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The dependence of surface temperature on IGBTs load and ambient temperature

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Abstract. Currently, older power electronics and electrotechnics are improvement and at the same time developing new and more efficient devices. These devices produce in their activities a significant part of the heat which, if not effectively drained, causing damage to these elements. In this case, it is important to develop new and more efficient cooling system. The most widespread of modern methods of cooling is the cooling by heat pipe. This contribution is aimed at cooling the insulated-gate bipolar transistor (IGBT) elements by loop heat pipe (LHP). IGBTs are very prone to damage due to high temperatures, and therefore is the important that the surface temperature was below 100°C. It was therefore created a model that examined what impact of surface temperature on the IGBT element and heat removal at different load and constant ambient temperature.

1 Introduction

The existing methods are based on the transport of cooling, the heat loss via the guidance of a well heat-conducting material cooler (usually copper or aluminium) to the ribs, from which the heat is removed by natural or forced convection to the ambient air. At elevated flow heat loss of the standard methods of heat transfer are insufficient and leads to overheating of electronic components. From the theory of heat and mass transfer is known to have the highest values of the heat transfer coefficients are obtained for the phase change, in particular by boiling and condensation, and therefore logically offers a choice of these events and the intensification of the removal of the loss of heat from electronic components. Especially when his transfer to places where the heat exchange surface, it can be substantially larger and take advantage of natural convection - the natural flow of coolant. [3]

Need for cooling by natural convection is typical for applications with high operating reliability. That the reliability of the system for removing heat loss increased, it is necessary to minimize the need to use mechanically or electrically powered elements, such as circulation pumps or fans. Experience to date with applications in specific heat pipe heat transfer systems of various potential unrealistic assumptions the use of phase change and thermosiphon effect thermokinetic and electrically suitable working fluid for removing heat loss by natural convection suitably modified heat pipe with closed-loop.

A simple capillary heat pipe closed loop, also has only LHP is shown in Fig.1. The activity LHP is based on the fact that at the start of the volume of liquid is sufficient for the completion of the condenser and the pipe with the liquid and vapour. This amount of liquid will be sufficient to saturate the mesh in the evaporator and the compensation chamber. If the bring the heat to the evaporator, the liquid starts to evaporate from the surface mesh and to a lesser extent, in the compensation chamber. Since the mesh has a strong heat resistance, temperature and pressure in the compensation chamber is less than the evaporator. The capillary forces in a mesh flow prevent vapour from the evaporator to the compensation chamber. If you increase the pressure difference between the evaporator and the compensation chamber, the liquid moves to the compensation chamber.

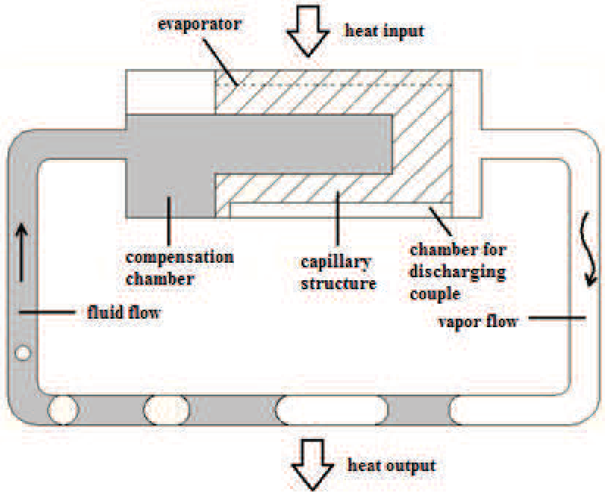

Figure 1 Thermal capillary tube with a closed-loop

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2 The proposal experimental heat pipe with a closed-loop

