COOLING SYSTEMS BASED ON HEAT PIPES FOR THERMALLY LOADED COMPONENTS OF PERSONAL COMPUTERS

Boris M. Rassamakin, Sergey M. Khayrnasov, Valery A. Rogachev, Olga V. Alpherova, Konstantin V.Koolick
Heat Pipes Laboratory
National Technical University of Ukraine
“Kyiv Polytechnic Institute”
of.709, 6 Politechnichna st, Kyiv 03056, Ukraine
Tel/Fax:(38 044) 241-86-66, Tel(38 044) 454-96-02
E-mail: lab-hp@tefntuu.kiev.ua

Abstract

Comparative analysis of known traditional coolers and coolers based on heat pipes has been done in accordance with the research results. Advanced cooler design based on heat pipes and having upgraded thermal specifications has been proposed. Proposed cooler is weighting twice less than foreign analogues. Approaches and methods for creation of effective and reliable cooling systems with Heat Pipes for thermally loaded modern PC devices

KEYWORDS

Heat Pipe (HP), cooler, finned surface, thermal resistance, thermal effectiveness.

INRODUCTION

Reliability and processing speed of modern PCs depends on strict maintenance of nominal thermal operation mode for their basic heat radiating micro units and devices. As computer components processing power is raising, diffused by them heat power is increasing steadily. However, permissible operation temperature range of PCs’ semiconductor devices as a rule continues to be invariable by virtue of their nature. Therefore, problem of thermally loaded PC components cooling becomes acuter for the PC customers and developers, especially for that ones, who try to increase processing speed at all costs including “racing”.

Permanent processors’ (CPU) cooling devices, made as a combination of finned surface and low-pressure axial-flow fan, so called “coolers” become wide spread [1].

Modern coolers of the famous producers such as: Thermaltake, Titan, Maxtron, having 65-75 W dissipation power and 70-90 °C temperature range of loaded processor kernel, are characterized by rather high maximal thermal resistance values, being in the range R_{max}=0.55-0.75 K/W, and that as a whole causes lowering of heat shedding ability of cooling system. Thus traditional coolers, comprising heat radiating surface and ventilator, already do not provide normal cooling regime, enough for temperature maintenance in operational range for powerful processors. Still more attention is being attracted to the alternative solutions. Cooling device, where Heat Pipes (HP) are used, is one of them. It is possible to refer to them new generation of multiplatform coolers of high-end class such as: Cooler Master Hyper6, Gigbyte 3D Cooler-Ultra, Thermaltake Silent Tower [2]. In comparison with usual ones indicated coolers have essentially low total thermal resistance R_{max}=0.3-0.4 K/W at Q=65-80 W dissipation power, that is explained by application in them of HPs and highly developed heat radiating surface. For example, total surface area for heat exchange of HPs condenser at Cooler Master Hyper6 is 3800cm^2, and at Thermaltake Silent Tower(CL-P0025) cooler is 7500 cm^2. Great mass of multiplatform coolers can be considered as their disadvantage, so Cooler Master Hyper6 made of copper HPs and finned surface weights 950 g. Further development of heat radiating surface and its effective ventilation for this cooler design type is rather limited. Besides, there appear difficulties with such heavy coolers arrangement inside the system unit case, and inevitable arrangement of the whole cooling system in the region of heightened heat radiation creates unfavorable working conditions for heat exchange surface and fan, because heated air passes through them.

RESEARCH METHOD AND EXPERIMENTAL DATA PROCESSING

In order to define efficiency of modern cooling devices and to carry out their comparative analysis, air cooling system with HPs has been investigated for heat loaded PC elements.

General view of cooling device with HPs, which has been developed at NTUU "KPI", is shown in Fig. 1.

