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APPLICATION OF THE ACTIVE IR THERMOGRAPHY FOR THE DETECION OF NON-UNIFORMITY OF MATERIALS IN BUILDING PARTITIONS

ZASTOSOWANIE TERMOGRAFII AKTYWNEJ DO DETEKCJI NIEJEDNORODNOŚCI MATERIAŁOWYCH W PRZEGRODACH BUDOWLANYCH

Abstract

The paper describes the problem of building envelope investigation with active thermography. Mainly emphasized is its application to detect different material of wall inclusions. Examples of active thermography application and description of experimental investigation has been shown on a model envelope, with inclusion of significantly different thermal conductivity and heat capacity materials; XPS polystyrene, steel and granite. Thermograms received for every kind of inclusion have been compared and analyzed. Finally, the summary and conclusion have been shown along with the prospects of development and practical application of this kind of investigation in construction.

Keywords: building partition, material inclusions, active IR thermography

Streszczenie

Artykuł porusza problem wykonywania badań przegród budowlanych za pomocą termografii aktywnej. Podkreślono w nim możliwość detekcji różnych wtrąceń materiałowych w przegrodzie. Praca przedstawia wykonane badanie doświadczalne na modelu przegrody, w którym zamodelowano wtrącenia z materiałów o znacznie różniącym się współczynniku przewodzenia ciepła tj. styropian XPS oraz stal. Otrzymane termogramy porównano ze sobą i poddano analizie. W podsumowaniu przedstawiono wnioski wraz z perspektywami rozwoju badań i praktycznego zastosowania termografii aktywnej w budownictwie.

Słowa kluczowe: przegroda budowlana, wtrącenia materiałowe, termografia aktywna

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1. Introduction

Thermography is a form of nondestructive testing, which means that such testing does not affect the properties of the object being tested and does not interfere with its structure. The thermovision testing is performed noninvasively, with a contactless method. It uses the electromagnetic radiation within the wave length of $3.0 < \lambda < 100$ μm [4], called infrared radiation or, commonly, thermal radiation. The measurements are made using a thermovision camera, that records thermal radiation emitted by each object being tested. The signal reaching the camera is processed into a thermogram, that shows the temperature field distribution over the surface of the element being tested. The thermovision testing is used in various fields of life and science, e.g., industry, medicine or in building industry [1, 2, 3]. Both passive and active method can be used when testing the temperature distribution field on the surface of a building partition. The former consists of performing the testing without interfering with the thermal processes occurring within the partition, which is a typical thermovision testing process for buildings. This method is practical in the heating season only, since the testing requires a difference in the air temperature at a level of circa 15°C [2]. On the other hand, the active IR thermography method introduces an additional source of heat/cold, as well as intensive heating/cooling of the building partition, followed by the recording of thermograms during the cooling/heating of the partition being tested, performed at certain time intervals. Depending on the type of the temperature source, the active IR thermography can be split into four types: pulse, modulation, pulse-phase and vibration [4]. This paper takes a closer look at the application of the pulse active thermopgraphy in building industry. The paper focuses on the presentation of the model of a building partition, that was subjected to experimental testing, along with the description of the built test and its method, followed by the quotation of exemplary test results. A particular problem with the use of active IR thermography is to achieve uniform heating of a large surface area along with limited penetration of thermal waves in the thick building partitions.

2. Active IR thermography in the thermal analysis of buildings

The active IR thermography is a relatively young field of science, that became globally acknowledged in the 80s. In Poland this method has been investigated since ca. 2000. Presently, various research centres throughout the world conduct work on the development of the active IR thermography in building industry. An interesting trend of the active IR thermography's development seeks to find its application for the contactless investigation of the properties of building materials to determine their heat conductivity. Another application focuses on the detection of defects in the tested partitions. This investigation can be particularly helpful in such building facilities, where more invasive tests are impossible to carry out. The detection of inclusions and their general location by itself does not pose a problem to the operator of a thermovision camera. On the other hand, an interesting issue to resolve is to determine the precise dimensions of such inclusions/defects or their depth, especially on a macro scale of a building partition. The investigation can be conducted both in the reflection mode (the camera and the source of temperature are located on the same side of the wall) and the transmission mode (the camera and the source of temperature are located on two different sides of the partition).

