Investigation of different types of heat sink and their applications

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***Abstract*: Microchannel heat sink is the most attractive field for researchers now a day, especially for thermal engineers. In order to satisfy the need of current market requirement of devises having high specific heat transfer microchannel heat sink is the most useful. Researchers have analyzed the effect of different process parameters of heat sink and also proposed the different methods through which the performance of heat sink get enhanced. here in this paper a complete review of heat sink was done which includes different methods and mechanisms.**

***Keywords*: heat sink, review, heat transfer, mechanism**

1. Introduction

Heat sink is an electronic digital component or simply a device of an electronic circuit which usually disperses heat via other parts (primarily coming from the power transistors) of a circuit into the neighbouring medium and so cools them for enhancing their very own effectiveness, consistency and also eliminates the early failure of the elements. For the cooling intention, it comes with a fan or chilling device. It is a passive heat exchanger which usually exchanges the heat provided by an electronic or a mechanical device to actually a fluid medium, quite often air or a liquid coolant, just where it is dissipated aside from the gadget, therefore permitting control of the device's temperature at best variants. In largely computer systems, heat sinks are applied to cool central processing units as well as graphics processors Heat sinks are employed with the high-power semiconductor devices just like power transistors and optoelectronics for example, lasers and light emitting diodes (LEDs), in which the heat dissipation potential of the component alone is deficient to limited its temperature.

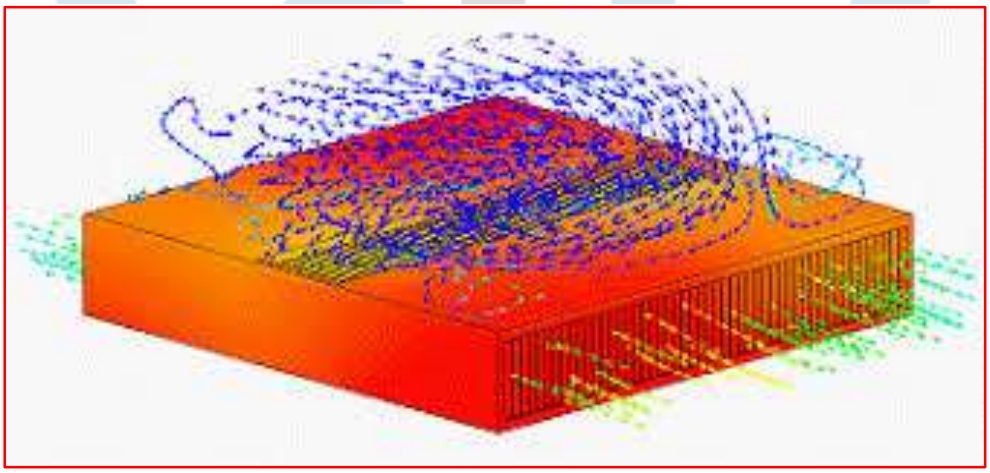

Fig. 1.3: Heat Sink

A heat sink is manufactured to improve its surface in touch with the cooling medium encircling it, like the fresh air. Air velocity, selection of material, protrusion style and surface area treatment are elements that affect the functionality of a heat sink. Heat sink add-on strategies and thermal user interface components also impact the die temperature of the integrated circuit. Thermal adhesive or thermal grease improve the performance of heat sink by stuffing air interruptions among the heat sink and the heat spreader on the device. A heat sink is commonly manufactured by copper or aluminium. Copper is employed since it has various suitable properties for thermally reliable and long-lasting heat exchangers. Initially and primarily, copper is a superb conductor of heat. This represents that copper's great thermal conductivity permits heat to pass throughout it promptly. Aluminium heat sinks are employed as a cheap, light in weight replacement to copper heat sinks, and have a reduced thermal conductivity when compared to copper.

2. Heat Sink Principle

A heat sink exchanges thermal energy from a more significant temperature device to actually a lower temperature fluid medium. The fluid medium is often air, however can certainly be water, refrigerants or oil. Whenever the fluid medium is going to be water, the heat sink is typically known as a cold plate. In thermodynamics a heat sink is definitely a heat reservoir which usually absorb an irrelevant amount of heat with no considerably changing temperature. Functional heat sinks for electronic devices need to have a temperature higher than the environment to transfer heat by convection, radiation, and conduction. The power supplies of

electronics are generally not 100% efficient, therefore surplus heat is generated that can be adverse to the function of device. As a result, a heat sink is associated in the design to distribute heat.

