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# RESEARCH ON HEAT FLOW IN GRANITE SAMPLE USING THERMAL IMAGING CAMERA

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***Abstract***

*Research on heat flow in granite sample and sample of aluminium foam with the use of a thermal imaging camera is presented in the paper. Temperature distribution on the surface of the sample as a function of time was obtained on the basis of data from the thermal imaging camera. Thermovision is one of the most universal technology, which is applied for detection of infrared radiation. This technique allows observing and record infrared radiation emitted by objects located in the surrounding environment. This technology allows obtaining, in a short time, temperature distribution on the surface of the sample. The thermograms (pictures showing on the surface of the object) are types of photos showing temperature distribution on the tested object surface which is achieved on the base of a specified range of electromagnetic radiation. Accurate measurement of the temperature distribution on the heated granite sample surface was obtained using a thermal imaging camera FLIR SC 6000. Thermal imaging camera was connected to the computer equipped with control software FLIR ResearchIR Max. Heat source was applied in the experiment as a cast iron hotplate with high efficiency heating, gradual control and 1500W power. Obtained results showed regular temperature distribution over the surface of researched sample.*

***Keywords:*** *thermovision, thermal imaging camera, temperature distribution, granite, aluminum foam sample, heat flow*

## 1. Introduction

Thermovision is one of the most universal technology, which is applied for detection of infrared radiation. This technique allows to observe and to record infrared radiation emitted by objects located in the surrounding environment. This technology allows obtaining, in a short time, temperature distribution on the surface of the sample. The thermograms are types of photos showing temperature distribution on the tested object surface which is achieved on the base of a specified range of electromagnetic radiation [2, 3].

Thermal imaging camera is a device, which is used for non-invasive thermal testing to the contactless measurement (NDTT). Detector of thermal imaging camera records the intensity of thermal radiation, which is emitted, by the test object warmer objects means higher intensity of radiation) and then using signal from the matrix measurement the appropriate temperature value is determined. Thermal imaging camera in opposite to the pyrometer (which contact measures the temperature at a given point contactlessly) allows showing the temperature distribution over the entire surface of the object by using a thermogram (colour palette assigned to the respective temperature values).

By using, the camera the application is of thermovision is still expanding to include more areas of life: from scientific research, medical diagnostics, criminalistics (the study of signs), military (all kinds of army equipment, observation in darkness) energy, industry and construction (energy certificates) [1, 4].

## 2. Object of investigation

The granite and aluminium foam sample (foamed aluminium alloy AlCu4Mg1) of 50x50x50 mm size were investigated (Fig. 1). The materials chosen for this study is differ due to their structure. Granite is a solid and consistent rock with a crystalline structure, composed of quartz, feldspar and biotite. Second sample is made of aluminium foam, which belongs to so called foamed metals. It is a porous material with closed pores, characterized by a low density and ease of processing.

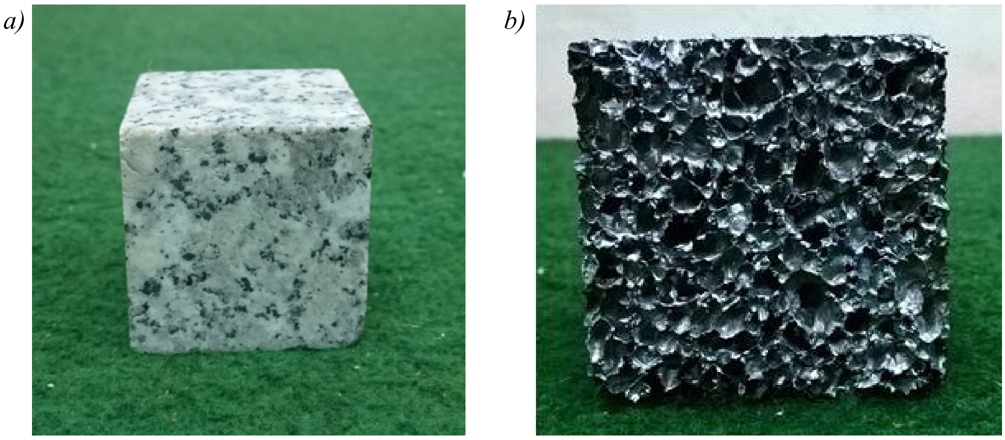

*Fig. 1. Tested samples made of: a) granite b) aluminium foam*

## 3. Test stand of the experimental research

Experimental studies were carried out on the testing stand shown in Fig. 2. Accurate measurement of the temperature distribution on the heated sample surface was obtained using a thermal imaging camera FLIR SC 6000. Heat source was applied in the experiment as a cast iron hotplate with high efficiency heating, gradual control and 1500 W power. The heat source was applied underneath the test sample.

