DISTRIBUTION OF HEAT FLUX IN LOOP THERMOSIPHON BY WORKING FLUID AT HEAT REMOVE FROM IGBT

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Abstract: *Due to the increasing power requirements of the electronic components, which in many cases leads directly to increasing production of heat flux is the topic of the electronic cooling still current. In order to maintain their quality and lifetime as long as possible is the heat dissipation of electronic components solves by sophisticated technology such as a heat pipe technology. The paper deals with the cooling of power electronic component by loop thermosiphon. The loop thermosiphon is one from many proposal of heat pipe devices. Object of the paper is design and construction of the device to provide heat removal from the electronic component, thermal visualization of loop thermosiphon during operation, evaluation its cooling efficiency and research results interpretation. Paper describes function principle of loop thermosiphon, testing of the loop thermosiphon function and measurement of cooling efficiency in dependence on input electric power of the electronic component. The findings from measurement of loop thermosiphon cooling efficiency are compared with natural convective alumina cooler on the end of paper. The main object of the work is thermal visualization of heat flux transport by working fluid in loop thermosiphon from evaporator to condenser evolution. The result of the thermal visualization loop thermosiphon give us how the hydrodynamic and thermal processes which take place inside affect overall heat transport at start-up and during loop thermosiphon operation and distribution dynamics of the working fluid in dependence heat load.*

Keywords: HEAT TRANSFER, LOOP THERMOSIPHON, ELECTRONIC COOLING, THERMAL IMAGING

1. Introduction

Given the rapid progress in the electronics industry, the thermal management of electronic components becomes an important and serious issue. Miniaturization of devices and increase their performance leads to increased heat flow. Natural and forced cooling for heat sink are often deficient and thus is limited to low and medium heat flux. One possibility for heat dissipation for high heat flux is using thermosiphon loop. A closed loop thermosiphon is an energy-transfer device capable of transferring heat from a heat source to a separate heat sink over a relatively long distance, without the use of active control instrumentation and any mechanically moving parts such as pumps. These devices are thus particularly suitable for cooling electronic components. The closed loop thermosiphon may be visualized as a long hollow pipe, bent and the ends joined to form a continuous loop, filled with working fluid and orientated in a vertical plane. If the one side of the loop is heated and the other side cooled, the average density of the fluid in the heated side is less than in the cooled side. An essentially hydrostatic pressure difference, as a result of the thermally induced temperature gradient between the hot and the cold sides, rives the fluid flows around the loop. The ‘buoyancy’ force, as it is often termed, driving the fluid is in turn counteracted by an opposing frictional force that tends to retard the flow [1]. A thermosiphon loop can transfer heat from the interior of a microelectronic system to a central location where space limitations are less stringent. The advantages that a thermosiphon system enjoys over a conventional refrigeration system include: (1) absence of moving parts leading to a more reliable system operation, (2) increased choices for selecting a working fluid compatible with microelectronics chips since it does not have to go through a refrigeration cycle, (3) reducing the decomposition rate of the working fluid as the higher temperatures at the compressor discharge in a vapor compression refrigeration system are not encountered, (4) clean operation as no oil is circulated through the system. In comparison to pool boiling systems employing vapor space condensation, a thermosiphon loop offers more flexibility in terms of providing a centralized condenser with different feed lines to individual evaporator stations. Further, with the addition of a liquid circulating pump in a thermosiphon loop, higher heat transfer coefficients associated with flow boiling systems could be realized [2].

2. Loop thermosiphon construction

The main part of the loop thermosiphon construction are evaporator, condenser and transport pipeline. In the figure is shown model of the loop thermosiphon used in experiment. Evaporator is located in the lower of the device. It composes from aluminum of dimensions 115x80x30 mm (HxWxD), inside there is a system of four vertical holes of diameter 5 mm, hole pitch 15 mm. On the sides of the evaporator are holes of diameter 10 mm, for the inlet and outlet of the working substance. On the evaporator is mounted semiconductor device and connected to a laboratory power supply voltage and current, whose actions it generates heat. To increase the heat transfer between semiconductor devices and evaporator is used heat conductive paste. Between the evaporator and semiconductor device is located the thermometer for temperature control of semiconductor devices as the prevention of thermal failure [3].

