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OBSERVATION OF THE THERMOSIPHON EFFECT IN THE CIRCULATION OF ACETONE AS WORKING FLUID IN MODERN COOLING SYSTEM

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Abstract

Packaging and thermal management of electronic equipment that are located i.e. in a novel marine power plants or computer server rooms has led to the demand for new and reliable methods for electronic cooling. Because of bigger and bigger power levels and miniaturization of the electronic devices, lack of free space in marine power plant, typical cooling techniques such as conduction and forced convection are not able to cool such a high heat flux. The increasing integration of electronic systems requires an improved cooling technology that supposed to be designed for high thermal performance, low mass, and able to work in harsh environments.

In this paper presented a prototype of thermosiphon loop heat exchanger developed in Institute of Energy and Industrial Processes in Gdansk University of Technology. This thermosyphon loop is heated from below horizontal side and cooled from upper horizontal side, the working fluid that circulate inside the loop is acetone.

Keywords: *marine power plants, heat transfer, heat exchangers, termosiphons. Loop Heat Pipes*

1.Introduction

The important function of a natural circulation loop (i.e. thermosyphon loop) is to transport heat from a heat source to a sink. Fluid flow in a closed thermosyphon loop is created by the natural forces that develop from the density gradients induced by temperature differences in the heating and cooling sections of the loop. An advanced thermosyphon loop consists of evaporator, where the working liquid boils; and the condenser where the vapour condenses back to liquid; and liquid and vapour lines connecting these two exchangers. Heat is transferred as the vaporization heat from the evaporator to the condenser. The thermosyphon is a passive heat transfer device, which makes use of gravity for returning the liquid to the evaporator. Thermosyphons are less expensive than other cooling devices because they feature no pump.

There are many engineering applications for thermosyphon loops such as, for example, solar water heaters, air heat recovery systems, thermosyphon reboilers, nuclear power plants, emergency cooling systems in nuclear reactor cores, electrical machine rotor cooling, gas turbine blade cooling, thermal diodes and electronic device cooling.

2. Literature review

A thermosiphon, gravity-assisted wickless heat pipe, has been used as a practical heat transfer device due to its simple structure Faghri 1995 [1] or Pioro 1997 [6]. The heat transfer between two ends of the thermosiphon occurs with negligible temperature difference because a thermosiphon utilizes liquid–vapor phase change phenomenon of fluid. The only disadvantage of thermosiphon in many application is its gravitational dependence and the limited operating temperature range that is specifically determined by the choice of working fluid. There has been a number of studies about termosiphons. Khandekar et al. [2] studied the overall thermal resistance of closed two-phase thermosyphon using pure water and various water based nanofluids (of Al2O3, CuO and laponite clay) as working fluids. They observed that all these nanofluids show inferior thermal performance than pure water since nucleation sites were closed by the deposition of the nanoparticles. Lee et al [3] studied double-evaporator thermosiphon for cooling high temperature superconductor system using nitrogen as the working fluid under sub-atmospheric pressure condition. Lee et al [3] conducted that double-evaporator thermosiphon can be a useful heat transfer device that can simultaneously cool-down the thermal loads vertically separated under a tight space limitation.

3. Design and Experimental Setup

3.1. Loop Thermosyphon Design

The experimental thermosiphon loop was constructed on the basis on existing test up stand for testing the performance of evaporators filled with wick made up with mixture of sintered material powder. This experimental test up stand previously worked as Loop Heat Pipe and was described in literature by Mikielewicz et al. [4] and Mikielewicz and Szymański [5]. The only element that has been changed is evaporator – at this construction evaporator is empty cylindrical tube made by cooper, heated over the entire length. This setup stand was also set vertically, to utilise the gravity forces for circulating the working fluid.

3.2. Experimental Setup

The experimental setup has cylindrical evaporator. Evaporator heat source is a resistance wire wrapped around evaporator. The wire length is 1,3m and resistance of 32Ω . This wire was connected to a DC laboratory power supply with adjustable voltage and current level. Condenser is a typical shell and tube heat exchanger where the shell is made by cylindrical cupper tube of Ø254 mm diameter and stainless steel tube of Ø6,35 mm diameter. The condenser was cooled by tap water at a temperature of approx. 7,5^{o}C and the mass flow was measured by a laboratory rotameter. The liquid and vapour lines are smooth stainless steel tubes of a length 5000mm and internal diameter Ø3,87mm. The whole system was insulated using polyethylene foam. Appearance of experimental set up presented at Figure 1 and details of termosyphon tested are given in Table 1.

