INVESTIGATION ON IMPERFECTION ON NATURAL FIBER REINFORCED POLYMER COMPOSITES USING INFRA RED THERMOGRAPHY

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Abstract—*In modern engineering fields, composite materials are rapidly replacing the existing materials. During the fabrication of composites, imperfections appear on the composites due to various parameters such as temperature, pressure and moisture. Imperfections are occurred during the recurring, were observed on the composites such as porosities and resin shrinkage. The presence of voids or cracks or inclusion in the composites can cause a sudden failure. There are several methods to characterize these defects. The main aim of the present study is to investigate the imperfection on natural fiber reinforced polymer composites by using InfraRed Thermography. This method is suitable to identify the random voids and its morphology and also the cracks in the natural fiber reinforced polymer composites nondestructively.*

Keywords—Natural fiber reinforced polymer composites, Infra Red Thermography

1. INTRODUCTION

Over the last decades the use of composite materials has steadily increased. Typical application areas are aerospace, vehicle industry and infrastructure. The main advantage of composites is the high strength and low density. However, a potential disadvantage is damage evolution such as matrix cracking, delaminations, fiber breakage and debonding, that appear before final structure. Therefore structure surveillance systems and methods, which are capable to indicate time of maintenance to reduce the life-cycle cost and to ensure a safe operation, are of interest for many applications. For this purpose nondestructive testing method is been used in both research and for industrial applications. The main objective for such a system is to indicate the occurrence of microcracking events, but also the possibility to identify the type of damage is of importance for an optimal use of a component.

Non Destructive Testing method has proved to be able to characterize damage accumulation, but in general, it does not give information about the position of the failure events on the specimen. A testing technology increasingly used in material testing is thermography. This technology offers various techniques for nondestructive characterization. A passive thermographic method exists where the damage is characterized by the temperature increase during fatigue testing due to hysteretic heating. A qualitative characterization technique has been published by Kurashiki for the investigation of the imperfections of natural fibre reinforce polymers. Active thermographic methods such as pulse thermography, lock-in thermography or ultrasound thermography are widely investigated for the detection of delamination in composite structures (see Maldague for further references). No work could be found in literature, where these techniques are used for the characterization of damage evolution during fatigue testing. The aim of this study is the assessment and development of thermographic techniques for the investigation of defects.

A. Basics of Infrared (IR) Thermography

Infrared (IR) thermography is a two-dimensional, non contact technique of temperature measurement. Basically, the infrared scanning radiometer (IRSR) detects the electromagnetic energy radiated in one infrared spectral band by an object (whose surface temperature is to be measured and which should be fully opaque to the detected band) and converts it into an electronic video signal.Since its introduction in the early 1960s, infrared thermography was regarded as an exciting scientific breakthrough. The produced two-dimensional images, which qualitatively allowed for seeing the invisible, were considered astonishing. Indeed, a fully computerized infrared imaging system of the new generation can provide both qualitative and quantitative measurements which are of utmost Importance in a vast variety of industrial as well as research fields.

Infrared scanners are often classed as total-radiation radiometers and thought to be based on the Stefan Boltzmann law even if their detectors sense radiation in a limited band width of the IR spectrum.The infrared detector, which is the core of the IR thermographic system, is a transducer that absorbs the IR energy emitted by the object (being measured) and convertsit to a signal, usually an electrical voltage or current.The overall performance of an IR imaging system is conventionally evaluated in terms of the amount of useful and accurate information that can be acquired per unit of time.The image resolution is the capability of a thermal imaging system to detect and accurately measure the surface temperature of small size objects.At present, many cameras provide 12-bit recording and enable the user to view and measure a scene that contains very hot and very cold temperatures without losing the ability to distinguish thermal variations of less than 0:1_C. Typical temperature ranges of IRSRs span from about −20 to 800_C and can be extended up to 1500 to2000C by using letters. In a material discontinuity such as a crack or a delamination , there is only partial or no contact between the internal surfaces, causing an obstruction of heat transfer perpendicular to it. Locally, this results in a change of the heat flow path; globally, this will cause a reduction of the average thermal conductivity normal to the extension of the discontinuity. As delaminations in FRPs lie typically parallel to the surface there will be a reduction of the effective thermal conductivity in thickness direction.

