CPU COOLING OF DESKTOP COMPUTER BY PARALLEL MINIATURE HEAT PIPES

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Abstract: *Heat transfer performance of parallel miniature heat pipes (MHPs) of 2.8 mm ID used for cooling desktop computer with different working fluids is presented in this paper. In cooling desktop processors, MHPs consists of six single tube heat pipes connected by a copper block at the evaporator section and fifteen parallel copper sheets used as external fins at the condenser section. Acetone and ethanol are used as working fluid. The copper block is placed above the heat source (on the top of the processor) and the condenser section is provided with external fins perpendicular to the MHPs. Heat transfer characteristics of MHPs using different working fluids are determined experimentally, based on the principle of phase. The experimental results show that, the maximum and steady state temperature of the processor has been reduced significantly by using MHPs with acetone as working fluid instead of conventional cooling fan. Additional use of a fan at the condenser section results much lower processor surface temperature for both working fluids.*

Key words: *CPU cooling, Desktop processor, Heat transfer performance, Miniature Heat Pipe , Working fluid.*

INTRODUCTION

Today's rapid IT development like internet requires PC performance capable of processing more data more speedily. To meet this demand, high performance devices built in PC have been developed. Especially, Central Processing Unit(CPU) shows competitive release of more speedy products and shift toward being more compact and thinner. This leads to higher heat density and increased heat dissipation, making CPU temperature rise and causing the shortened life, malfunction and failure of CPU. Cooling of CPU has been taken seriously. Traditional desktop computer design has relied on natural convection from a heat sink placed directly on the processor. With the increasing power of today's microprocessors, a processor cooling fan is used to these local heat sinks. At present, heat released by the CPU of a desktop and server computer is 80 to 130 W and of notebook computer is 25 to 50W [1]. In the latter case, the heating area of the chipset has become as small as 1–4 cm^2. This problem is further complicated by both the limited available space and the restriction to maintain the chip surface temperature below 100^{o}C [2]. It is expected that conventional cooling fan system will not be able to meet the futuristic thermal needs of the next generation computers. Other technologies like liquid cooling and thermoelectric coolers have good potential but still create major integration, reliability and cost issues. With the development in the two-phase heat transfer systems and porous media technology, heat pipes(HPs) have come up as a potential candidate to meet these challenging needs. A HP heat sink is a passive cooling device that requires no moving parts, operates silently and more importantly, reliably. Notebook computers involved the first high volume use of HPs when Intel introduced the Pentium® TCP packages in 1994 [3]. The main reason for the use of HPs is the Pentium® power dissipation level and the limitation and constraints of space and weight in notebooks. Compared to metal plates or heat sinks, HPs offer excellent thermal performance with much less weight and can spread the heat away from the CPU to other areas where the heat can be rejected. Today, Pentium® based notebooks and sub-notebooks are estimated to use several millions of HPs annually based on the PC based notebook volume. The performance of natural convection heat sinks is directly dependent on the effective surface area: more effective surface area results in better performance. The increase of the microprocessor speed and number of transistors cramped into the processor core silicon die has continuously driven up its power dissipation. Heat sink sizes have been increasing in personal computers, from the 2”× 2” aluminum extrusion heat sinks for i486 to the 3”× 3” heat sinks for Pentium® and even larger heat sinks for the latest Pentium® II microprocessors. HPs, as higher level thermal solutions are naturally being investigated as the potential thermal solutions for these systems [4].