The loop was equipped with 8 thermocouples “type T” and sensitivity of 40μV/°C. The thermocouples were connected to Pico Technology Thermocouple Data Logger Type USB TC-08. The thermocouples were located at the most important measuring points of the system that are: 1 - evaporator casing, 2 - vaporator outlet/vapour line inlet, 3 - vapour line outlet/condenser inlet, 4 - condenser outlet/liquid line inlet, 5 - liquid line outlet/evaporator inlet, 6 - condenser cooling water inlet, 7 - condenser coiling water outlet, 8 - ambient. The system was equipped with two pressure transducers connected to displays and powered by a laboratory DC power supply. The first pressure transducer measured the internal pressure inside the system (Swagelok PTU-F-AG60-12AI), and the second one measured the differential pressure between evaporator inlet and outlet. This differential pressure transmitter was made by Regin company (DTK100-420). View and distribution of pressure transmitters were shown in Figure 1.

Tab. 1. Details of thermosyphon

Working fluid	Acetone
Temperature range	60°C- 80°C
Evaporator casing	Cupper
Heated part	210 [mm]
Diameter	Ø14 [mm]
Wall thickness	1 [mm]
Vapour line	Stainless steal
Internal diameter	Ø3,87 [mm]
Length	5000 [mm]
Wall thickness	1,24
Liquid line	Stainless steal
Internal diameter	Ø3,87
Length	4940,4
Wall thickness	1,24
Condenser	Cupper
Length	270 [mm]
Internal diameter	Ø3,87 [mm]