3. Adopted partition model and test stand

The building partition model was adopted as an construct comprising two major elements. The first one constitutes a homogenous material, that reflects the major wall building material. The other element constitutes material inclusions located inside the partition. A OSB-3 board type was adopted as a homogenous material, having a heat conductivity amounting to 0.13 W/m·K. The model partition is made up of 4 board layers of varying thicknesses: 22 mm; 10 mm; 10 mm and 22 mm, successively. Such structure is fitted with 20 mm thick inclusions inside the model partition. Three different material inclusions, with a considerably differentiated heat transfer conductivities (steel, XPS polystyrene and granite) were used. Each inclusion is characterized by a different heat conductivity amounting to: 50.0 W/m·K for steel, 0.033 W/m·K for polystyrene and 2.80 W/m·K for granite. Each of the inclusions has the size of 100 × 200 × 20 mm. They are located both vertically (steel) and horizontally (polystyrene, granite) over the whole surface of the homogenous material – an OSB board of 1250 × 1250 mm. The partition model applied will allow good observation of the temperature field variation during the test conducted with the active IR thermography. Should the building partition of an order of 20 – 40 cm had been applied from the very beginning, it might have been impossible to notice the impact of the inclusions in the material in the reflection mode in the initial investigation conducted with active IR thermography. Conclusions were drawn on the basis of the previously conducted investigation, where a similar partition of 13 mm was applied on the OSB board [3]. The proposed partition model increases the thickness of the front plate up to 22 mm and at the same time introduces three different inclusions in the same partition.

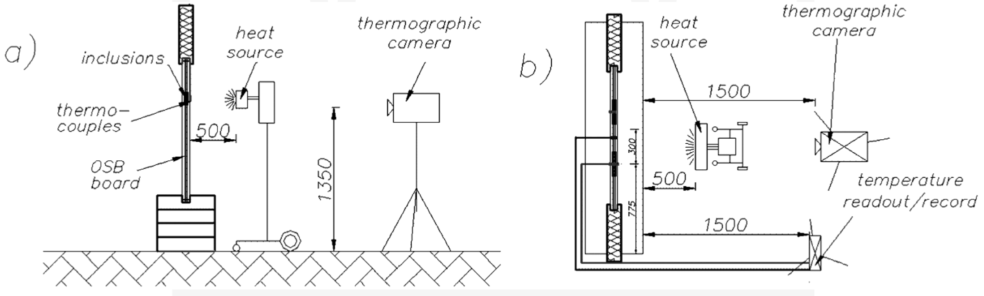

Fig. 1. Schematic of the built test stand. Section of the test stand (a) and its horizontal projection (b)

The schematic of the test stand is shown in Fig. 1. Its core element is the partition model made of an OSB board with inclusions, around which a 50 cm broad frame of 12 cm thick polystyrene boards was placed. The whole segment was supported by a layer of polystyrene boards. The above operation was conducted taking into account the convective heat transfer to the back of the partition. Without a polystyrene band an uncontrolled heat flow and warming-up of the other side of the OSB board would take place. A thermovision camera made by the Flir company, model P65, K type thermocouples, an infrared radiator type FOBO EP 102 of 1.0 kW power (to warm up the partition) and the Ahlborn unit for carrying out the recording of temperatures and relative humidity of air were used. The camera was placed at the distance of 1.5 m from the partition being warmed up, while the infrared radiator was set at the distance of 50 cm from the OSB board. Beside the recording of the thermograms of the cooling-down partition, the temperature in the vital places of the tested section was also recorded by thermocouples.