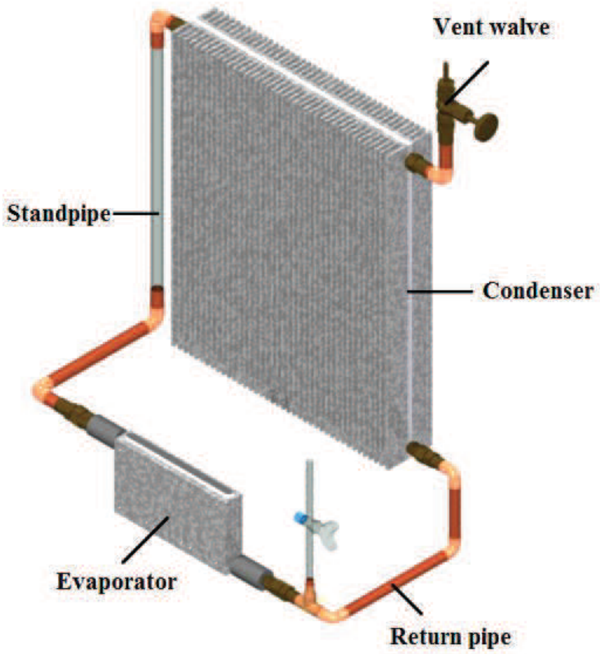

Figure 2 Schematic of experimental cooling circuit

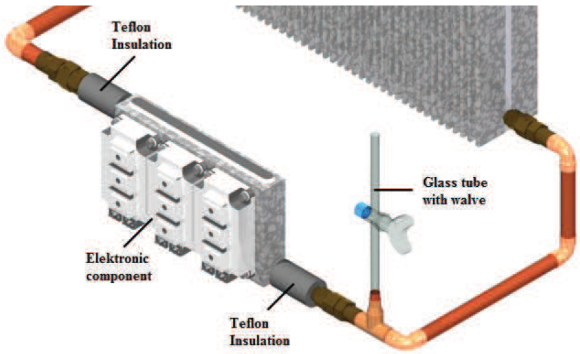

Figure 3 Vaporization of the cooling circuit

To assess the performance parameters of temperature and cooling, the scheme is shown in figure 2. Cooling circuit consists of two heat exchangers (evaporator and condenser). The evaporator and condenser are connected to each other via line such that a closed circuit.

A comparison of thermodynamic and electrical properties of various refrigerants as the cooling medium, we chose Fluorinert FC-72. FC 72 has similar properties to ethanol, but is electrically non-conductive. [7]

In terms of heat and mass transfer experimental equipment can be divided into two separate parts, namely:

- evaporation part
- condensation part

3 Implementation of this experimental heat pipe with closed-loop

To verify the calculated values can be implemented experimental device heat pipe closed loop according to the proposal. The device was realized according to the wiring diagram shown in figure 4. (C – condenser, E – evaporator, L – logger) [2]

Figure 5 shown to shoulder contact surface thermocouples to power electronic devices with flat evaporating part of the experimental facility. Under each semiconductor device are a thermocouple (labelled 6, 7, 8), the wall of the pipe outlet of the evaporator (Part 5) and the wall of the tube to the inlet of the evaporator (Part 5) and the wall of the tube to the inlet of the evaporator (Part 9)

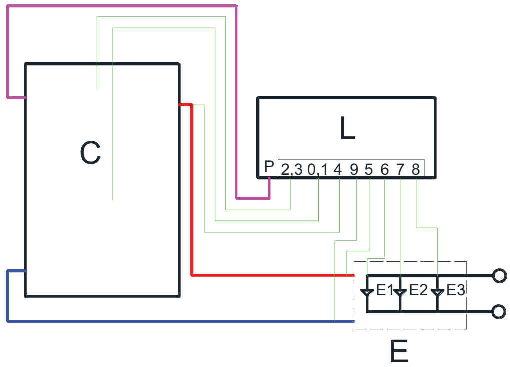

Figure 4 The wiring diagram

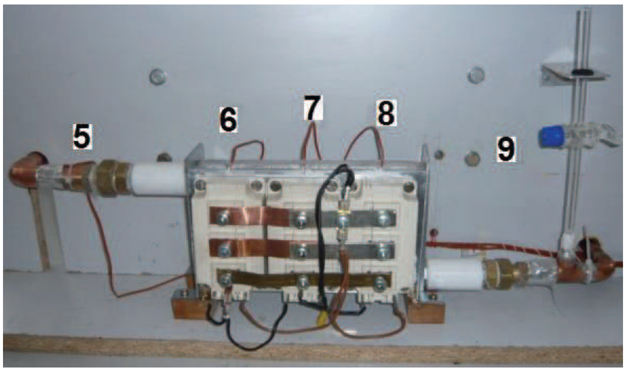

Figure 5 Consolidation of power electronic components for experimental LHP evaporator

In a similar way, thermocouples were placed on the condenser of the LHP. Installation of thermocouples on the condensation of the experimental apparatus is shown in figure 5. Four thermocouples were installed to measure the temperature entering the condenser pair. Thermocouples labeled 0, 1, 2, and 3 are intended for measuring the surface temperature of the condenser.

In order to monitor the surface temperature of the condenser, a TIC, the capacitor sprayed with black paint emissivity value of 0.96.

The ambient temperature was monitored, the condenser, using a thermocouple No. 10, as shown in figure 6.