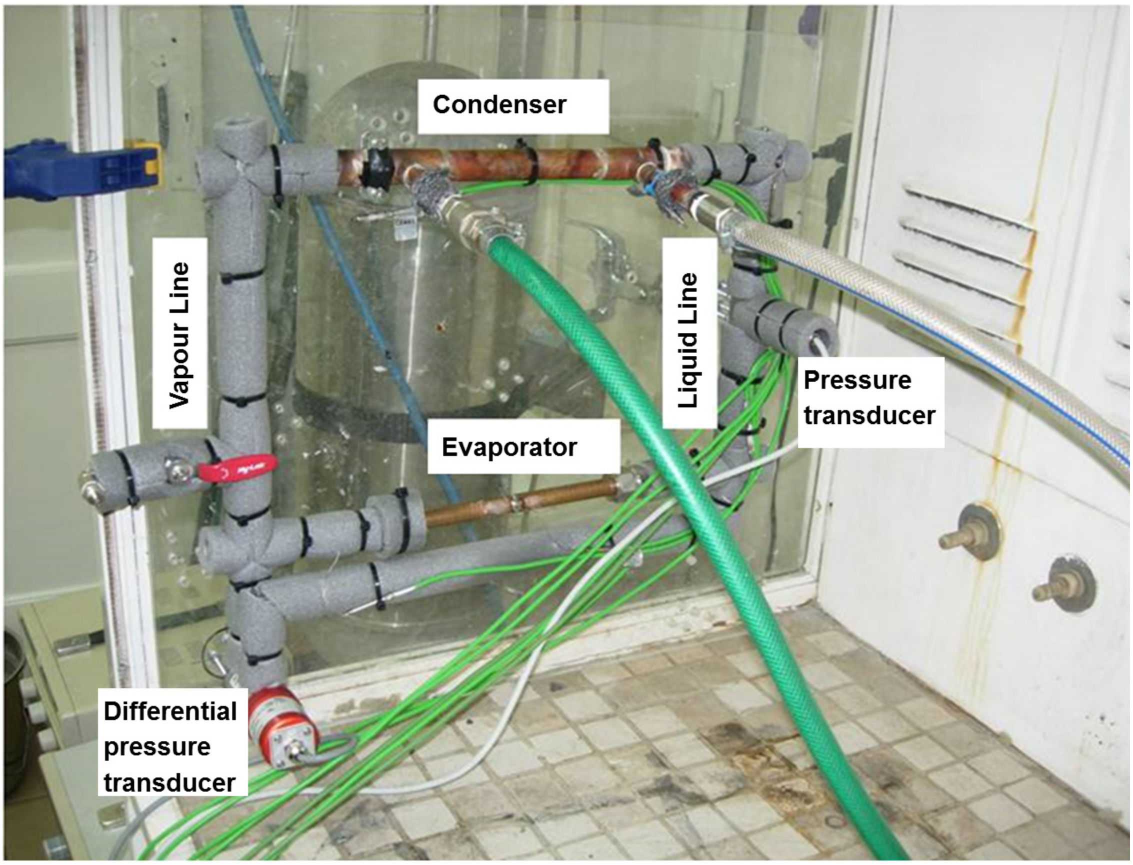

Fig 1. Scheme of experimental test-up stand

4. Experimental Result and Discussion

The purpose of preliminary test is to measure the maximal pressure maximum pressure difference obtained before and after the evaporator for acetone as the working fluid. Tests were performed for 6 heater power settings (30W, 40W, 50W, 60W, 70W and 80W) and the various flow rate of condenser cooling (30 l/h, 50 l/h, 100 l/h, 150l/h). The results are shown in a line graph (Figure 2) showing the dependence of the pressure difference obtained before and after the evaporator on heating power.

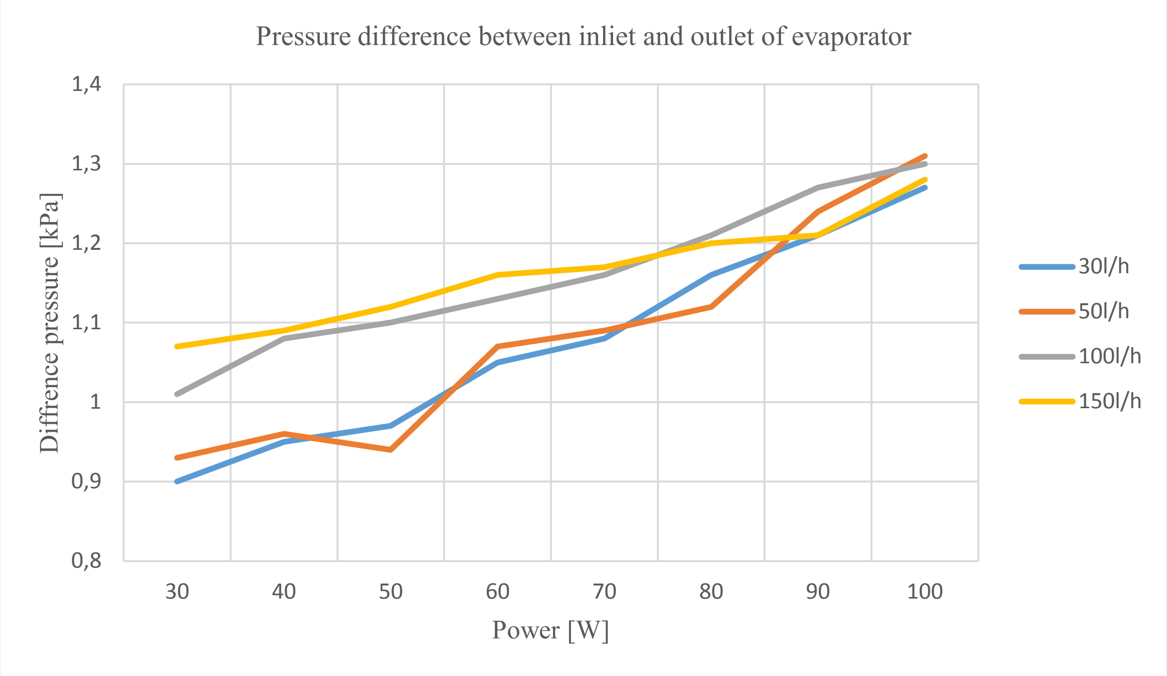

Fig. 2 The dependence of the pressure difference obtained before and after the evaporator on heating power

4. Conclusions

As shown in Figure 2. the best thermosiphon performance is achieved using applying to condenser cooling of flow rate of 150l/h. For the heater power of 30-80W the pressure rise before and after the evaporator achieved in a range from 1,08-1,28 [kPa]. It gives us a good predictions for future studies of pressure rises and heat transfer at the termosiphon loops. It also give us new hints to improve the design of thermosiphon loop.

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