*Fig. 2. Testing stand*

In front of the testing stand, the thermal imaging camera FLIR SC6000 was installed, in order to record the temperature distribution on the heated surface of the sample. The thermal imaging camera was connected with the computer with FLIR ResearchIR Max control software. In the computer code that supports the camera the temperature range 0-350°C was set. It was carried out in order to calibrate the camera to make temperature changes visible in all areas of sample. The temperature of heating plate was set on 90°C. Total time of temperature change recording by the thermal imaging camera was 3600 s for granite sample and 1800 s for aluminium foam one. The time was set on the basis of initial test results. In order to isolate the tested sample from the surrounding environment and to avoid its influence on the measurement results, the sample of dimensions of 50x50x50 mm was covered with styrafoam walls 10 mm thick at its four sides. Therefore, one wall of sample allowed applying the heat source and the second one was exposed and located in front of the thermal imaging camera in order to make measurements.

After determining the parameters of the sample and the environment, such as camera distance, ambient temperature, air humidity, the emissivity values in the control software infrared camera were defined. The emissivity value of the surface of the sample was defined on the base on literature review [4]. All parameter values are shown in Tab. 1.

*Tab. 1. The parameters defined in control software*

| Distance between camera and object [m] | Ambient temperature [°C] | Air humidity [%] | Emissivity of the surface of the sample [–] |
|---|---|---|---|
| 0.5 | 22 | 50 | 0.90 |

## 4. Test results

After carrying out experimental research, recorded of the process were saved in the computer disc. Collected data allowed to gather and to process results in order to obtain the temperature distribution as a function of time at the sample surface and graphs of temperature versus time for the granite and aluminium foam samples with and without isolation.

Selected frames from the recorded movie of the temperature distribution change in time during heating of the granite sample with isolation were presented in Fig. 3.

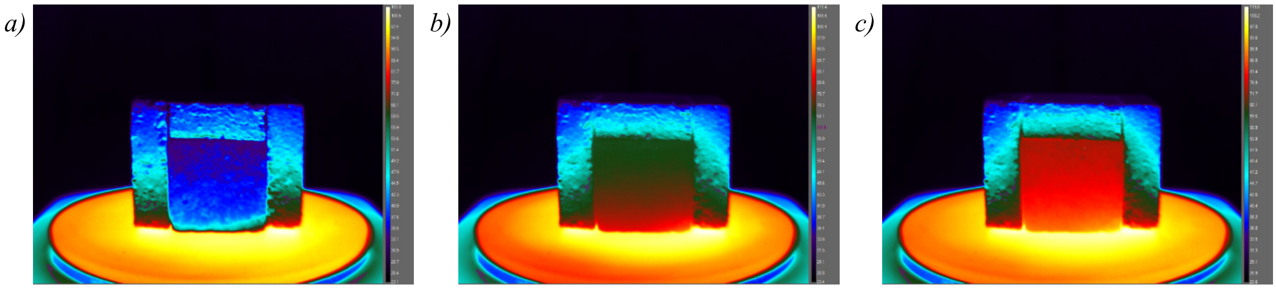

*Fig. 3. Temperature distribution change in time during granite sample with isolation heating for time a) t = 100 s, b) t = 1800 s, c) t = 3500 s*

Selected frames from the recorded movie of the temperature distribution change in time during heating of the aluminium foam sample with isolation were presented in Fig. 4.

