversity, from microscale matrix cracking and local fibre/matrix debonding to mesoscale and macroscale intra-yarn cracking and delamination. The present paper aims at assessing the sensitivity of infrared thermography to such damage. Several experimental techniques are tested: once the limits of conventional active and passive thermography are identified, the relevance of lock-in thermography is highlighted. Optical microscopic observations as well as acoustic measurements are used to strengthen the conclusions of the thermal study.
☏ Video Presentation

ID: 115

Fatigue and damage behaviour of CFRP elements in presence of wrinkles
by F. Panella*, A. Pirinu* and A. Saponaro*
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Abstract
In this work, defect type "wrinkle" was characterized in CFRP notched specimens, performing fatigue and static experimental tests, coupled with non-destructive thermographic, optical and ultrasonic controls. This study includes an analysis of the damage to rupture behaviour of the material through the mechanical tensile test and a non-destructive inspection procedure is adopted during HCF load, in order to detect in real time local compliance variations and damage initiation. Thermographic continuous monitoring and occasional ultrasonic analysis are implemented with the purpose to analyse composite anomalies during fatigue life and elaborate a method for the identification of the wrinkle induced failure.
☏ Video Presentation

ID: 118

Using bispectral (IR-Visible) Unmanned Aerial Vehicle (UAV) for detailed aerospace structures inspections
by L. Gavérina*, C. Trottier*, F. Passilly and J.-M. Roche*
* ONERA, Materials and Structures Department, Châtillon, 92320, France, ludovic.gaverina@onera.fr

Abstract
In this paper, a Non Destructive Testing approach by active infrared thermography mounted on the Unmanned Aerial Vehicle (UAV) is used to investigate damage due to lightning-strike in composite specimen. In this study, an experimental bench is developed using pulsed thermography in reflection mode and compare to static flash method in order to detect delamination of this material.
☏ Video Presentation

ID: 119

A comparison among different way to perform the lock-in multi-frequency test in a CFRP composite sample
by E.D'Accardi*, D.Palumbo* and U.Galietti*
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Abstract
Active thermography for non-destructive testing enables a contactless, fast, remote and not expensive control of materials and structures. Different works have confirmed the potentials of lock-in thermography as a flexible technique for its peculiarity to be performed by means of a low-cost set-up. In this work, a thermographic basic equipment with halogen lamps and a microbolometer IR camera was used for evaluating the effect different excitation modes. A CFRP sample with imposed defects has been used with the aim to give some quantitative indications about defects detection. In this regard, the capability of the technique was evaluated by adopting different heating configurations and modulated frequencies.
☏ Video Presentation

ID: 124

Performance assessment of clustering algorithms for the thermal testing of industrial components
by G. Ferrarini *, P. Bison **, A. Bortolin ***, G. Cadelano ****, L. Finesso *****
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Abstract
Infrared thermography is a widely applied technique for the thermal testing of industrial components. The thermal data obtained with an infrared test are processed with different algorithms to improve the detection of defects. This work investigates the performance of the clustering algorithms to define the defective and non-d[illegible]tive regions of a steel specimen, with flat bottom-hole defects, inspected with a flash thermography setup. A clus[illegible] algorithm with different parameters is used to analyze the thermal data coming from the experiment, assessing the performance of the algorithm in terms of defect detection.

Video Presentation

ID: 141

Influence of defect shape in quantitative thermography

by A. Stoynova* and B. Bonev**
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** Technical University of Sofia, 8, Kliment Ohridski Blvd., Sofia, Bulgaria, bonev@ecad.tu-sofia.bg

Abstract
This article examines the impact of the form of hidden defects on their detection and evaluation using flash and lock-in thermography. The influence of the defect shape on information characteristics of quantitative thermography has been studied through digital thermal modeling and simulation. The following information characteristics are analyzed and compared - amplitude and phase contrast, temperature difference between defect and non-defect area, the moment of reaching maximum thermal contrast for different modes of optically active thermography. The results from the model study were experimentally verified using specially designed test specimens with artificial defects. The results obtained were evaluated, compared and analyzed.
Video Presentation

ID: 148

Comparison of infrared thermography modelling approaches for detection of defect areas in electronic structures

by A. Stoynova and B. Bonev
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Abstract
The article presents an approach to obtain solutions by channelling the electro-thermal (ET) analogy and using an electrical circuit simulator to model active infrared thermography in non-destructive testing of electronic structures. The analogy can be used to determinate an optimal thermographic procedure parameters to effectively detect hidden defects and malfunctions in electronic devices and structures. To evaluate the effectiveness of the approach, the results of the FEM, FDM, and ET modelling of different regimes of active thermography for non-destructive testing of electronic structures have been compared and verified by experimental measurements.
Video Presentation