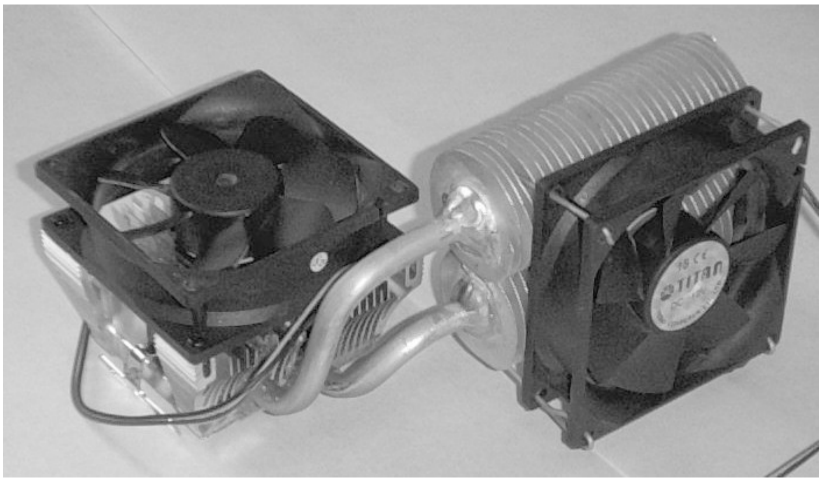

Fig. 1. Cooling device with HPs

Cooling system consists of: contact heat radiating finned surface, being fixed to heat radiating PC component and joined with evaporating parts of HPs, two HPs with finned heat radiating surfaces at condensing parts, two serially produced small-sized fans.

Schemes of investigated cooling devices in the form of usual standard cooler (Fig. 2, a) and cooler with HPs (Fig. 2, b) are given in Figure 2.

Cooling ambient air was ventilated with the help of the fan 1 from above to finned heat exchange surface 2, as it is clear from Fig. 2, a scheme.

Electric heater 3, which has dimensions 30×30×10 mm and is pressed tightly to the base of finned surface by means of heat conductive paste **КТП-8**, is used as a simulator of PC heat radiating component.

Smooth part of the base and the heater were shielded by thermal insulation 4 in order to avoid of heat losses. Version of Fig. 2, b varies from version of Fig. 2 a. by application there of two aluminum HPs (TT) 5 Ø8 mm [3]. Evaporative parts of HPs were fixed inside the fins' interspaces of contact heat radiating finned surface by means of heat-resistant heat-transfer joint.

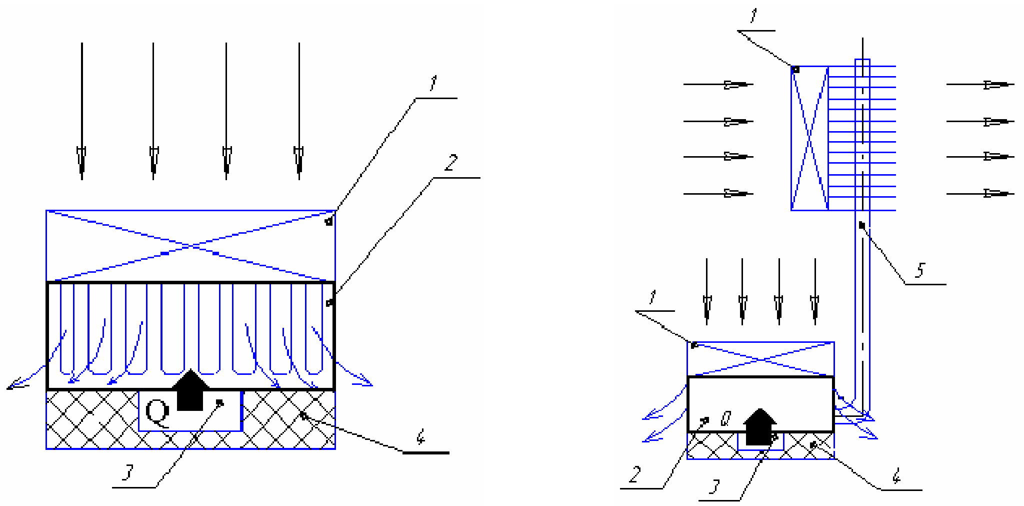

Fig. 2. Schemes of cooling devices
1 – fan; 2 – heat radiating surface; 3 – heater; 4 – thermal insulator; 5 – HPs.

Compensative parts of HPs are equipped with transverse spiral fins, made by means of knurling, as a result of which ideal thermal contact between fins and bearing wall of HP is provided. Surface of HPs condensing parts is ventilated with the help of second fan 1, which is fastened to their fins.

Two small-size fans of TFD-8025M12B type, which are components of cooler Titan, were used for blowing of heat radiating surfaces.

The overall dimensions of axial-flow fan are 80×80×25 mm, rotation frequency is 2000 rotations/min (RPM) when electromotor power supply current is 0.11 A, noise performance is not higher than 30 db.