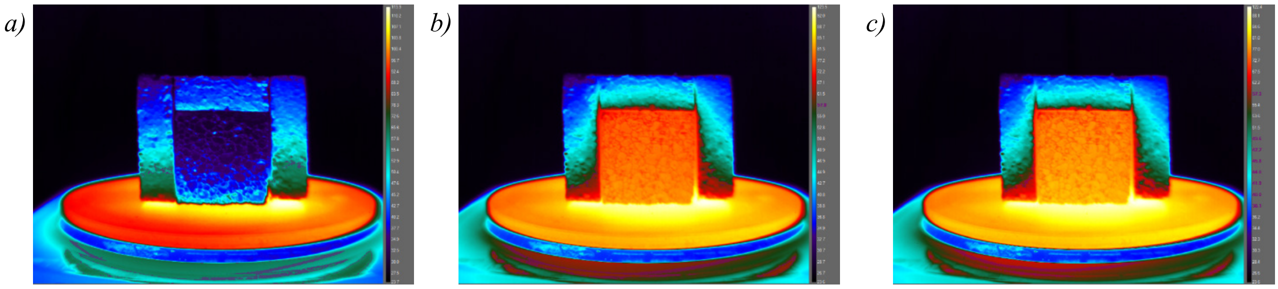

*Fig. 4. Temperature distribution change in time during aluminium foam sample with isolation heating for time: a) t = 100 s, b) t = 470 s, c) t = 1800 s*

Selected frames from the recorded movie of the temperature distribution change in time during heating of the granite sample without isolation were presented in Fig. 5.

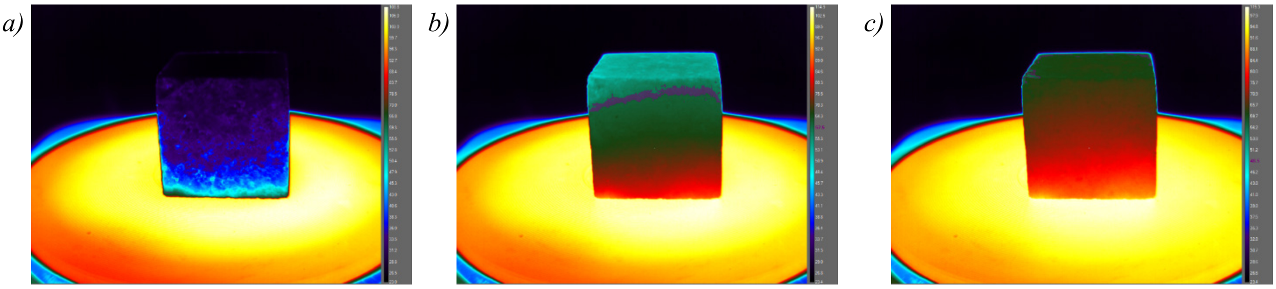

*Fig. 5. Temperature distribution change in time during granite sample without isolation heating for time: a) t = 100 s, b) t = 2000 s, c) t = 3600 s*

Selected frames from the recorded movie of the temperature distribution change in time during heating of the aluminium foam sample without isolation were presented in Fig. 6.

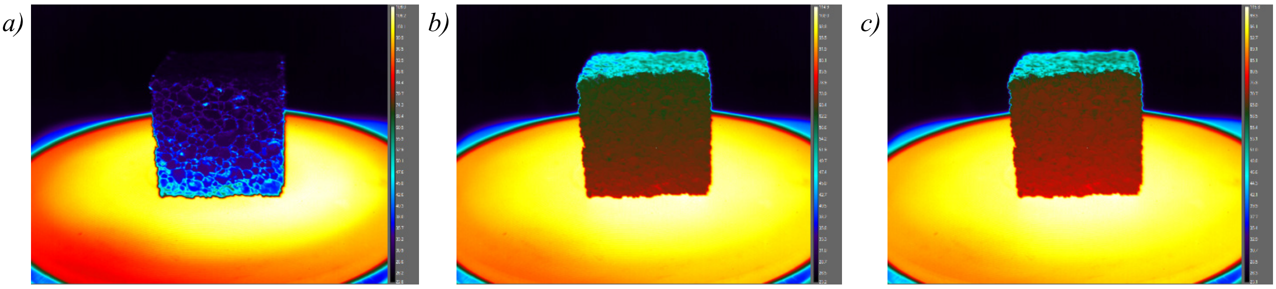

*Fig. 6. Temperature distribution change in time during aluminium foam sample without isolation heating for time: a) t = 100 s, b) t = 400 s, c) t = 900 s*

Temperature distribution change in time on the basis of which graphs below were determined, was carried out using selected measurement segments on sample surface as it was shown in Fig. 7.

