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Detecting of defects in polymeric materials using pulsed infrared thermography

M. Szczepanik*, J. Stabik, G. Wróbel, Ł. Wierzbicki
Department for Processing of Metals and Polymers,
Institute of Engineering Materials and Biomaterials,
Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: monika.szczepanik@polsl.pl

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ABSTRACT

Purpose: The aim of this paper was to determine the possibility of the use of non-destructive thermographic testing to detect defects in polymeric materials and steel in compare purpose. To use the technique of infrared thermography for non-invasive monitoring of objects the temperature changes during cooling down or heating processes are determined by measuring the infrared emission from the surfaces. In this paper the subsurface defects of specimens made from polymeric materials such as PE, PMMA, laminate experimentally detected and directly displayed by thermographic image are presented.

Design/methodology/approach: In this paper the development of a real-time non-invasive technique using pulsed infrared (IR) thermography for measurement of the temperature of polymer materials is described. In this study 16 specimens were heated during specific time using infrared lamp. After that the specimen's surface temperature was measured during cooling down process by thermovision camera, next defects were detected by means of thermographic images analysis.

Findings: The experimental results have demonstrated that radiation heating and thermographic images analysis is effective method for revealing defects in the polymeric materials.

Research limitations/implications: It is not possible to detect defects at a long time of heating of researched material because it results in uniform temperature on whole surface of specimen.

Practical implications: It is possible to detect subsurface defects in polymeric materials by infrared thermography method. It is possible to see the defects on thermographic image, but the determination of their geometry and position is restricted and not very precise, it requires specific skills and as well as long labor-consuming attempts. The specimen's area with defect show higher temperature than area without defect also cooling down process proceeds longer in the area with defect.

Keywords: Non-destructive testing (NDT); Thermography; Defect; Polymeric materials

PROPERTIES

1. Introduction

There are many different non-destructive testing techniques which can be applied to polymer materials, but so far ultrasounds occupy one of the leading places [1-4]. In this day and age the also utilization of thermography in various technical disciplines became increasingly common. This non-destructive testing technique has applications in ecology, medicine (cancer testing), rescue, building, in observing thermal process and in material testing and also in monitoring of manufacturing and transforming process in casting. The purpose of non destructive testing is to determine defects of various type and size and their properties. It is not possible with one technique thus various techniques are used to describe various defects.

Taking into account the way of thermal process activation thermography is classified into two categories: passive thermography, where object's outside temperature distribution and changes are observed without observer interference;

- active thermography which consists in observing of researched object's thermal answer to external thermal impulse stimulation being a function of time and in registering this answer by means of thermograph.

There are several types of thermography depending on method of thermal activation:

- pulsed thermography,
- lock-in thermography with modulate heating,
- pulsed phase thermography.

The term thermography and thermovision include testing methods based on registering infrared part of radiation spectrum emitted by body which then is converted by special camera into a colour map of temperature [5, 6]. The thermovision system allows to measure temperature remotely and in many places at once. Therefore, the suitability of infrared thermography (IRT) to non-destructive testing depends on the ability to detection of the temperature variation or thermal contrast induced by a defect. Indeed, the defect visibility depends on several factors which involve the defect geometry (mainly defect diameter and position in testing material), the relative thermal characteristics (e.g. thermal conductivity, thermal diffusivity) between the defect and the host material, the way thermal stimulation is performed and the sensitivity of the infrared imaging system used. The presence of a defect at a certain depth interferes with the heat flow causing local surface temperature variations [7-13].

2. Experimental

The aim of this research is to determine the possibility of the use of non-destructive thermographic testing to detect defects in polymeric materials. The research had a preliminary character.

2.1. Materials

Thermographic research was carried on twelve polymeric materials specimens [14] and four steel specimens. In compare purpose holes with the same geometry were made in each specimen. The photograph of specimens is shown in the Fig. 1.

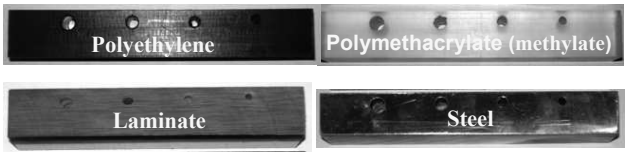


Fig. 1. Specimens for testing

The specimens in the form of rectangular prism with dimensions of 23,5x35x150 mm and with through holes with different diameter placed in distance of 3 mm from searched surface were tested. All specimen surfaces were uniformly painted with black matt coating to assure good heat emission.

2.2. Methodology

The specimens were tested using one of active thermographic methods namely pulsed infrared thermography [6, 10]. The method used in the describe research belongs to activate thermography with static thermal activation. In purpose to carry out this testing a special stand was prepared (Fig.2). This stand include: infrared radiator (IR) (Victory Lightning) (1)[15], insulating shield in the form of frame (2) with specimen mounted (3) and thermovision camera (Inframetrics type 760B USA) (4). Specimens were activated by short time heating. Research lies in observing the temperature distribution of the surface with subsurface defects after short thermal impulse. Specimens were researched during cooling dawn process. Specimen's surface temperature during cooling down process was observed in areas above defects and in areas without defects. The specimens were located at a constant distance of 80 mm from radiation source. Together with the end of the heating process the surface temperature recording procedure begun.

