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The measurement system for thermographic research on characteristic of cooling selected radiators in conditions of free convection

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Abstract:
The aim of this paper is to discuss method to compare cooling parameter in selected ***radiators***. In this purpose ***measurement system*** was created which can be used to generate identical temperature under four radiators in the same time and conditions. Readings from ***analog sensors*** and ***thermograms*** were used to compare which radiator has the lowest temperature at the beginning and at the end of the measurement. Paper describes method to compare radiators using measurements from sensors and thermograms which is supplement to the theoretical calculations. Literature positions discuss this method slightly. Method is given capabilities to analyze whole process of cooling and deduce additional conclusions.

Key words: thermography, radiators, natural convection, calculations with COMSOL Multiphysics® software

Introduction

Design of radiators is a very complex and important issue. Optimal shape of radiator comes to reduction in weight and size. It follows the reduction of material used in factories [1, 2, 3, 4, 5, 6].

During experiments and model research should be noted some basic restrictions. This publication is focusing on natural convection in a room. Real devices are closed in a cover which generates additional problems to be solved. In the literature there is many publications using forced convection which reduces size of radiator but generates noise.

Measurement system

Measurement system was created to heat four radiators in the same time and heat transfer conditions. User is able to change maximum temperature of the board. Range is between 30 and 115 °C. Thermostat is installed under the board to reach selected temperature and preserve it. Red diode is installed into measurement system to inform about power on of the heater. Heat bed MK3 from RepRap 3d printer was used to achieve regular temperature on the whole surface. Every radiator field has individual analog sensor to check temperature using measurements. Aluminum and copper were used as heat conductors because of their good performance. Differences between fields are lower than one °C. Every field has the same size of the area - square with a side of 6 cm.

LabVIEW software is used to read 5 analog sensors e.g. four sensors from fields and one sensor located in the center of the heat bed which is used by thermostat. Measurements are displayed in charts and saved to file for later comparison.

Maximum temperature is reached after 15 - 20 minutes. Stabilization of the system is visible because of chart characteristic and short time when heater is turned on. When system is stable, radiators can be placed on the fields and start to cooling heat bed. Radiators shouldn't affect on each other because of additional space between them (4.5 cm).

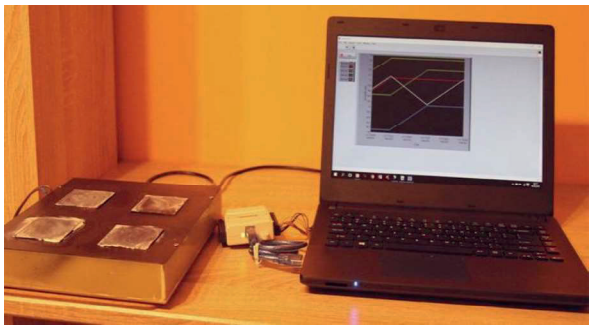

Fig. 1. Measurement system: heat bed, data acquisition device (NI USB-6008), laptop with data charts

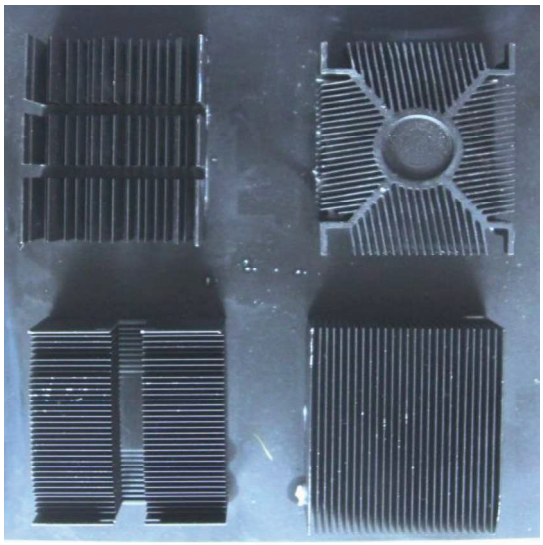

Fig. 2. Heatbed with installed four radiators

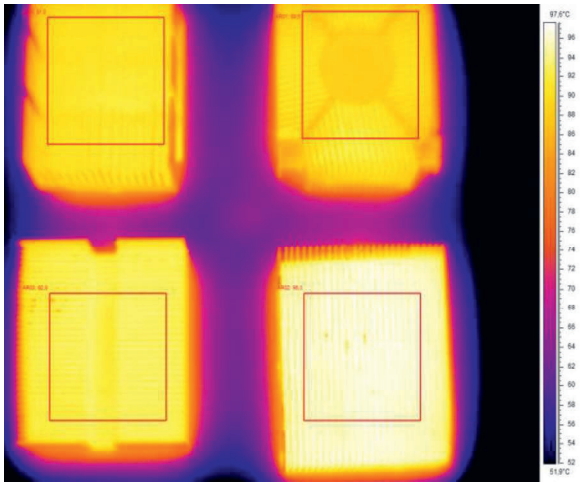

Fig. 3. Thermogram shows system with radiators

Model research

System from the experiment (fig. 2) was described in the model. COMSOL Multiphysics® program was used for this purpose [7]. The model research was performed on a high power computer in ACK CYFRONET AGH.