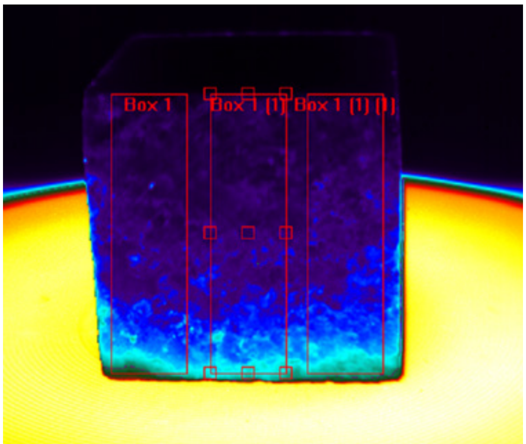

*Fig. 7. Selected temperature measurement segments*

The graphs illustrating the change in temperature versus time are presented in Fig. 8-11.

Analysing results showed in Figs. 3-6 which illustrates frames from the recorded movie of temperature distribution as a function of time during heating change each sample and charts presented in Figs. 8-11, the differences in the results between granite and aluminium foam samples and the test samples with isolation and without separating the sample from the environment were visible (Tab. 2).

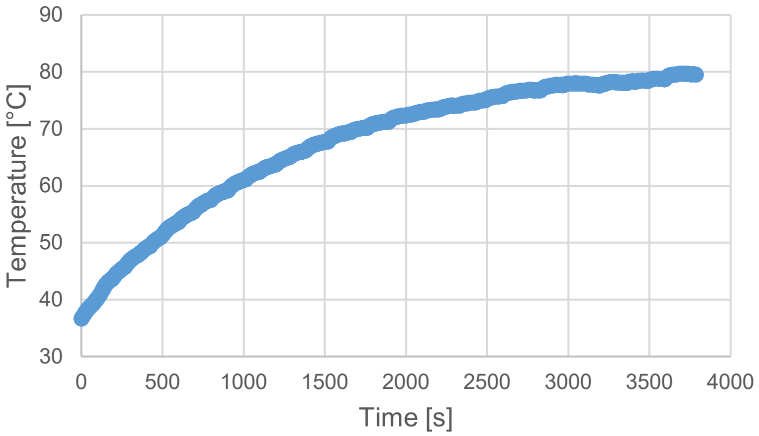

*Fig. 8. Temperature vs. time chart for granite sample with isolation heating*

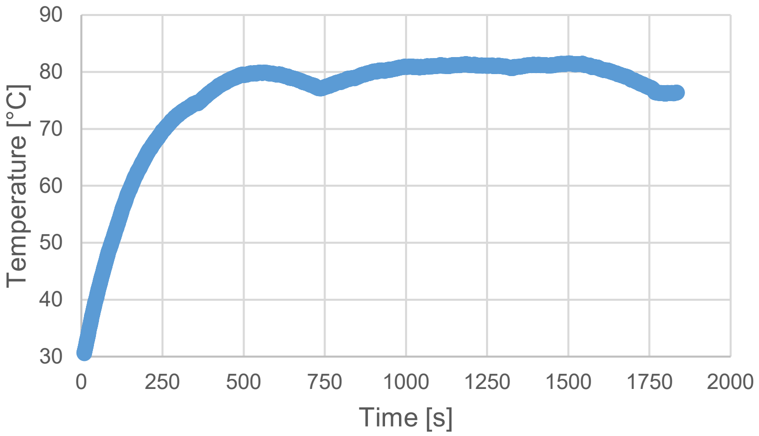

*Fig. 9. Temperature vs. time chart for sample of aluminium foam witch isolation heating*