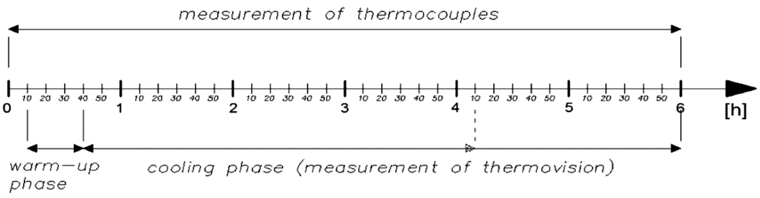

Fig. 2. Schematic of the graphic schedule of the conducted test

The thermocouples were placed in alignment over the inclusions and 20 cm from the edge of the inclusion, 4 thermocouples in each section: on the OSB board surface, on both sides of the inclusion surface and at the rear of the partition model. As the result, the temperature distribution in time throughout the section can be observed. The thermocouple wires were placed in the outer cut-out grooves of the partition boards. Measurements started with the activation of the temperatures recording from all thermocouples placed on the partition, as well as the temperatures and relative air humidity. After 10 minutes, the switch-on of the heat radiator occurred, warming up the board for exactly 30 minutes. Afterwards, the heat radiator was removed from before the board and the recording of thermograms started, lasting for a minimum of 4 hours, until a uniform temperature over the partition surface was reached. The recording of thermograms followed periodically every 1 minute, while the recording of temperature and humidity values followed every 10 seconds (Fig. 2).

4. Selected experimental results

Figs. 3–4 below present the selected experimental measurements made with a thermovision camera. The white colour areas show the warmest places, whereas the violet areas show the coolest places. Fig. 3 (top) shows how – after a time period of 30 minutes after the start time of the element's cooling – the zone of warmest temperatures moves over the defect from polystyrene, that "does not allow" the heat flow to the other side of the partition. A reciprocal situation (Fig.3 at the bottom) takes place with a steel inclusion. After a time period of around 30 minutes, a zone of lower temperatures in relation to a homogenous section without an inclusion is visible. It comes from the fact, that steel (having a high heat conductivity) "allows" easy heat displacement onto the other side of the partition. An interesting temperature distribution is also visible in Fig. 3 on its extreme right side.

A slightly cooler zone is visible over the polystyrene inclusion, while the partition surface over an inclusion from steel is slightly warmer than the other area visible on the thermogram. This happens due to a different volumetric heat capacity of materials. Polystyrene of a low volumetric heat capacity yields heat more quickly, on the other hand, steel having a high volumetric heat capacity radiates out heat for a significantly longer time, which is shown in the thermogram in form of a temperate increase on the graph.

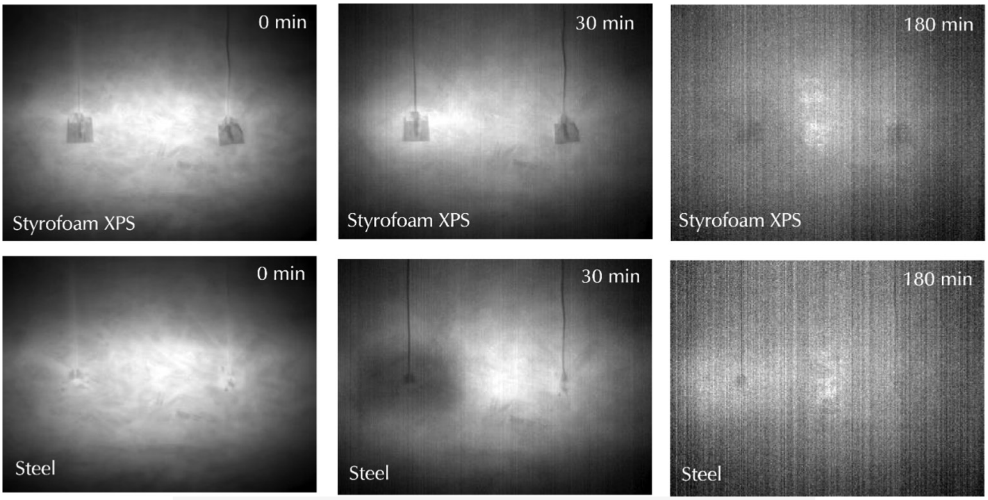

Fig. 3. Thermovision pictures in crucial moments of the element's cooling; styrofoam XPS inclusion (top line), and steel inclusion (bottom line)