ID: 149

Latent Low Rank Representation Applied to Thermography

J. Fleuret[1;2], C. Ibarra-Castanedo[1;2], S. Ebrahimi[1;2], X. Maldague[1;2]

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Abstract
This paper introduce a evaluate the Latent Low-Rank Representation (LatLRR) on pulsed thermographic data. The LatLRR decompose an image on a linear association of three kind of informations, observed, unobserved and noise. These information are then used in order to separate the salient and principal features. This study has found that when use as a post processing tool or when a state of the art method is apply on any features the LatLRR failed to provide any valuable results. Nevertheless the results when applied on the best image of a state of the art method allow a significant improvement regarding the detection of the defects.
Video Presentation

ID: 150

Pulsed Thermography Signal Reconstruction Using Linear Support Vector Regression

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Abstract
This study introduces and evaluates a new approach for the reconstruction of image sequences acquired during non destructive testing by pulsed thermography. The proposed method consists in applying two linear support vector regressions, to model the evolution of the data from both a spatial and temporal point of view. Each regressor will map the data with respectively the number of pixels and the number of frames using a convex optimization. Then the regressors are used to predict a more robust representation of the data which is thus used to reconstruct the sequence. The proposed method has been applied to data related to a reference sample of carbon reinforced fiber with known defects. This approach has given good results in terms of noise reduction as well as the quality of the reconstructed image than most of the state of the art methods. The proposed method was able to outperform many of the state of the art algorithms and give comparable results otherwise despite being sensitive to non-uniform heating.

Video Presentation

ID: 151

Application of Blind Image Quality Assessment Metrics To Pulsed Thermography

J. Fleuret[1;2], S. Ebrahimi[1;2], C. Ibarra-Castanedo[1;2], X. Maldague[1;2]

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[2]Laboratory of Computer Vision and Numerical Systems, Multipolar Infrared Vision team, Quebec City, Quebec, Canada

Abstract
This paper introduces an application of Blind Image Quality Assessment (BIQA) metrics to pulsed thermography. This study investigates the application of BIQA in association with state of the art methods in order to improve the detection of defects in PT sequences. The experiments show that BIQA may significantly improve the detection of defects when applied to steel, but fails to capture informative features on CFRP.

Video Presentation

ID: 156

Thermoelastic stress profiles for different frequencies

by António Ramos Silva[a, b, c], Mário Vaz[a, c], P. Moreira [c], Sofia Ribeirinho Leite [b, d] and Joaquim Mendes [a, c, e]
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Introduction
Nowadays, structural components where weight is a critical requirement, like in aeronautics, are usually designed based on a damage tolerance principle. This leads to a near 90% of the failures by crack and fatigues. [1]. The early detection of cracks is of the utmost importance, both for the structure and users. One of the best solutions is to use non-destructive image testing techniques to locate cracks prematurely, preventing serious damages [2]. The usage of Thermal testing to access the stress in a component is a well-established technique. Here, a sinusoidal load is applied and the thermal amplitude is calculated, which is then correlated with the mechanical stress. Using the model developed by D. S. Mountain and J. M. B. Webber (1979) and their thermoelastic stress analyses (TSA) system, the SPATE [3]. According to the literature, a load should be applied with a frequency between 5 and 200 Hz [4].
The main goal of this work was to access the influence of the stimulation frequency in the thermal patterns during a thermal stress test/analysis (TSA). A detailed emphasis is given to the crack tip. The tests and consequent analyses were performed for several frequencies in order to assess its influence in the thermal patterns.

Video Presentation

Novel Technique

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Novel Technique Forum

This is the spot for open discussion of the abstract / videos on **Novel Technique** (1 article)

ID: 54

Research on the detection of delamination defect of CFRP using thermal-wave radar tomography (TWRT)

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Abstract
Carbon fiber reinforced polymer (CFRP) has been widely used in modern industry due to its excellent properties. However, due to its strong anisotropy, it is easy to produce delamination defect which seriously affect the performance of the material. Therefore, for CFRP composites, how to effectively and accurately detect and identify internal defect have become a hot and difficult research field. In this paper, a new tomography method called thermal-wave radar tomography (TWRT) is introduced, and it is applied to the visualization detection of CFRP delamination defect. Firstly, the time delay correlation dual orthogonal demodulation (DOD) algorithm is used to extract the frequency domain and time domain characteristic sequence of the thermal-wave signal of the pulse radar, and the TWRT method is established, the applicability of the method is analyzed by the COMSOL simulation. Then, the correctness of the simulation analysis is verified by the experiment of detecting the flat bottom holes which used to replace the delamination defect of CFRP composites by TWRT, and the accuracy of the shape and position (depth) of the defect detected by TWRT is determined. Finally, the ultrasonic C-scan imaging method and TWRT are used to compare and analyze the delamination defect of CFRP composites, which proved the superiority of TWRT. The experimental results illustrate that TWRT technique can achieve high-quality 3D geometric reconstruction of delamination defect, which provides a new method and idea for nondestructive testing and tomography of CFRP composites.