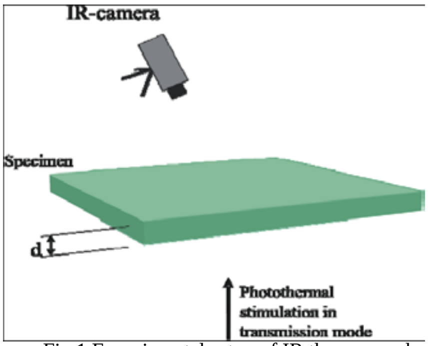

Fig.1.Experimental setup of IR thermography

2. LITERATURE REVIEW

John Montesano et al., [1] The thermographs were capable of establishing local high temperature regions that corresponded to damage within the braider yarns. In addition, the ability of the thermographic technique to capture the influence of material anisotropy on damage growth and damage localization.

Suriania et al., [2]IR thermal imaging technique is a surface thermal radiation measurement technique that is used to detect spatial variations in the measured surface temperature pattern. It also reveals flaws by searching anomalous hot-spots after
thermal excitation

Steinberger et al., [3]the study investigates the thermographic testing technique with the aim of providing an in situ characterization technique of damage during fatigue testing of the mentioned CFRP specimens. With this technique it is possible to monitor localized phenomena as was shownby localized heat sources indicating starting points for damage growth.

Pravin Patil et al., [4]during a tensile test, the material absorbs energy to deform.Since most of the (plastic) deformation energy would convert to heat energy, it is therefore possible to estimate the amount of damage (accumulated) by means of analyzing its heat energy dissipation.

3. EXPERIMENTAL DETAILS

A. *Sample Preparation*

The material used in this study is made of the epoxy resin RTM6 and the natural fibre fabric. FRP plates are manufactured by th RTM technique. The tensile specimens with the required dimensions are cut out with the fibres oriented in 0 and 90 directions.

And additionally another specimen of butyl rubber of 5 mm thickness were obtained by compression-molding between a cloth in clear and polished molds, adjusted beforehand at 150 C for about 10 min. A pressure of 10 MPa was applied by the press on the mold surfaces for 5 min. Moldings were then cooled under compression.

B. *Heat dissipation measurement*

In fibre reinforced polymers (FRPs) fatigue damage occurs by accumulation of fibre breakage, matrix cracking, debonding, transverse ply cracking and delamination. This damage accumulation has various effects on the mechanical properties of the FRP such as stiffness reduction, reduction of the residual tensile strength or change of damping. The former two are commonly used for the fatigue characterization of FRPs. The latter is more difficult to measure accurately, especially in FRPs becauseof their high stiffness and low damping. However, a large number of experimental studies underlines the effectiveness of damping as a measure of damage in FRPs by using IR camera.

The IR-camera used for the temperature measurement. The camera has a focal plane array detector with 320X240 pixels which is sensitive in the wavelength range between 3 and 5 lm. A temperature calibration curve was determined on the FRP-material in order to be able to determine absolute temperatures from the radiative measurement. This calibration already takes the emissivity of the material and the radiation conditions of the environment into account. The IR-camera was set up for the measurement of the temperature distribution on the specimen and the air temperature Tair as reference at the same time. Tair was measured on a paper in the background of the specimen.