Mechanical components with moving parts are the most unreliable components in desktop computers. One of the severe problems of today's processor cooling fans is the generation of noise. Much effort has been made in recent years to minimize noise generated by CPU cooling fans, a fact that has been demonstrated by the popularity of variable and low speed fans coupled with efficient CPU heat sink designs. Even with the adjustable fans generating lower noise at lower speeds, the main noise sources in a computer system are fans and hard drive. Therefore, the best way to eliminate the noise is to remove these sources. As it is impractical to get rid of the hard drives, it seems like a good idea to cool the CPU without a fan. After looking at products based on HP technology, such as Zalman's graphics card coolers, a good idea could be to try passive CPU cooling utilizing HPs [5-7]. The HP can, even in its simplest form, provide a unique medium for the study of several aspects of fluid dynamics and heat transfer and it is growing in significance as a tool for use by the practising engineer or physicist in applications ranging from heat recovery to precise control of electronic equipments. Normally for these equipments HPs of diameter 3 to 6 mm and length less than 400 mm are preferred [8]. Most preferable length is 150 mm [9]. The HP applications for cooling computer CPU was started in the last decade and now 98% of notebooks PCs are cooled by using HPs. Studies on the application of HPs having the diameter of 3 or 4 mm for cooling notebook PC CPU have been actively conducted by the American and Japanese enterprises specializing in the HP recently [7,10,11]. An experimental study has been performed by Tanim et al. [12] to investigate the performance of cooling desktop processors using HPs of 5.8 mm ID and a length of 150 mm with respect to the normal fanned CPU unit. They reported that the use of HPs may eliminate the use of the processor fans and their inherent reliability concerns. Additionally HP technology is emerging as a cost-effective thermal design solution for the desktop industry. So far no investigation has been conducted for cooling desktop processor with MHPs. The concept in this experiment is to draw the heat from the CPU into one end of MHPs while providing the other end of the MHPs with extended fins of copper plate to expel the heat into the air. Finally the performance of the MHPs in cooling desktop processor is investigated with respect to conventional fanned CPU cooling system.

EXPERIMENTAL APPARATUS AND TEST PROCEDURE

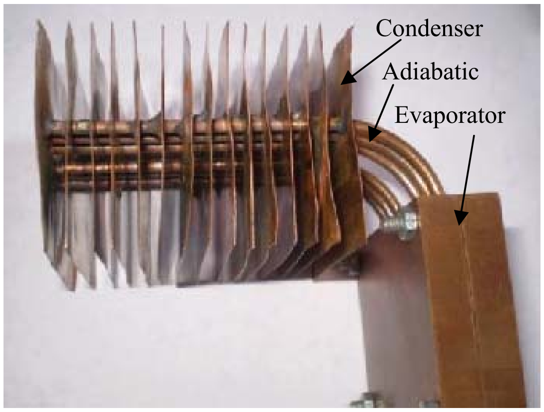
The experimental setup for this study mainly consists of four parts – parallel MHPs, a desktop computer, temperature measurement system and cooling system. Six MHPs made of copper tubes are placed parallel to each other for cooling purpose. For all MHPs the tube has an inner diameter of 2.8 mm, outer diameter of 3.8 mm and a length of 150 mm. There are three sections in every MHP: evaporator, adiabatic and condenser. Acetone and ethanol are used as the working fluid in this experiment.

The condenser section of MHPs is made of copper sheets of 67mm×50mm (thickness 0.5mm) placed parallel as extended fins at a constant interval of 5 mm as shown in Fig. 1. Plates are welded with the MHPs for better heat transfer. As there is space constrain inside the CPU, the MHPs are bend at 90^o in adiabatic section. The evaporator section of MHPs is inserted into the grooves of two copper blocks shown in Fig. 2, which is placed on the top of the processor to remove the generated heat. Two copper blocks of 67mm×50mm×8mm are made very precisely to mate with the MHPs. Grooves are cut inside the blocks. The blocks are precise in dimension. The surfaces are finished highly to reduce the contact resistance as well as to increase the heat transfer rate. The different sections of parallel MHPs are shown in Fig. 3 (a).

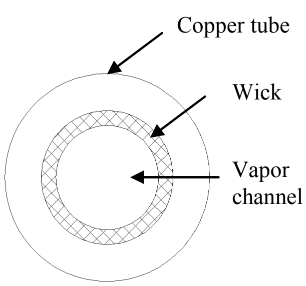
Figure 1. Extented fins of copper sheet in the condenser section.

Figure 2. Grooves cut in the copper blocks for inserting MHPs in the evaporator section.

Heat generated in the processor enters the MHPs at their evaporator sections where it causes working fluid to vaporize. The vaporized fluid creates a pressure gradient which forces the vapor



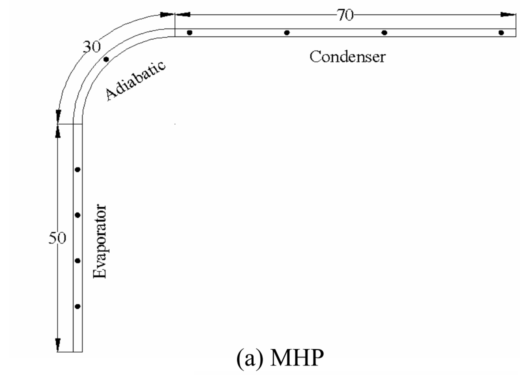
(a) Dfferent sections of MHPs



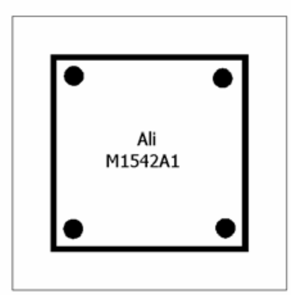
(b) Cross section of a MHP

Figure 3. MHPs with evaporator, adiabatic and condenser sections for cooling desktop processors.