Video Presentation

Thermomechanics

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Thermomechanics Forum

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ID: 91

Spatial heterodyne flying spot technique for in-situ thermal characterisation of metallic sample under tensile test

by A. Sommier*, O. Plekhov**, T. Palin-Luc*, E. Abisset*, J.C. Batsale* and C. Pradere*
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Abstract
This paper addresses the problem of the quantitative orthotropic estimation of thermal diffusivities fields of metallic

sample under tensile stress. This investigation gives us a promising possibility for estimation of an effect of irreversibledeformation on thermal conductivity of metal and, consequently, experimentally determine the additional part in the thermodynamic potential of the material caused by structure evolution. The main difficulty of such measurement is the very high thermal conductivity of such metallic sample. To develop an appropriate technique we used samples made from (i), Titane (a = 9.4.10-6 m2.s-1), Nickel (a = 2.3.10-5 m2.s-1),) and Iron (a = 2.3.10-5 m2.s-1). For the most conductive sample figure 1.a, the characteristic diffusion time can reaches around 0.1 s for 1 mm of diff[illegible]n length. Then, to be able to monitor the thermogram the minimum frequency rate of acquisition should be between [illegible]0 kHz. To realize such performance with InfraRed Thermography in full frame mode, the only solution comes from heterodyne or cardbox methods [1]. If usually the high frequency modulation is realized in time domain, we propose here to realize same frequency range by using spatial flying spot modulation as illustrated figure 1.b. With this new experimental technique, thermogram of such metallic sample can be acquired with a good temporal resolution lower than 10 µs time step. Finally, from the acquired thermogram, the Logarithmic Parabolas Method [2] is applied in order to measure the orthotropic along x, y and z directions thermal diffusivities fields for the several samples where different stress stage was applied. One result is to link the thermal properties change as function of the stress applied to the sample as well as the anisotropy behaviour.

Video Presentation

ID: 97

Study of the plasticity effect at the crack tip in Titanium by using thermal signal analysis

by F. Di Carolo*, R. De Finisi* D.Palumbo* J. M. Vasco-Olmo** ,F. A. Díaz**, U. Galietti*
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Abstract
The fatigue crack growth is strictly related to the dissipated energy at the notch/crack tip. Among the different approaches developed, those focusing their attention on energy dissipated in the plastic area seems to be more promising in the evaluation of the crack growth behaviour and it can be used to describe the plastic work at the crack tip. In this work, an experimental approach was adopted in order to obtain thermographic parameters capable of describing the plastic work at the crack tip. In particular, the influence of tests parameters such as the loading frequency, has been investigated.

Video Presentation

ID: 131

Dissipated energy based fatigue crack propagation law for complex loading conditions

by O. Plekhov, A. Izumova, A. Vedernikova and A. Vshivkov
Institute of Continuous Media Mechanics, Russian Academy of Sciences, Ak. Koroleva str 1, 614013 Perm, Russia, poa@icmm.ru

Abstract
The experimental study of heat flux evolution at the fatigue crack tip during uniaxial and biaxial loading was carry out in this work. The plane samples of stainless steel AISI 304 and titanium alloy Grade 2 with were weakened by notch to initiate fatigue crack. During tests, the samples were subjected to cyclic loading with constant stress amplitude and different biaxial coefficient. Infrared thermography, lock-in thermography and the contact heat flux sensor based on the Seebeck effect are used to monitor the dissipated thermal energy. A linear correlation between the crack rate and dissipated energy was obtained by these techniques.

Video Presentation

TSR Method

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TSR Method Forum

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ID: 117

Detection of manufacturing defects in ceramic matrix composite (CMCs) by using the active thermography
by L. Gavérina*, A. Debarre*, F. Passilly* and J.-M. Roche*
* ONERA, Materials and Structures Department, Châtillon, 92320, France, ludovic.gaverina@ ﻉ.fr

Abstract
Defects such as inhomogeneities or cracks are often present after elaboration of composites materials. In this paper, a Non Destructive Testing approach based on active infrared thermography is used to investigate porosity of oxide/oxide CMC specimens. In this study, pulsed thermography in reflection or transmission modes is used in order to correlate microstructural defects and mechanical properties.
☏ Video Presentation