3. RESULT AND DISCUSSION

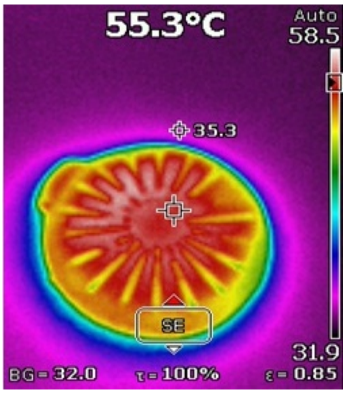

Fig.2. Thermography image of Butyl rubber

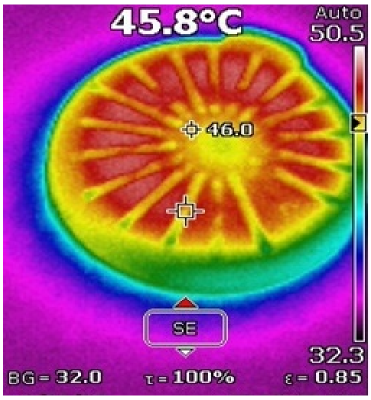

Fig.3. Thermography image of nitrile rubber

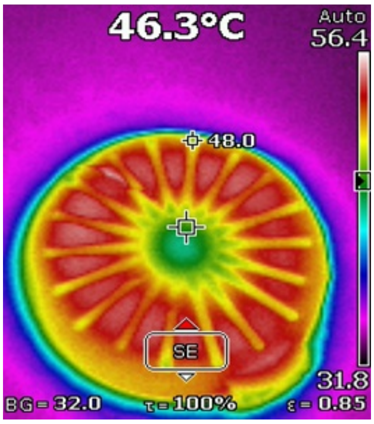

Fig.4. Thermography image of fluoro-silicone rubber

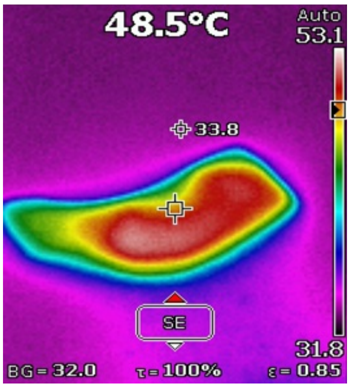

Fig.5. Thermography image of nature rubber

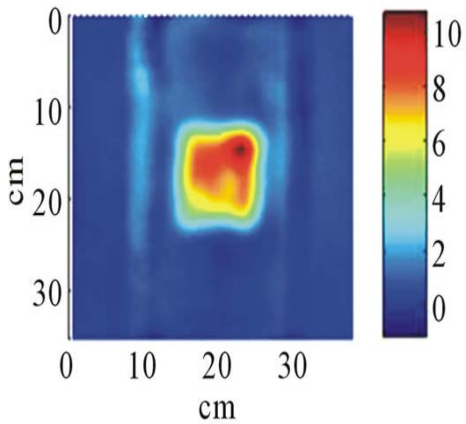

Fig.6. Thermal contrast between the specimen at initial instant

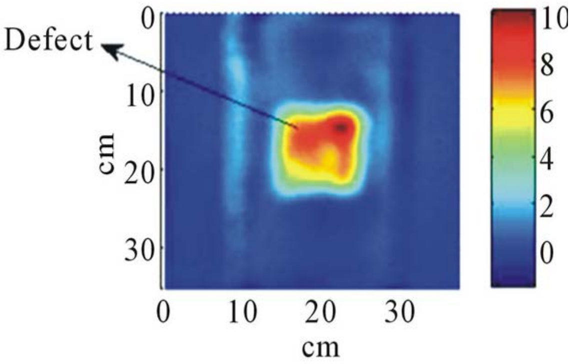

Fig.7. Thermal contrast between the specimen with defect

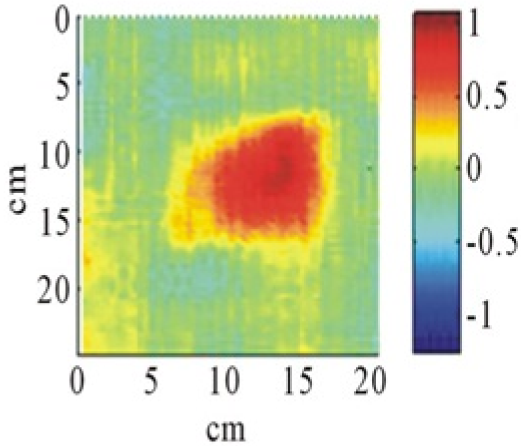

Fig.8. Thermal contrast between the specimen with adhesive

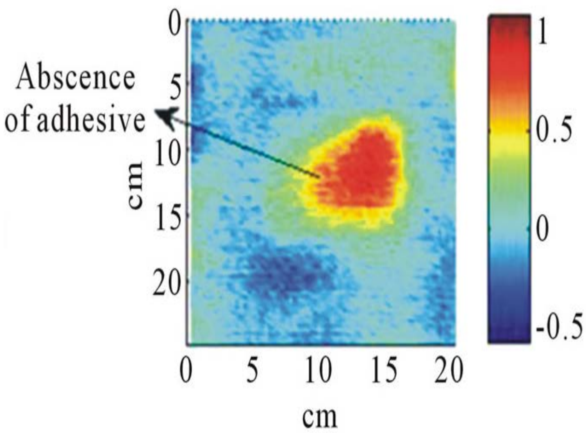

Fig.9. Thermal contrast between the specimen in the absence of adhesive

The thermography image of the various types of rubber (**Figure 2,3,4,5**) shows the temperature distribution across the surface of the rubber,which can be used to identify the material concentration.

The thermal contrast thermogram compared to initial instant (**Figure 6**) and thermal contrast between the specimen with defect (**Figure 7**) shows clearly the defect at the middle of the specimen, which is hotter than other healthy area.

The thermogram in (**Figure 9)** is the subtraction of the thermogram in (**Figure 8)** and its initial thermogram in order to consider only the defect as the difference between both samples (not taking into account the contrast made by their different initial temperatures). It shows clearly the defect at the middle of the sample. The absence of adhesive (replaced by the air, which has a smaller thermal conductivity) made it hotter than other area without defect.

4. CONCLUSION

Infrared thermographic technique was employed for the characterization of defects present in the material. Infrared thermography is capable of supplying detailed information about size, position and nature of defects and of discriminating between layered structures.