The condenser section is located at the top of the device. For this application was used heat exchanger, which composes from copper pipe with the ribs from sheet of steel. Dimensions of the heat exchanger: length 740 mm, width 140 mm, height 30 mm, 3 mm rib pitch. Pipe has a length 1.5 m, diameter 10 mm and wall thickness of the pipe is 1 mm. The volume of the pipe is calculated to 301.6 ml [4].

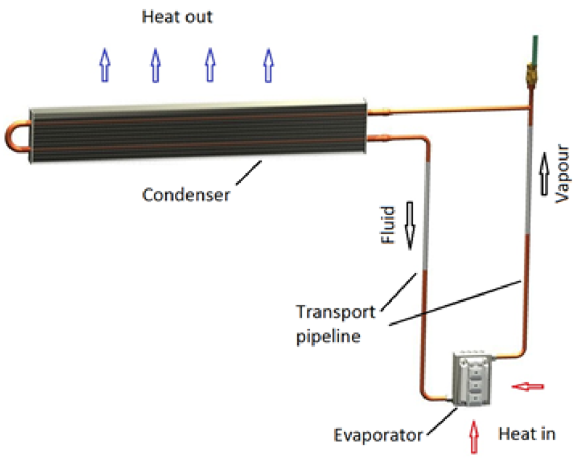

Fig. 1. *Loop thermosiphon model*

Transport pipeline is composed from copper pipes, copper and brass fittings and thoroughfares, which are connected to evaporator and condenser with the soft solders and soldering technology. Diameter of a copper pipe is 10 mm, wall thickness 1 mm. The total length of the transfer pipe, including fittings and thoroughfares is 1 m. Pipeline volume is 50.3 ml [5].

As a working fluid used in loop thermosiphon was chosen acetone due its good combination of thermophysical properties (table. 1) and low value of the boiling [6].

Table 1: *Thermophysical properties of Acetone*

Properties	Acetone
Chemical Formula	CH3 CO CH3
Molecular Weight	58.08
Liquid Specific Heat	125.45 J/mol·K
Liquid Thermal Conductivity	0.181 W/m.K
Density at 20 °C	790 kg/m^3
Dielectric Constant 25 °C	21.45
Latent Heat of Vaporization (at normal boiling point)	520 J/kg
Vapor Density at 20°C	0.64 kg/m^3
Vapor Pressure at 20 °C	181.7 mmHg
Viscosity at 20 °C	0.32 cP
Surface Tension at 20 °C	23.7 mN/m
Auto ignition Temperature	560 °C
Boiling Point (760 mm)	56.1 °C
Melting Point (freezing point)	-93.9 °C

3. Experiment

The experiment consist of thermal field visualization of the loop thermosiphon by infrared camera, temperature measurement in significant points of the evaporator and condenser part to compare with thermal imaging and comparison cooling efficiency of the loop thermosiphon with alumina air cooler depending on the input heat load.

Thermal field visualization of the loop thermosiphon

The experiment deal about distribution of heat flux by working fluid in loop thermosiphon and evolution of free convection from loop thermosiphon condenser to the surrounding. This experiment was realized with loop thermosiphon described in the part loop thermosiphon construction. The condenser part of LT was created, so that heat loaded to the evaporator was dissipate to the surrounding by natural convection. The volume of the working fluid in LT is 50 % of overall LHP volume. In the figures 3 to 8 are shown thermal images of the loop thermosiphon loaded by heat of 150 W. On the figures is seen heat flux distribution by working fluid at the time [7].