COMSOL Multiphysics® assembles and solves models using state-of-the-art numerical analysis methods. Several different methods are used in the add-on modules, including finite element analysis, the finite volume method, the boundary element method, and particle tracing methods, but the emphasis of COMSOL Multiphysics® is on the finite element method. Many types of finite elements are available, and fully coupled elements are automatically generated by the software at the time of solving [7]. The basics of the theory of heat transfer used in this paper are presented in [8, 9, 10, 11].

The same geometry and materials was used as in the experiment. A result temperature was in the same range as in the experiment. The coolest radiator was the same as in the experiment. The hottest radiator was different.

Comparisons between results of two described methods are shown in table 2.

Tab. 1: Weights and surface areas of the radiators

The radiator number	Weight, kg	Surface area, m^2
1	0.327	0.134
2	0.257	0.154
3	0.289	0.156
4	0.207	0.077

Tab. 2: Temperature of the radiators

The radiator number	Temperature from the experiment, °C	Temperature from the model research, °C
1	89.5	75.8
2	96.3	74.3
3	92.8	74.2
4	91.0	83.1

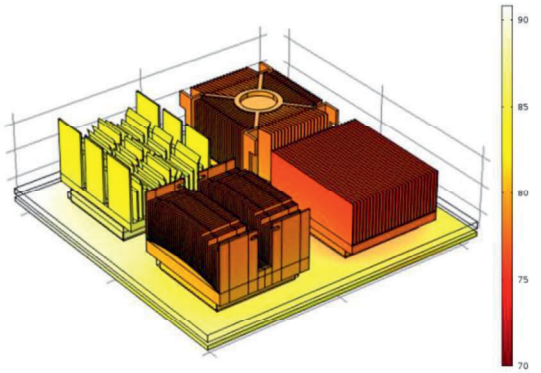

Fig. 4. 3D thermogram calculated in program COMSOL Multiphysics®

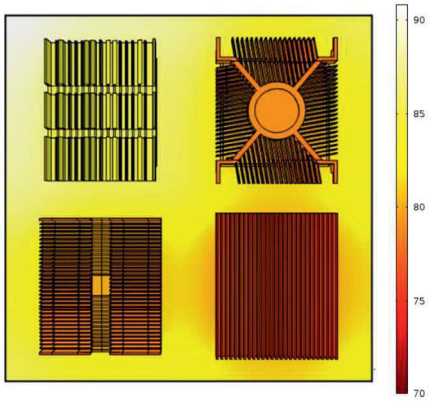

Fig. 5. 2D thermogram calculated in program COMSOL Multiphysics®

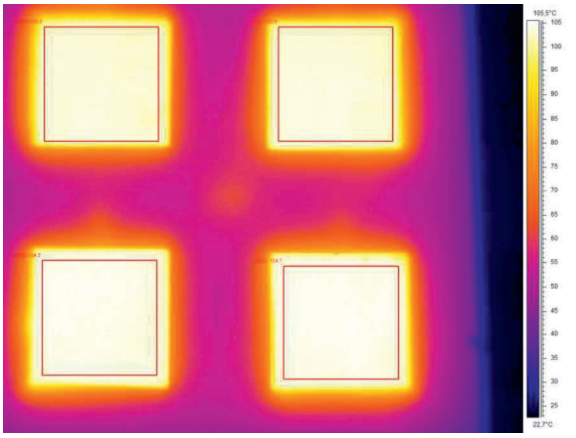

Fig. 6. Thermogram shows system without radiators when it's steady-state

Research and conclusions

Radiators are able to cool system faster than heather recover heather loses. This can be minimized using lower maximum temperature. The temperature drop is acceptable because conditions for all radiators are always the same.

Differences between temperatures of the radiators are noticeable and can be used to select the most performance radiator.

Result temperatures from the experiment and model research are in the same range. Differences could be generated because many small factors. Measurement system generates almost the same temperature on all of the fields. Differences are less than one degree during research without radiators. Model research could contain errors caused by approximations of the surface area. Research comes to conclusion that heat sinks can drain the same power regardless of the shape.