Contact aluminum finned surfaces were investigated: serially produced of Titan cooler and developed at NTUU "KPI" lamellar-ribbed, having equal heat radiating surfaces each of 500 cm^2 area. Heat exchange area of HPs condensing parts was 1000 cm^2, and area of heat radiating surfaces of cooler with HPs totaled 1500 cm^2.

Temperature fields at heat radiating surfaces of cooling systems(Fig. 2, a, b) and ambient air temperature were measured by means of copper-constantan thermocouples Ø0.16/0.1mm. Thermocouples were placed at the smooth part of finned heat radiating surface base, at the evaporative and condensing parts of HPs, near the fan sucks. Maximal cooler temperature was measured by the thermocouple, which was fastened in the centre between plane surfaces of the heater and the base. There were ten of them. Thermocouple readings were logged and screened out to PC by Computer Aided Multi-channel Temperature Measuring System "**АМСИТ**", developed at NTUU "KPI" [4]. Electric heater was fed by alternating current through the voltage stabilizers, and its power Q was controlled by the **Д592** type wattmeter having 0.1 exactitude class.

It was assumed that practically whole radiated by heater power was dissipated with the help of finned heat radiating surfaces, because the heater, smooth part of evaporative zone of heat radiating surface, HPs transfer zones were covered with thermal insulating layer.

Maximal overheating (maximal redundant temperature) of cooling system is determined as follows $\Delta t_{\max} = t_{\max} - t_{amb.}$, where $t_{\max}$ – maximal temperature in the centre of basic heat radiating surface base (so temperature of processor kernel is approximately simulated), $t_{amb.}$ – ambient air temperature. Maximal thermal resistance of the system is calculated from the expression $R_{\max} = \Delta t_{\max} / Q$, where Q – dissipated (shed) heat power. Relative mean-root-square error of temperature drop determination for dissipated power of low levels did not exceed $\pm 5\%$.

Experiments were conducted within the range of dissipated power Q=20…130 W and ambient air temperature $t_{amb} = 20...25$°C.

RESEARCH RESULTS

Comparison of thermal efficiencies for various cooling systems is executed according to the analysis results of graphical relations $\Delta t_{\max} = f(Q)$, which are given in Fig.3.

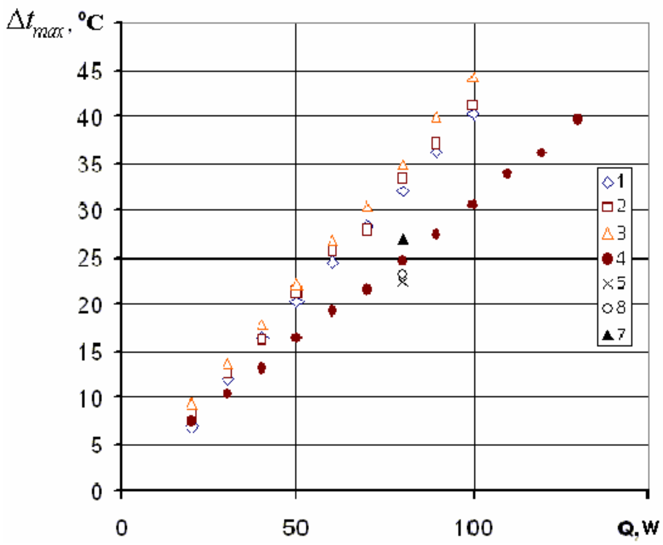

Fig. 3. Thermal characteristics of cooling systems
1 – cooler Titan when electric current is 0.16A, 2 – cooler Titan when electric current is 0.11 A, 3 – NTUU "KPI" cooler when electric current is 0.11 A, 4 – cooler with HPs of NTUU "KPI", 5 – Cooler Master Hyper6 (2 fans), 6 – Cooler Master Hyper6(3000RPM), 7 – Cooler Master Hyper6 (2000RPM)

Curves 1 and 2 illustrate thermal characteristics of Titan coolers for fan's current 0.16 A and 0.11 A, that corresponds to its impeller rotation with 3000 RPM and 2000 RPM.

Titan cooler thermal efficiency is better for 0.16 A electric current, and that is caused by higher speed of heat radiating surface ventilation.