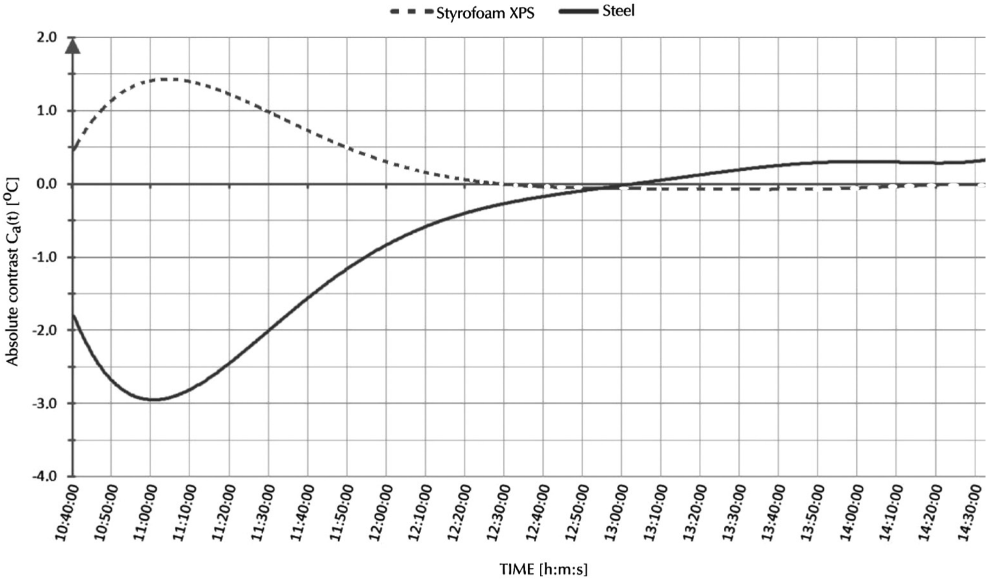

Fig. 4. The temperature difference between the surface of the section with a defect and a homogenous section for styrofoam XPS inclusion and steel inclusion (absolute contrast)

A conclusion may be drawn, that with the pre-set geometry (a hidden defect under a homogenous material of a thickness above 20 mm), using the active IR thermography exclusively, it is possible to simply identify the inclusions' material. In order to show various dynamic changes in both sections of the surface of the object being tested, the absolute contrast for a steel inclusion and a styrofoam XPS inclusion were compared (Fig. 4). The absolute contrast defines the difference between the temperature at a freely selected point on the surface (over an inclusion) and the temperature of the surface over a homogenous area. The maximum absolute contrast is perceptible circa 25–30 minutes after the initiation of the element's cooling. Also at that time, for the assumed partition model, a material inclusion is best visible in the thermogram.

5. Summary

The investigation conducted emphasizes a special suitability of active themography in the reflection mode to detect material inclusions in building partitions. A significant advantage of such investigation is its non-destructive nature, thanks to which it can be used in investigations of the existing building facilities. In the next step of the experimental investigation a test of a granite inclusion will take place. The test will also feature the comparison of temperature contrasts, depending on the degree of the element's warm-up and an attempt to find a reciprocal solution of the heat transfer issue [5–7]. To compare the test results, an additional analysis consisting of warming-up of the whole partition with all inclusions installed simultaneously will be carried out. Under the research work conducted, the investigation on real objects is also scheduled.

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