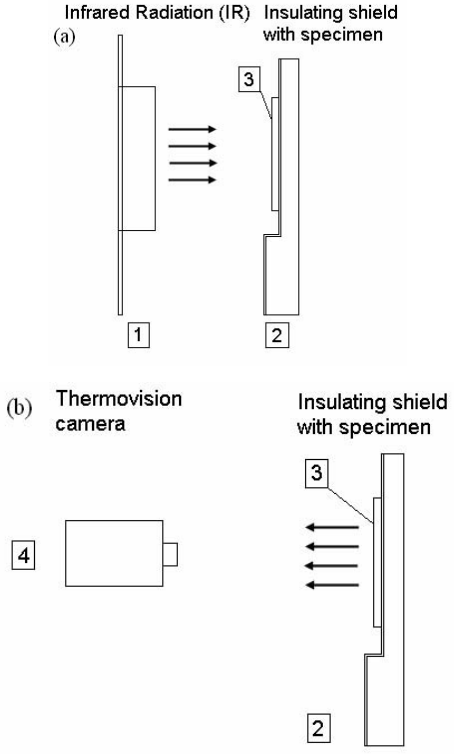


Fig. 2. Schematic draw of thermovision research stand: a) specimen heating process, b) observing specimen's surface by thermovision camera

3. Results

Thermal imaging technique enables to obtain the description of the surface temperature changes. It is not possible to present all thermographic images and temperature measurement results so

only chosen examples will be shown. Fig.3 presents thermographic image taken 12 seconds after the end of heating process. The range of temperature is about five degrees. The subsequent photographs (Fig.4, 5, 6 and 7) show thermographic images registered after 60, 150 and 2 seconds after the beginning of temperature measurement for the different materials and geometry specimen by range two degree.

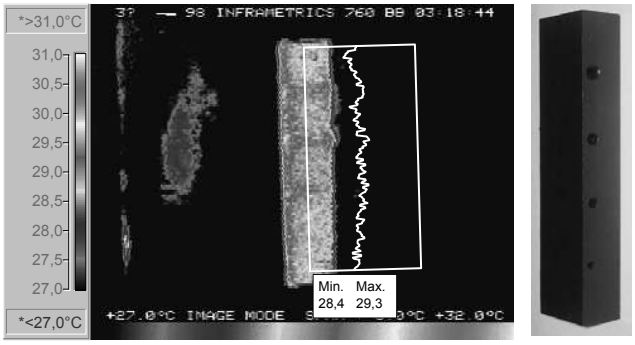


Fig. 3. The thermal image of polyethylene specimen registered twelve seconds after the end of heating process – the first signs of subsurface defects

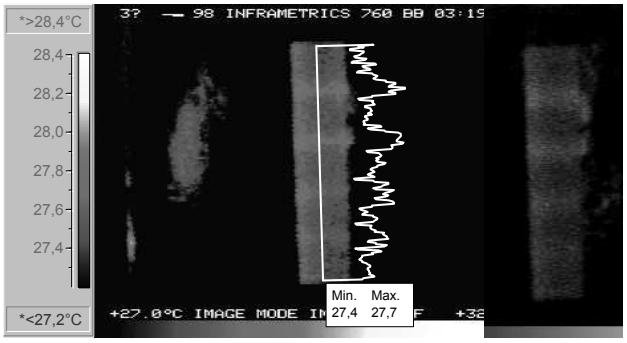


Fig. 4. The thermal image of polyethylene specimen registered sixty seconds after the end of heating process – clearly visible defects manifested by temperature incensement

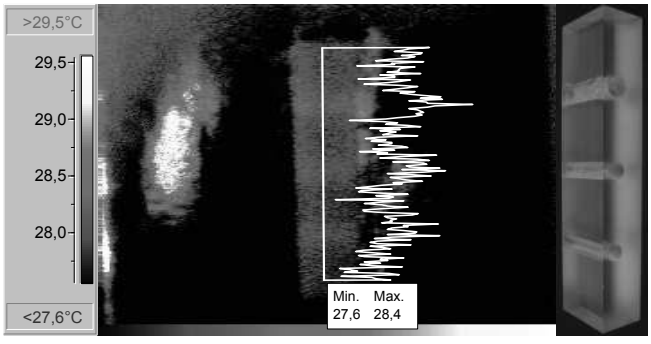


Fig. 5. The thermal image of polymethacrylate (methylate) specimen registered one hundred fifty seconds after the end of heating process