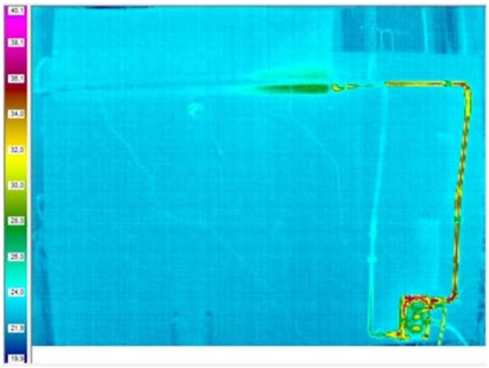

Fig. 2. *Surface temperature develop at time 2 min from heating start*

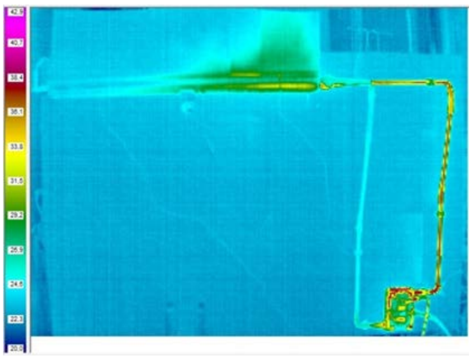

Fig. 3. *Surface temperature develop at time 3 min from heating start*

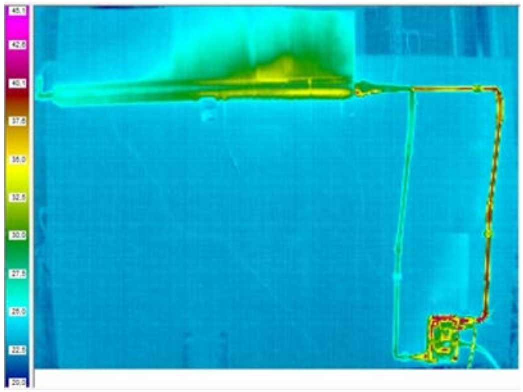

Fig. 4. *Surface temperature develop at time 4 min from heating start*

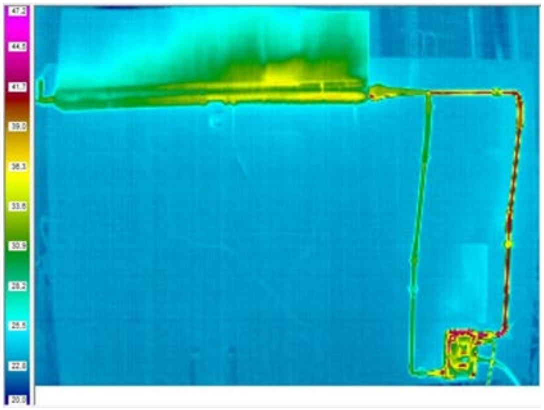

Fig. 5. *Surface temperature develop at time 6 min from heating start*

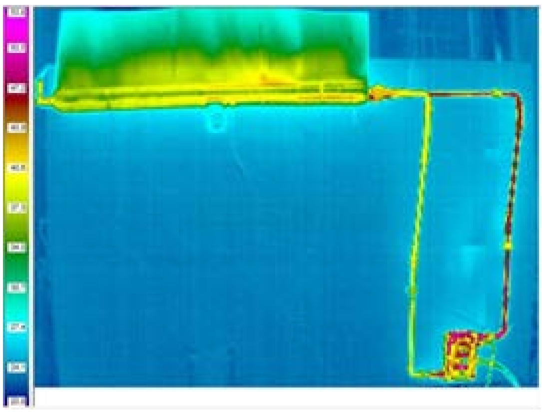

Fig. 6. *Surface temperature develop at time 12 min from heating start*

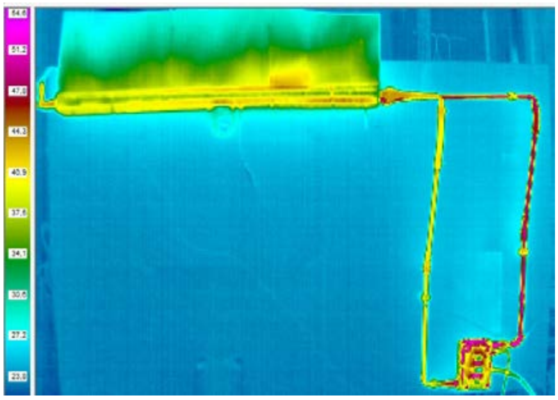

Fig. 7. *Surface temperature develop at time 32 min from heating start*

On the first four thermal images is seen startup of loop heat pipe, where is the heat flux gradually transferred by working fluid from evaporator to the condenser part. On the last two thermal images is seen fully operated loop heat pipe with no temperature changes at time. There is seen different temperature between vapor line (on the right) and condenser line (on the left), too. The vapor line is hotter than the condensation line. It means that the vapors of the working fluid transfer all heat flux from evaporator (on the bottom) to the condenser (on the top). The vapor of the working fluid heat sink to the surrounding, condense to liquid and working fluid is return back to the evaporator.