Efficiency of NTUU "KPI" cooler at 0.11 A fan's power supply current is 6% lower than of Titan coolers, and that corresponds to the higher position of curve 3 relatively to other curves. Gradual stratification of 1, 2 and 3 curves is seen for heat shedding increase within power range Q = 50-100 W. Heat removal power of compared coolers for fixed redundant temperature practically is identical at small dissipation power Q = 20-50 W, as it is seen from the diagrams.

NTUU "KPI" cooler with HPs has better thermal efficiency, as it appears from the lowest position of the curve 4 in the diagram. So, thermal efficiency is 25-30 % higher in comparison with traditional coolers when temperature of overheating is maximal $\Delta t_{\max} = 25^{o}C$.

Temperatures of overheating for processors power Q=80 W are plotted in Fig. 3, and they are represented as 5, 6 and 7 points for modern cooling systems Cooler Master Hyper6 (2 fans), Cooler Master Hyper6 (3000RPM), Cooler Master Hyper6(2000RPM) [2].

Overheat of Cooler Master Hyper6(2 fans) equipped with two fans is 1.5 °C lower than of NTUU "KPI" cooler equipped with HPs, when dissipation power is the same.

Characteristics of NTUU "KPI" cooler and CMH6(3000 RPM) coincides, but overheat of CMH6(2000 RPM) is 3 °C higher, that indicates worsening of its thermal efficiency.

Total maximal thermal resistances for the investigated cooling systems in the form of graphical dependencies $R_{\max} = f(Q)$ are shown in Fig. 4.

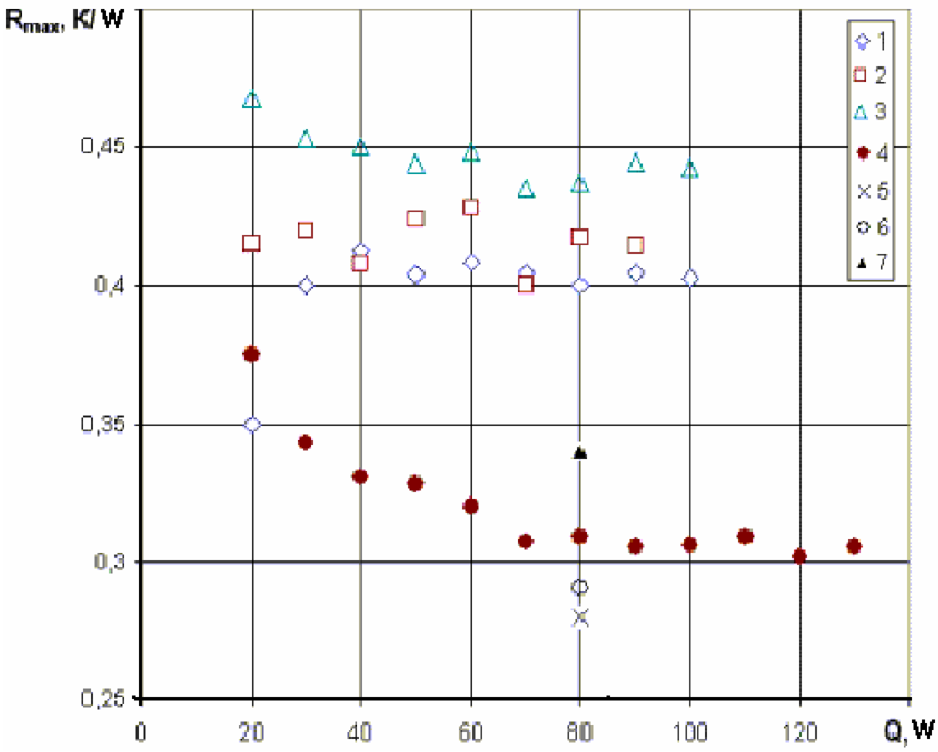

Fig. 4. Maximal thermal resistances of cooling systems
1 – cooler Titan when electric current is 0.16A, 2 – cooler Titan when electric current is 0.11A, 3 – NTUU "KPI" cooler when electric current is 0.11 A, 4 – cooler with HPs of NTUU "KPI", 5 – Cooler Master Hyper6 (2 fans), 6 – Cooler Master Hyper6(3000RPM), 7 – Cooler Master Hyper6(2000RPM).

As it is clear from the figure, thermal resistances of traditional coolers within dissipation power range 20-100 W vary within their narrow range of 0.4-0.45 W. The best among the compared coolers is Titan cooler (3000RPM) with admissible thermal resistance $R_{\max} \approx 0{,}4$ K/W.