The visibility of the absolute pressure in the system was equipped with a needle valve for the pressure sensor of the range 0 to 3.5 bar. [4]

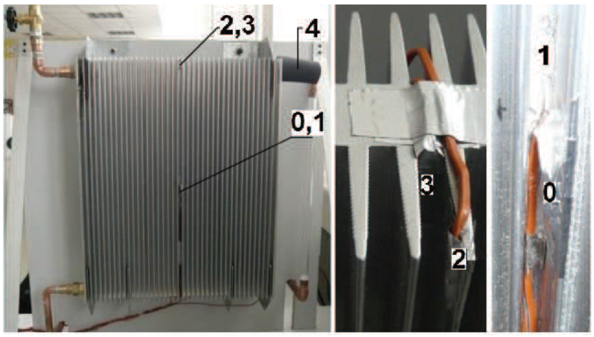

Figure 6 The condensation of the experimental facility

4 Comparison of experimental results with mathematical models

For better clarity trends of various dependencies are measured and calculated results of the processed form of graphs that give a more comprehensive view of addressing the application.

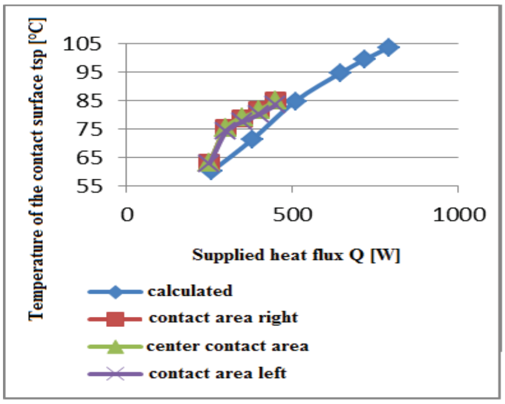

Figure 7 Temperature dependence of the contact surface of the heat flow.

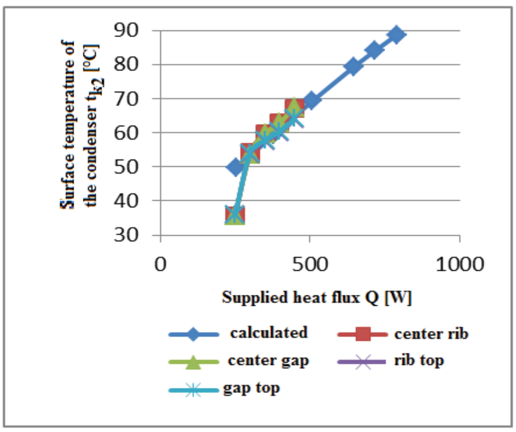

Figure 8 Dependence of surface temperature on the heat flux capacitor.

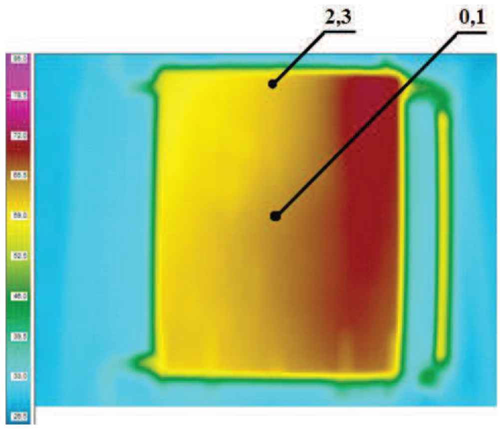

Figure 9 The surface temperature of a capacitor measured by thermovision camera to the heat flux Q˙ = 500 W (p = 216 kPa)

For visualization of temperature (figure 8) that is not capacitor equally stoked. To dissipate the heat flow is not needed the entire condensation surface. As follows the proposed heat pipe still has substantial reserves.

5 Comparison of the experimental results of the mathematical model at ambient temperature 27°C

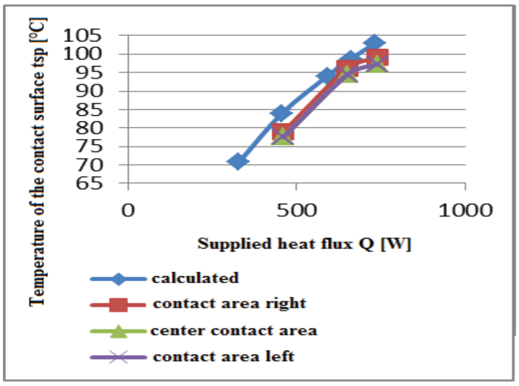

Figure 10 Temperature dependence of the contact surface of the supplied heat flow

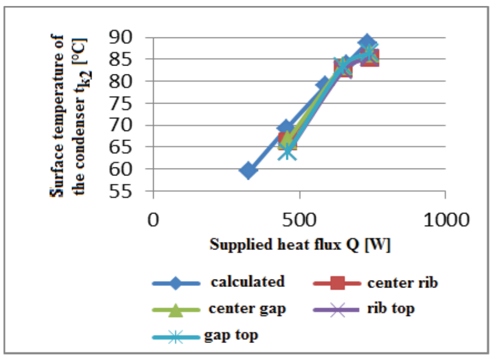

Figure 11 Dependence of the surface temperature of the condenser heat output of the supplied