toward the condenser section. Vapor travels from the evaporator to the condenser through the adiabatic section. The working fluid condenses and releases its latent heat of vaporization. The condensed working fluid is drawn back into the pores of the wick. The wick surves as a pump using capillary pressure to return the fluid from the condenser to the evaporator. Before bending in the adiabatic section to the desired angle, a single layer wick of stainless steel of 200 mesh is inserted into each MHP which remains in contact with the inner surface of the tube as shown in Fig. 3 (b). The amount of working fluid poured into the MHPs has a charge ratio of 0.9. The charge ratio is defined as a ratio of the volume of the fluid actually charged to the volume of the evaporator section. Both ends of the MHPs are properly sealed. Nine calibrated K-type (Φ = 0.18 mm) thermocouples are attached at the wall of each MHP using adhesive to measure the wall temperature: four units at the evaporator section, one unit at the adiabatic section and four units at the condenser section. Locations of thermocouples connected on different points along the length of the MHP are shown in the Fig. 4 (a). The surface temperature of the processor is also measured by four K-type thermocouples as shown in Fig. 4 (b). All thermocouples are connected with a digital



(a) MHP



(b) Processor surface

Figure 4. Locations of thermocouples on the MHP axial position and surface of the processor.

Figure 5. Experimental setup for cooling desktop processor by using MHPs.

temperature indicator (YF-160A, type-K thermometer, made in Taiwan) through selector switches. Thermocouples used for temperature measurement on the walls of MHPs and processor surface are estimated to have uncertainty smaller than 0.2°C. Experiment is conducted in two arrangements. In one arrangement, the CPU is cooled by using MHPs only as shown in Fig. 5. In the other arrangement, the cooling is enhanced by using a conventional cooling fan in addition to the MHPs at the condenser section as shown in Fig. 6. Processor surface temperature and wall temperatures of MHPs are recorded for 150 minutes at an interval of 10 minutes. Experiments have been performed in a room condition having an ambient temperature of 28.5°C to 29.6°C. To simulate the experimental condition with the normal running condition of the CPU, no insulation is applied on the processor surface. For this reason heat generation in the processor is not considered. Experimental parameters and configurations of the desktop computer used in this experiment are given in Table 1 and Table 2 respectively.

Figure 6. Experimental setup for cooling desktop processor by using MHPs with cooling fan.

Table 1. Experimental parameters

Parameters	Condition
Number of the heat pipes	6
Diameter of the heat pipe (mm)	ID- 2.8 OD- 3.8
Length of the heat pipe (mm)	150
Length of the evaporator section (mm)	50
Length of the adiabatic section (mm)	30
Length of the condenser section (mm)	70
Working fluid	Ethanol, Acetone
Dimension of the copper block (mm)	67×50×8
Dimension of the copper sheet (mm)	67×50×0.5
Charge ratio	0.9
Wick (SS)	200 mesh

Table 2. Configuration of the desktop computer

Components	Specification
Processor	Ali M1542A1
Fan	Power logic- DC brushless Fan, Model- PL80S12H-1;DC-12V, 0.18A
Ram	16 MB
Hard disk	Seagate; Model ST34321A; 10GB
Power box	115/230 VAC,15 A/ 10 A

TEST RESULTS AND DISCUSSION

Heat generated in the processor enters the evaporator section of MHPs causes working fluid to vaporize. This lowers the temperature of the processor surface. Fig. 7 shows the variation of the processor surface temperature with time. Results of

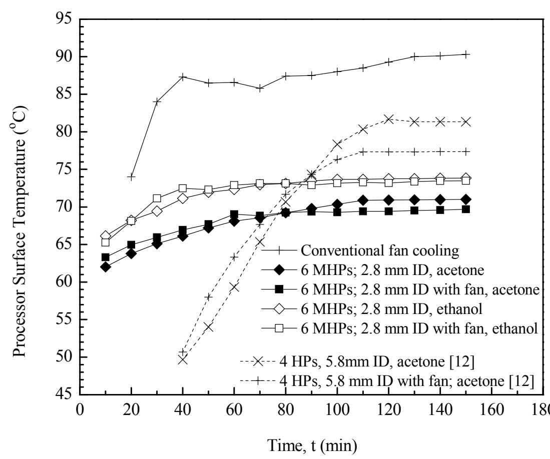


Figure 7. Variation of processor surface temperature with time.