Thermal resistances of coolers with heat pipes are 1.3 – 1.5 times lower than of traditional ones. Thermal resistance of NTUU "KPI" cooler is near 0.305 K/W when its dissipation power is $Q \geq 60$ W, and it continues to be stable as power increases. Gradual resistance increase is observed at power Q<60W, and that is due to scanty effective operation of Hps at low power.

Points, which correspond to thermal resistances of advanced coolers of high-end class: Cooler Master Hyper6 (2 fans), Cooler Master Hyper6 (3000RPM) and Cooler Master Hyper6 (2000RPM), are plotted on the diagram for 80 W dissipation level.

As it is shown in Figure 4, thermal resistances of cooling devices Cooler Master Hyper6 (2 fans) and Cooler Master Hyper6 (3000RPM), having better heat removal, are 0.28 W and 0.29 W respectively, and they are 5-9 % lower than resistance of NTUU "KPI" cooler for the set power. However, resistance of NTUU "KPI" cooler is 11 % lower than the same one of Cooler Master Hyper6 (2000RPM). It is necessary to mark, that thermal resistance depends not only on thermal aerodynamic factors but also on, for example, way of its flattening against the processor and cooler's mounting place architecture, which in turn is defined by the platform type. Minimally possible values of compared coolers' thermal resistances for Socket 478 platform are adduced as an example. Thus, in consequence of thermal resistance experimental data analysis, NTUU "KPI" development is able to compete with world analogues and to meet mass gain for the whole cooling system. Proposed cooler weights 480g, and it is twice less than the same one of Cooler Master Hyper6 (3000RPM, 2000RPM).

CONCLUSION

Research has proved that application of coolers based on Heat Pipes is one of methods of efficiency increase for heat removal from PC elements and devices.

Further research on considered coolers should be carried out in the following directions:

- development of concrete design solution for cooling systems of thermally loaded PC devices;
- development of intensifying heat releasing surfaces' areas for evaporative and condensing parts of HPs;
- ensuring of reliable thermal contact between the surface of HP's evaporative part and the base of contact heat releasing surface;
- finding of the most rational cooling system arrangement inside the system unit case.

References

1. Makarov S. Processors coolers: summer abundance in computer // *Computer Review (Komp'uternoe Obozrenie*. Kiev, Ukraine*)*. 2001. No. 29. Pp. 16-31. – *In Russian*.
2. Krynitsyn V. Multiplatform coolers "Cooler Master Hyper6", "Gigbyte 3D Cooler-Ultra" and "Thermaltake Silent Tower" // vit@ixbt.com . 22.09.2004. – *In Russian*.
3. Rassamakin B.M., Tarasov G.V., Khayrnasov S.M., Rassamakin A.B., Diachenko E.N. Modeling and analysis of results ground and flying trial of a heat pipes honeycomb panel on the space apparatus AUOS-SM-KF, in: *Space Engineering. Rocket Armament (Kosmicheskaya Tehnika. Raketnoe Vooruzhenie)*, Dnepropetrovsk, Ukraine, 2004. Pp. 364-376. – *In Russian*.
4. Рассамакин Б.М., Тарасов Г.В., Хайрнасов С.М., Рассамакин А.Б., Дьяченко Э.Н. Моделирование и анализ результатов наземных и летных испытаний сотопанели с тепловыми трубами на космическом аппарате АУОС-СМ-КФ // *Космическая техника. Ракетное вооружение, Днепропетровск, Украина,* 2004.- с.364-376
5. Rassamakin B.M., Rogachev V.A., Khayrnasov S.M., Khominich V.I., Shevchenko V.A., Fedorenko S.K. Experimental modeling of thermal modes of operation of an // *Space Science and technology (Kosmichna Nauka i Tehnologia*. Kiev, Ukraine*)*. 2003. Vol. 9, No. 4. Pp. 34-39. – *In Russian.*
6. Рассамакин Б.М., Рогачев В.А., Хайрнасов С.М., Хоминич В.И., Шевченко В.А., Федоренко С.К. Экспериментальное моделирование тепловых режимов эксплуатации оптико-электронного измерительного прибора для микроспутника // *Космічна наука і технологія. Киев, Украина,* 2003.-9,№4. - с.34-39