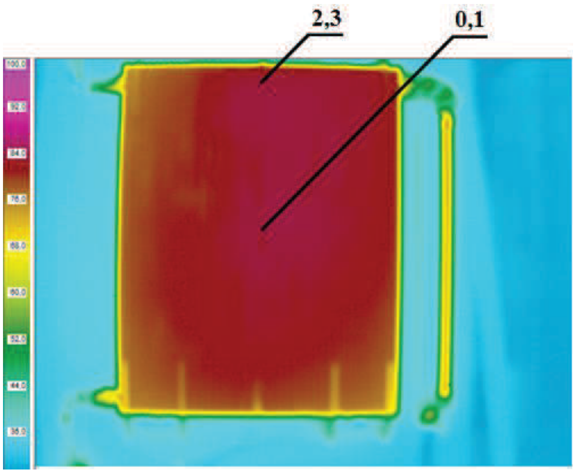

Figure 12 The surface temperature of a capacitor measured thermovision camera to the heat flow Q˙ = 738 W (p = 267 kPa)

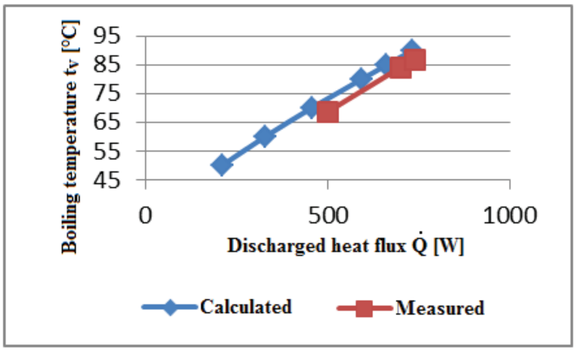

Figure 14 The dependence of the heat flow dissipated to the boiling point at ambient temperature 27°C

For visualization of temperature (figure 11) that the capacitor is evenly stoked than with the lower heat flows. For discharging the heat fluxes is a need for greater condensing surface or provide forced convection. However this is to be avoided due to the increased risk of malfunction influence of moving parts.

5.1 Exhaust heat flux depending on the ambient temperature

Of these dependencies shows that the ambient temperature greatly affects the amount of exhaust heat output. Were compared only two cases, at a temperature of 23 ° C and 27 ° C. Lower temperatures we do not care, because they involve a more intensive heat removal from components on its own IGBT. In summer the ambient temperature reaches a value much higher. In such cases it must be ensured already forced convection, otherwise there would be a disproportionate increase in the size of the condenser.

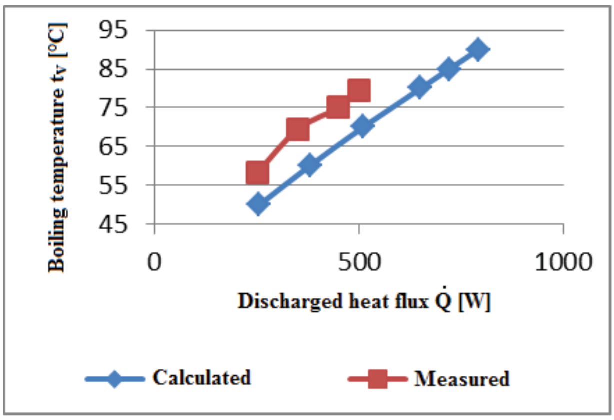

Figure 13 Dependence of the exhaust heat flow to the boiling point at ambient temperature 23°C

Conclusion

The basis for measuring the impact of ambient temperature on the thermal performance LHP was constructing experimental facility with measurement range of reference temperatures and heat output respectively the density of the heat flow to the evaporator. A series of measurements confirmed the significant effect of ambient temperature on heat output piped LHP, as the graphs show waveforms (figure 13 - 14). At an ambient temperature of 23 ° C boiling point is lower, but also the power transmitted is less than ambient temperature 27 ° C.

Based on the results obtained it can be concluded that the heat pipe closed loop is a suitable device for exhaust heat loss from the powerful electronic and electrical components and operating at high voltage electrical work, it allows large exhaust heat flux density, but also safely isolate these elements from the outer environment at any operating temperature.

Acknowledgment

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References

1. D. Reay, P. Kew, (2006),
2. P. Nemec, M. Malcho, J. Jandačka, AIP (2013)
3. P. Nemec et al. Comunications (2012)
4. P. Nemec et al., Mathematical and computing modelling (2013)
5. K. Ferstl, Vybrané state z prúdenia a prenosu tepla (1995)
6. J. Ruppresberg, Flow and heat transfer in closed loop thermosyphon (2007)
7. TOXNET (2013) http://toxnet.nlm.nih.gov/cgi-bin/sis/search/r?dbs+hsdb:@term+@rn+64-17-5
8. Fluidproperties (2012) http://fluidproperties.blogspot.sk/