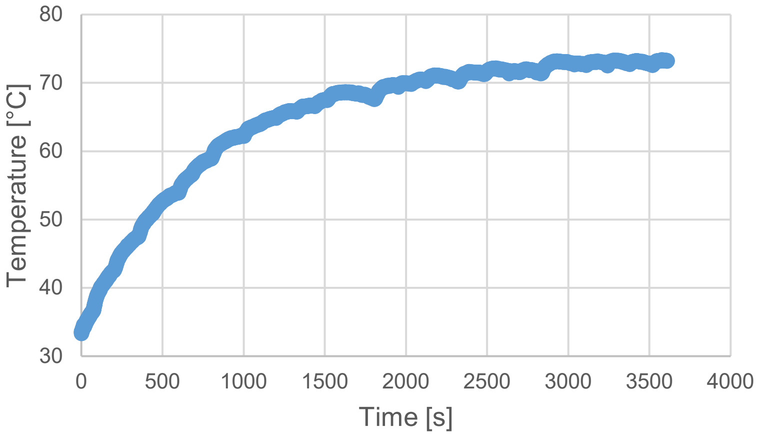

*Fig. 10. Temperature vs. time chart for granite sample without isolation heating*

In case isolated granite sample maximum heating time to steady state achievement was 3600 s, and obtained maximum temperature was 80°C, while the sample of aluminium foam reached a maximum temperature of 80°C during 1800 s time.

For the non-isolated granite sample, maximum heating time was 3600 s, and maximum sample temperature was 73°C, while the sample of aluminium foam reached a maximum temperature of 72°C during 900 s time.

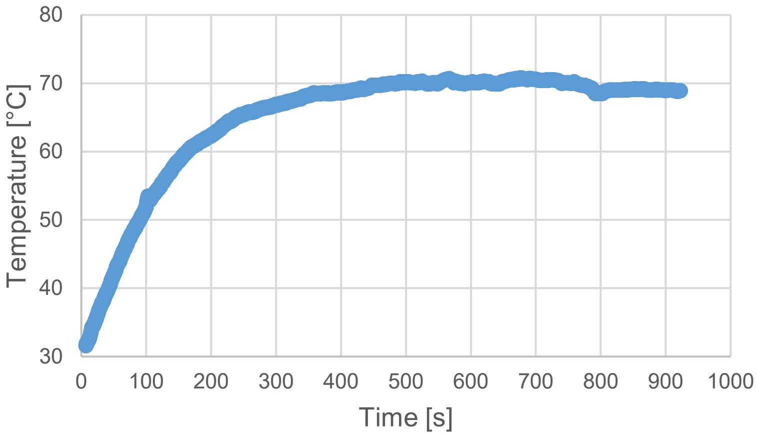

*Fig. 11. Temperature vs. time chart for sample of aluminium foam without isolation heating*

Comparing the results for samples with the isolation and without a significant difference in the values was obtained for both temperature and time values. Samples without isolation while heating did not reach such a high temperature as in cases where isolation was used due to dissipation of heat energy to the environment.

Results of the max heating time and max temperature for the individual samples are presented in Tab. 2.

*Tab. 2. Results of analysis*

| Sample type | Max. heating time [s] | Max. temperature [°C] |
|---|---|---|
| Granite sample with isolation | 3600 | 80 |
| Aluminium foam sample with isolation | 1800 | 80 |
| Granite sample without isolation | 3600 | 73 |
| Aluminium foam sample without isolation | 900 | 72 |

## 5. Conclusions

Based on the analysis of the results of the experimental studies the following conclusions can be made:

- Structure of analysed material plays an important role in heat transfer research.
- The granite sample as an example of solid rock obtained maximum temperature over a longer time, compared to the sample of aluminium foam, which is a porous material in which heat propagates faster because of pores pilled with air pressure and metal matrix.
- Isolation of samples highly influenced the results. Samples without insolation while heating did not obtain such high temperature as in cases of isolated ones due to dissipation of heat energy to the environment.
- Finally it should be mentioned that the thermal imaging camera is a device that is used for non-invasive thermal research and enables registration of radiation which is emitted from the external surface of the tested element (inability to register temperature inside the element) and then to create pictures that are representation of the temperature distribution on the observed object.

## Acknowledgements

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