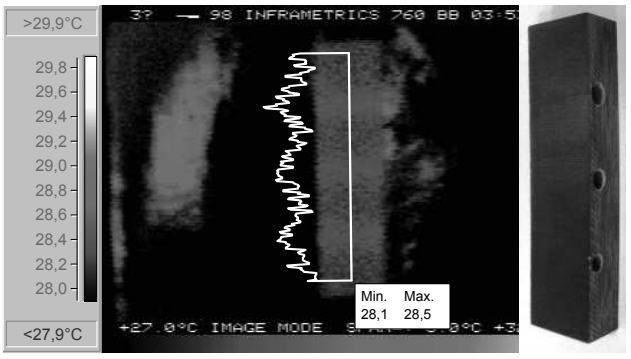


Fig. 6. The thermal image of laminate registered one hundred fifty seconds after the end of heating process

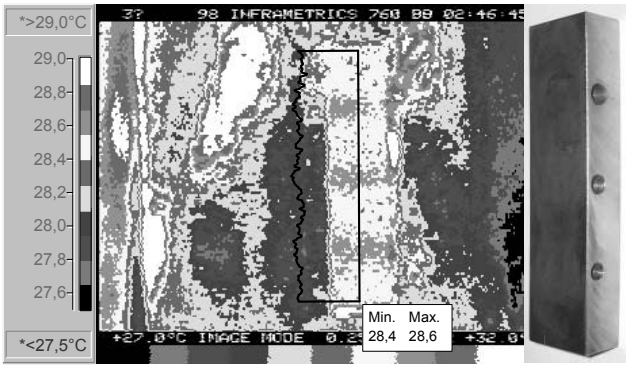


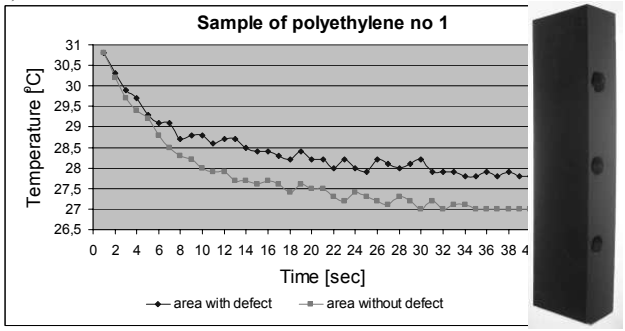
Fig. 7. The thermal image of steel specimen registered two seconds after the end of heating process

Fig. 8 presents temperature changes of the heated side of the specimen at, area with defects and area without defects. These curves were prepared for each type of specimen's ~~of~~ material. Observed dependences allowed to distinguish initial stage of temperature decrease almost linearly with time. The speed of cooling is bigger in area without defect than area with defect for all specimens. It is the result of bigger thermal resistance of the defect then tested material.

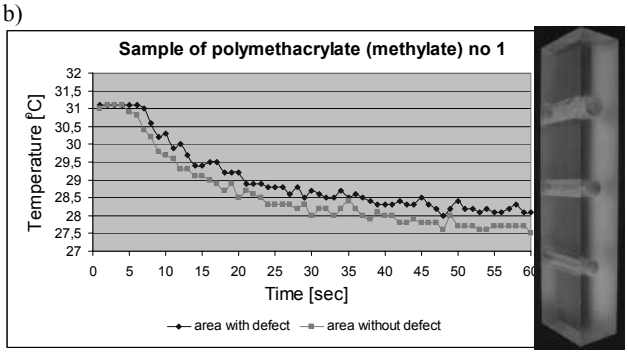
4. Conclusions

The experimental results have demonstrated that radiation heating and thermographic images analysis is effective method for revealing defects in the polymeric materials. It is possible to see the defects on thermographic image, but the determination of their geometry and position is restricted and not very precise. It requires specific skills and as well as long labor-consuming attempts (tests; probations). The specimen's area with defect show higher temperature than area without defect also cooling down process proceeds longer in the area with defect. It is not possible to detect defects after long time of heating of researched material because it results in uniform temperature on whole surface of the specimen.

a)



b)



c)

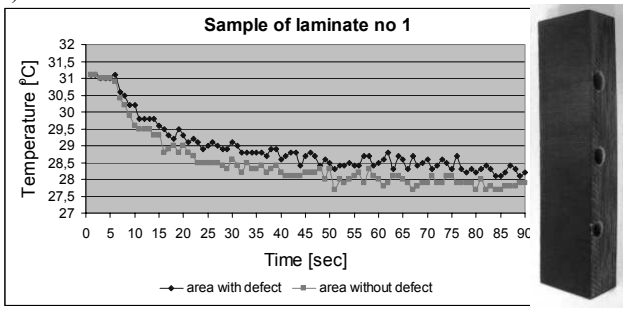


Fig. 8. The dependences of temperature on cooling time for areas with and without defect. (a) polyethylene (b) polymethacrylate (methylate), (c) laminate

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