Tanim et al. [12] are included in this plot to compare their results with results of the present study. The figure indicates that the maximum temperature on the processor surface by using conventional cooling fan and aluminum heat sink is 90.8ºC. Replacement of the cooling fan and aluminum heat sink with six MHPs of 2.8 mm ID is efficient as it can reduce the maximum processor surface temperature to 73.8°C by using ethanol as working fluid and 70.7°C by using acetone as working fluid. In both cases the temperature is lower than in case of 5.8 mm ID without cooling fan in condenser and acetone as working fluid. The MHP system with six MHPs is significantly better than the solution with four bigger HPs with 5.8 mm ID. Similar findings about the effect of diameter on enhancement of boiling heat transfer are also reported by Ishibashi and Nishikawa[13] and Klimenko et al. [14]. Addition of a cooling fan in the condenser section of six MHPs gives much better result as it can reduce the processor surface temperature to 72.9°C for ethanol and 69.7°C for acetone. In phase change heat transfer boiling point plays an important role. Acetone has a lower boiling point compared to ethanol and changes its phase at lower temperature. For this reason acetone shows better performance in both cases compared to ethanol. The steady state temperature of the processor surface is attained approximately after 110 min from the start of the CPU which can be reduced to approximately 70 min by using a cooling fan with MHPs. For ethanol, the steady state temperatures in both cases are attained approximately after 70 min from the start of the CPU.

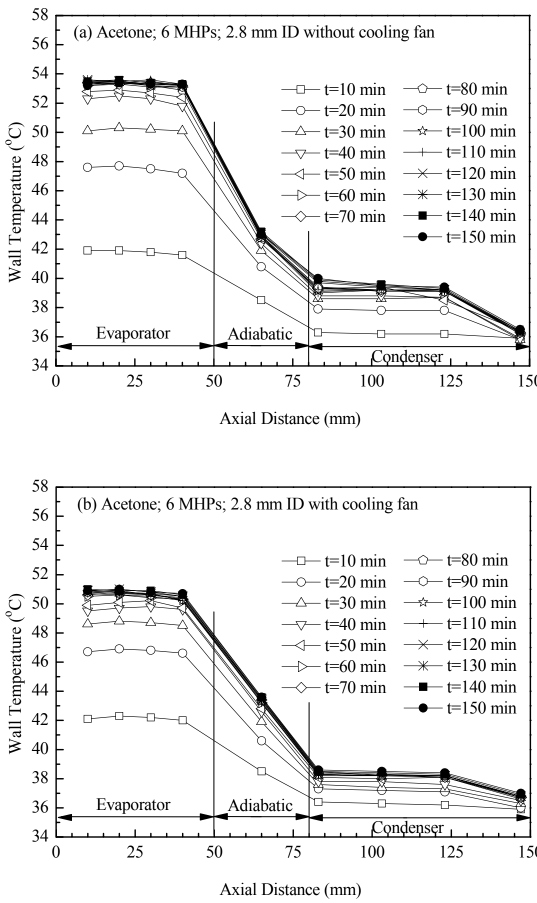


Figure 8. Temperature profile along the length of the MHPs using acetone as working fluid.

Figure 8 shows the axial wall temperature distribution along the length of the MHPs for the time duration of 150 minutes for acetone as working fluid. For six MHPs without fan, the maximum wall temperature in the evaporator section rises to 53.8°C as shown in Fig. 8(a). Addition of a cooling fan lowers the temperature to 51°C which is shown in Fig. 8(b). The steady state temperature is attained approximately after 110 min from the start of the CPU which can be reduced to approximately 70 min by using a cooling fan with MHPs.

Axial wall temperature distribution along the length of the MHPs for the time duration of 150 minutes for ethanol as working fluid is shown in Fig. 9. For six MHPs without fan, the maximum wall temperature in the evaporator section is 55.3°C as shown in Fig. 9(a). Addition of a cooling fan lowers the temperature to 53.4°C which is shown in Fig. 9(b). For ethanol, the steady state temperatures in both cases are attained approximately after 70 min from the start of the CPU.