Infrared thermography, as a quick imaging system, can be used for quick evaluation of large surfaces; what is more, being a non-contact technique, it can be used also for the study of various engineering materials.

Pulse thermography in reflection mode might be more suitable for the depth resolved characterization, especially of surface near defects. However, every testing technique has its own advantages and there is still a need to investigate the relation between the various damage measures presented and the material damage mechanism in the specimen.

REFERENCES

[1] John Montesano et al .,Application of infrared thermography for the characterization of damage in braided carbon fiber reinforced polymer matrix composites. Composites: Part B 60 (2014) 137–143

[2] Suriania et al., Detection of Defects in Kenaf/Epoxy using Infrared Thermal Imaging Technique. Procedia Chemistry 4 (2012) 172 – 178

[3] Kurashiki K et al. A study on evaluation of fatigue damage of GFRP by infrared thermography (2nd report, evaluation of damage under two step fatigue test). Trans Jpn Soc Mech Eng (A) 2000;66(645):966–71.

[4] Maldague XPV, editor. Infrared and thermal testingMoore PO,editors. Nondestructive testing handbook, vol. 3. Columbus: American Society for Nondestructive Testing Inc.; 2001.

[5] Zhang Z, Hartwig G. Relation of damping and fatigue damage of unidirectional fibre composites. Int J Fatigue 2002;24:713–8.

[6] Chandra R, Singh SP, Gupta K. A study of damping in fiberreinorced composites. J Sound Vibrat 2003;262:475–96.

[7] Lazan BJ. Damping of materials and members in structural mechanics.Oxford: Pergamon Press; 1968.

[8] Rittel D. On the conversion of plastic work to heat during high strain rate deformation of glassy polymers. Mech Mater 1999;31(2):131–9.

[9] Carslaw HS, Jaeger JC. Conduction of heat in solids. Oxford: Oxford University Press; 1959.

[10] Grigull U, Sandner H. Wa¨rmeleitung. Berlin: Springer; 1990. Bailey CD, Freeman SM, Hamilton JM. Detection and evaluation of impact damage in graphite/epoxy composites, materials and processes-in service performance. In: Proceedings of the ninth national technical conference, Atlanta, GA, USA; 1977. p. 491–503.