Works of Art

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Works of Art Forum

This is the spot for open discussion of the abstract / videos on **Works of Art** (5 articles)

ID: 9

Active Thermography for non-invasive panel paintings inspection: Absolute Thermal Contrast analysis of an artwork
by M. Rippa*, V. Pagliarulo*, A. Lanzillo**, G. Fatigati**, M. Grilli**, P. Ferraro* and P. Mormile*
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Abstract
Active thermography is a well-known non-invasive imaging technique that represents a reliable means for providing a fast and low-cost analysis of an artwork. In this study, experimental data from a panel painting, representing an original artwork dating from the 16th and 17th centuries, was acquired in situ by pulsed thermography and processed by absolute thermal contrast analysis. Our results confirm as active thermography is a powerful technique to achieve valuable pre-restoration information concerning the detection and characterization of various types of defects present on the painting layer and a suitable tool for in situ analysis of artworks.
☏ Video Presentation

ID: 61

Multi-instrumental characterization of porous media: the role of the Spilling Drop Test
by J. Melada*, P. Arosio*, M. Gargano*, and N. Ludwig*
* Dipartimento di Fisica "Aldo Pontremoli", Università degli Studi di Milano, Via Celoria 16, 20133 Milano, Italy

Abstract
Spilling Drop Test (SDT) is a non-destructive method able to characterize water absorption and diffusion on the surface of building materials through the visualization by passive thermography of the spread of a water drop. This method was used in this research to study the surface characteristics as roughness and open porosity of geo-materials considering different methods of statistical treatment of the wet spreading area. The information acquired by SDT was compared with two standardized methods: the saturation test and the capillary absorption test. In order to test the proposed methods a set of ancient roman plaster and modern mocks-up where analysed.
☏ Video Presentation

ID: 70

Pulsed Thermography applied to multi-material and multi-layer pomological models

by E. Grifoni*, J. Melada*, L. Bonizzoni*, M. Gargano*, I. Mignani**, N. G. Ludwig* * Physics Department Aldo Pontremoli, University of Milan (UNIMI), via Celoria 16, Milan. ** Faculty of Agricultural and Food Sciences, University of Milan (UNIMI), via Celoria 2, Milan.

Abstract

Pulsed Thermography (PT) proves to be particularly suitable for the analysis of artworks realized with particularly heat-sensitive materials. The analytical integration of PT and other Imaging techniques (High Resolution Technical Photography and High Resolution Digital X-Radiography) provide information from the superficial, sub-superficial and innermost layers of the object, respectively, capturing both accurate spectral, spatial and density data. The paper presents a case study in which PT proves to be a highly predictive technique able to prevent or limit the loss of pictorial film in multi-material and multi-layer artifacts such as pomological models.

Video Presentation

ID: 72

Monitoring the Scrovegni Chapel Crypt by IR thermography

by Paolo Bison[1], Alessandro Bortolin[2], Gianluca Cadelano[2], Giovanni Ferrarini[1], Fabio Peron[3], Piercarlo Romagnoni[3] and Antonio Stevan[4]

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Abstract

The Scrovegni Chapel in Padova (Italy) is worldwide renowned for the fresco cycle due to Giotto. The outstanding value of this work of art requires a continuous monitoring of its state of conservation. Starting from 1995 a Scientifictechnical Board coordinates the many initiatives and, among them, several measurement campaigns by IR thermography had been carried out. More recently, the hypogeal environments under the Chapel has been considered due to the presence of water which frequently submerges the floor and part of the vertical structures of the crypt. The present work reports on the activities and the results of those surveys.

Video Presentation

ID: 107

Contribution to the improvement of the detection of defects located in heritage by stimulated infrared thermography associated with a spatial reassignment of the color dynamics of thermograms

by K. Mouhoubi**, K. Dieng*, C. Fomena*, H. Feddini*, A. Salami*, J.M. Vallet***, J.L. Bodnar*

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Abstract

In the context of the conservation of works of art from the cultural heritage, stimulated infrared thermography allows the non-destructive detection of the presence of defects invisible to the naked eye. However, images obtained with a thermal camera are sometimes difficult to interpret directly. Indeed, optical parasitic effects due to absorptivity variations in surface or excitation inhomogeneities can lead to detection artifacts. To reduce these effects, it's possible to use postprocessing algorithms. The work we present here follows this framework. We show first theoretically, then experimentally, that a spatial re-allocation of the colorimetric dynamics of the obtained image makes it possible to significantly reduce these parasitic radiative effects. The theoretical study is based on a simulation, using finite element methods, the experimental part was developed on a plaster block containing 32 defects and a multicoloured paint layer.

Video Presentation