This is the initial research. Next stage of the work will be carried out extensive research with the other radiators which will contain different shapes, weights and surface areas. Research setting vertical orientation is predicted.

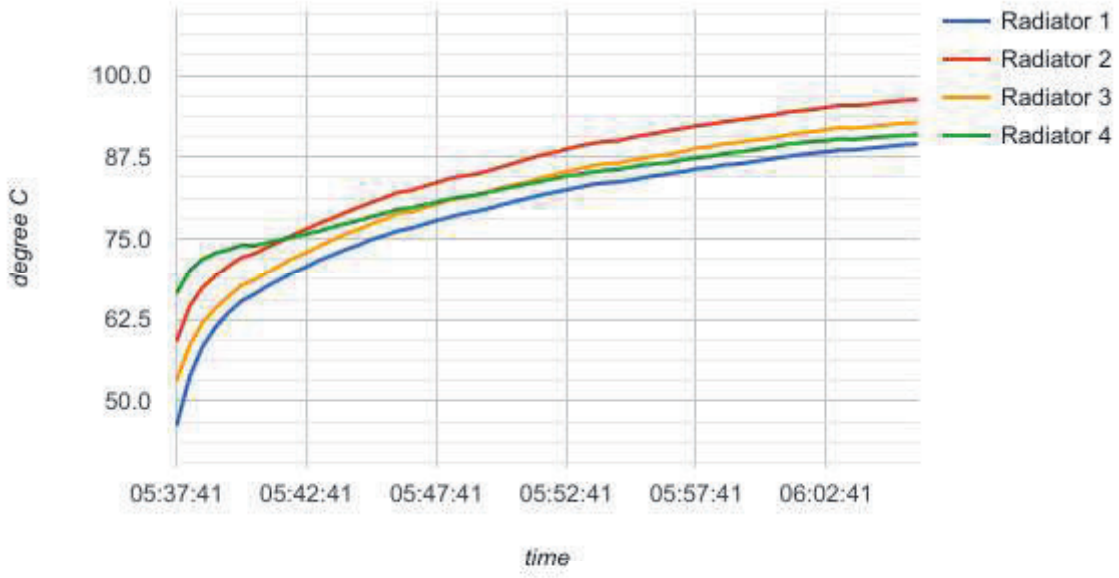

Fig. 7. Characteristic of the temperature of the radiators during time of the experiment

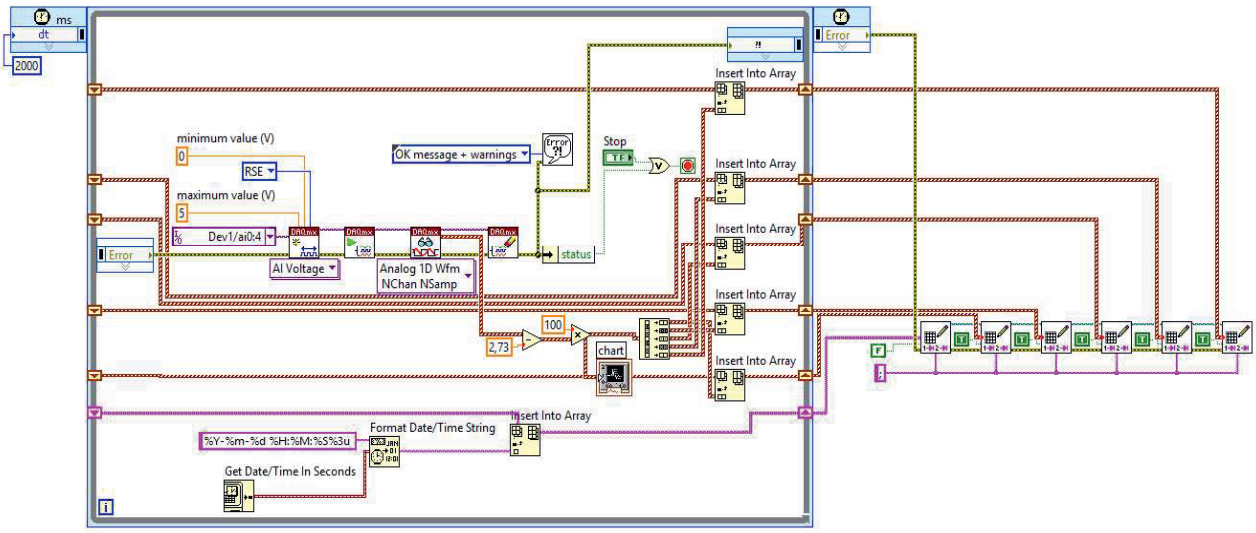

Fig. 8. Example of two-columns figure in LabVIEW software

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