Variation of the axial wall temperature along the length of the MHP for ethanol and acetone with and without the cooling fan for a transient time t =30 min after the start of CPU is shown in Fig. 10. For both the working fluids, uniformity of temperature in the evaporator and condenser sections indicates the reliability of using MHPs for the cooling of desktop processor.

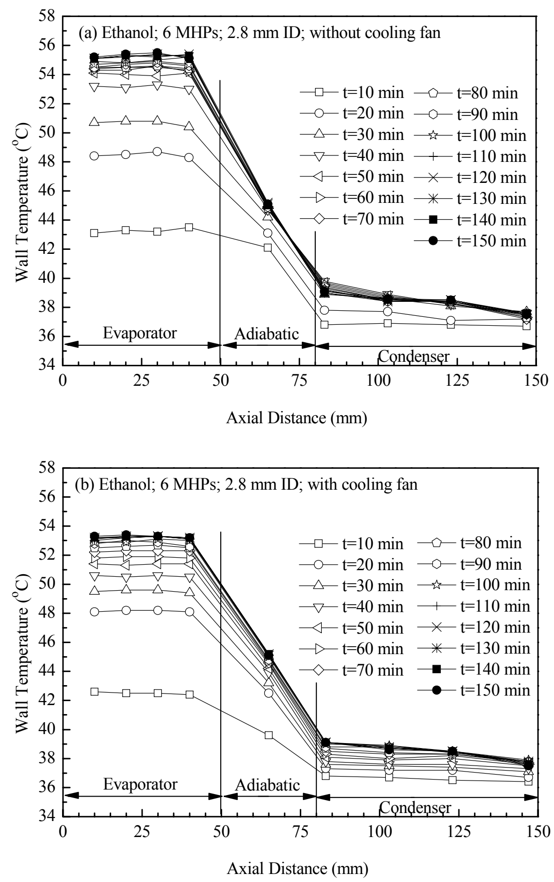


Figure 9. Temperature profile along the length of the MHPs using ethanol as working fluid.

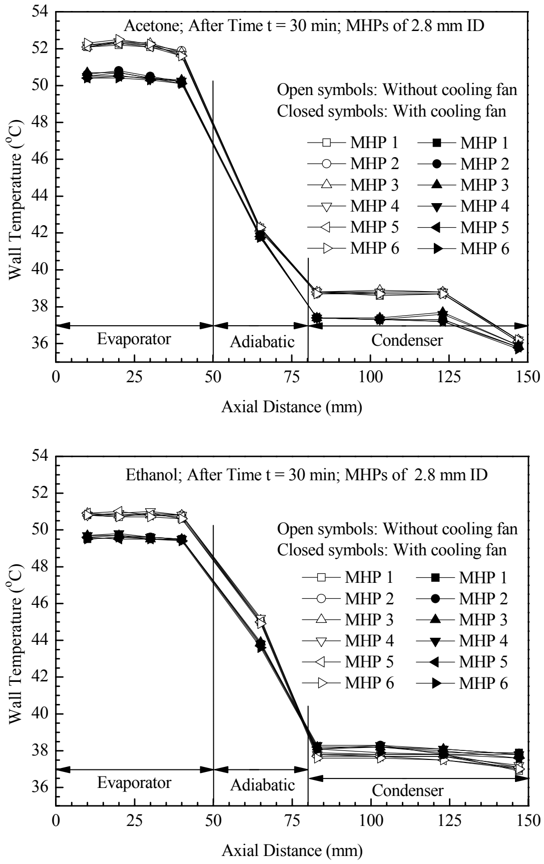


Figure 10. Temperature profile of the six MHPs along their length after a time t = 30 min.

CONCLUSIONS

The following conclusions can be drawn from the experimental study of the performance test of MHPs in cooling of desktop computer:

(i) Replacement of conventional cooling fan and aluminum heat sink with MHPs shows efficient cooling system for desktop processor.
(ii) Additional use of a fan at the condenser section of the MHPS reduces the surface temperature of the CPU further, both for acetone and ethanol.
(iii) Steady state temperatures in the evaporator sections of MHPs with fan is attained earlier for acetone than that of MHPs without a fan.

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