Temperature measurement of the loop thermosiphon

During loop thermosiphon operation was measured temperature in significant points of the evaporator and condenser part to compare with thermal imaging. In the figure 8 is shown experimental measurement with position of each devices. The loop thermsiphon is situated on the figure background, in front the figure is IR camera, on the table are situated laboratory electric power source to electric load of the electric component mounted on the loop thermosiphon evaporator and computer with software to imaging thermal images scanned by IR camera. The result of the loop thermosiphon temperature measurement are shown in the figure 9.

Fig. 8. *Thermal visualization experiment*

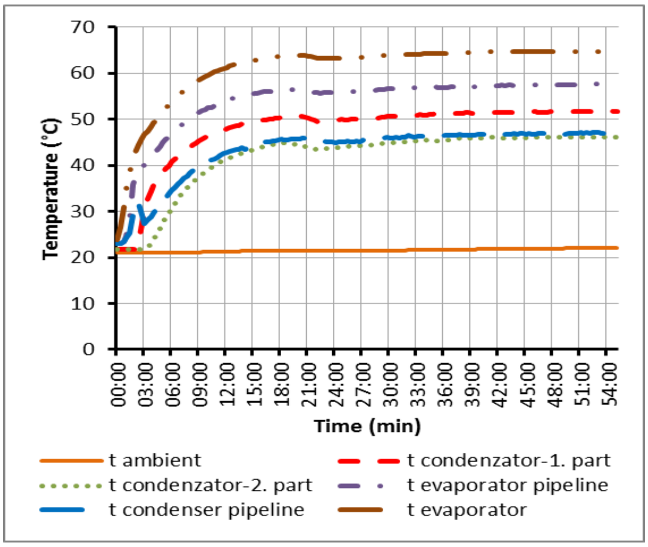

Fig. 9 Results of the loop thermosiphon temperature measurement

There is seen that approximately in range from 15 to 55 minute from heating start have all temperature stable development and that the temperature differences between evaporator and condenser are after longer time still approximately 15 °C which mean that heat from evaporator is removed constantly. Results temperature measurement of the loop thermosiphon confirm the results thermal field visualization of the lop thermosiphon.

Cooling efficiency of the loop thermosiphon

On the end experiment was performed measurement cooling efficiency of the loop thermosiphon and compared with cooling efficiency of the alumina air cooler. In the figure 10 are shown results of both measurement, where is seen that heat remove from electronic component by loop thermosiphon is more effective than by air cooler, when temperature of the electronic element even at heat load 300 W not exceed 80 °C.

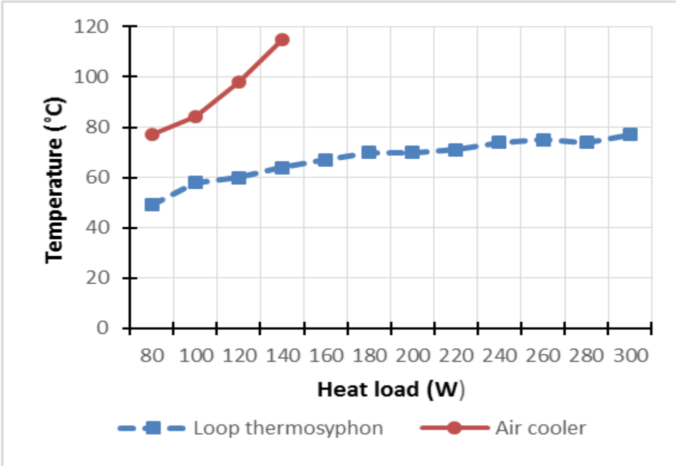

Fig. 10 Temperature development depending on the heat load

4. Conclusion

The paper deal with the cooling of power electronic component by loop thermosiphon. There was designed and constructed loop thermosiphon to heat removal from electronic element, performed some experimental measurement during its operating and comparison cooling efficiency with air cooler. The experiments have three conclusions. Firstly thermal field visualization shown that our design of loop thermosiphon operating correctly. Secondly the effect of the heat remove from electronic element by loop thermosiphon is quick, approximately 15 minutes form heat load start. Thirdly heat removal by the loop thermosiphon is more efficient than air cooler, when was find that the temperature of the electronic element even at heat load 300 W not exceed 80 °C.

Acknowledgment

This work has been financially supported by the projects APVV-15- 0778 Limits of Radiative and Convective Cooling through the Phase Changes of Working Fluid in Loop Thermosyphon (50 %) and KEGA 042ŽU-4/2016 Cooling on the basis of physical and chemical processes (50 %).

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