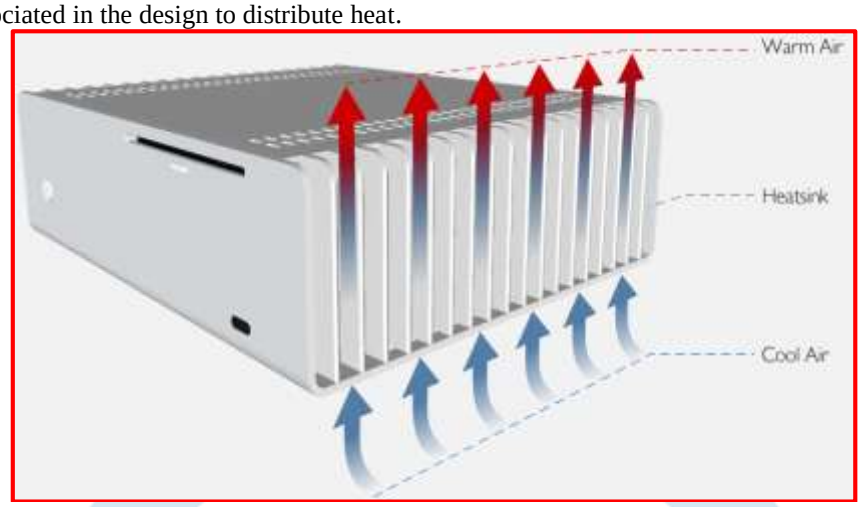

Fig 1.4 Heat Sink Principle

Fourier's law of heat conduction expresses that whenever temperature gradient is associated with a body, then the heat will certainly flows from a high-temperature section to low temperature section. And, the following can be accomplished in three distinct approaches that is convention, conduction and radiation. When two elements with distinct temperature arrive in contact with one another, conduction happens causing collision of the fast-moving molecules of the high-heat objects with the slow-moving molecules of the cooler objects, thereby exchanges thermal energy to the cooler object, and simply that is known as thermal conductivity.

2.1 Fourier's Law of Heat Conduction

The law of heat conduction is also known as Fourier's law. Fourier's law states that

"The time rate of heat transfer through a material is proportional to the negative gradient in the temperature and to the area."

- **Fourier's equation of heat conduction:**

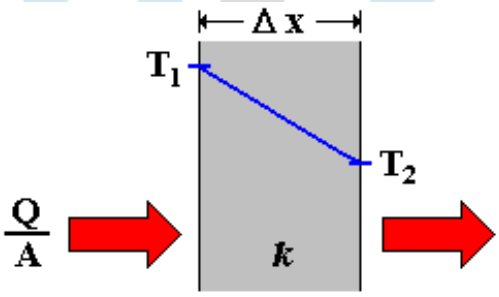

Fig 1.5 Fourier's law

$$Q = -kA\,(dT/dx)$$

Where, 'Q' is the heat flow rate by conduction (W), 'k' is the thermal conductivity of body material ($W \cdot m^{-1} \cdot K^{-1}$), 'A' is the cross-sectional area normal to direction of heat flow (m^2) and 'dT/dx' is the temperature gradient ($K \cdot m^{-1}$). Here, the negative sign of the Fourier equation means that the flow of heat lies in negative gradient temperatures and helps to react to the heat flow positive.

3. Heat Transfer Enhancement Techniques

The way to improve heat transfer performance is referred to as heat transfer enhancement (or augmentation or intensification). The research in this field was strongly stressed by the need of developing high performance thermal systems. The development of heat transfer enhancement during the past 2-3 decades is such that enhanced surfaces are used routinely in refrigeration, automotive, electronic industries, food industries, textile industries and even more and more often in process industries. The improvement of the heat transfer coefficient requires quite different approach according to the phase of the fluid (gas or liquid) and to the process type: techniques are quite different for only sensible heat transfer or for phase change such as evaporation or condensation. Heat transfer enhancement techniques can be classified as active methods, which require external power, or passive methods, which require no direct application of external power. The major passive cooling solutions are obtained through conduction (heat spreaders, thermal interface materials), natural convection (heat sinks, liquid immersion), radiation (coating, surface treatments) or phase change (heat pipes, phase change materials). However, passive cooling techniques have low cooling performance requiring

a large device size. Consequently, high-power systems require active techniques, which require input power but have larger heat removal capacity.

3.1 Passive Techniques

- **Treated surfaces:** This method involves the fine-scale alteration of the surface finish which affects single-phase heat transfer. This method is used for condensing and boiling.
- **Rough surfaces:** This application is generally chosen to promote turbulence rather than heat transfer enhancement and its application is directed to single-phase flow. These surfaces are produced in many configurations ranging from random sand-graintype roughness to discrete protuberances.
- **Extended surfaces:** This technique is one that is currently the focus of many studies (including this study). The method involves the extension of the surface and examples of this method that are being used in practice are micro-fin tubes and most recently, herringbone type tubes.
- **Displacement enhancement devices:** These devices are inserted into the flow channel so as to improve the energy transport indirectly at the heated surface and these devices are used with forced flow.
- **Swirl-flow devices:** Examples of such devices are coiled tubes, inlet vortex generators, twisted tape inserts and axial-core inserts. These devices create a rotating flow and/or a secondary flow. **Surface tension devices:** These devices consist of wicking or grooved surfaces to direct the flow of liquid during condensing or boiling.
- **Additives for liquids and gasses:** Additives for liquids include solid particles and gas particles in single-phase flow, while for gas additives, liquid droplets or solid particles are used.

3.2 Active Techniques

- **Mechanical aids:** These aids stir the fluid by mechanical means or by rotating the surface. Equipment with rotating heat exchanger ducts is found in commercial practice (Bergles and Chyu, 1988; Lasance, 1997). Surface vibration: To improve single-phase heat exchange, the surface is vibrated at either low or high frequencies.
- **Fluid vibration:** The fluid is vibrated at pulsations of 1 Hz with ultrasound. This is the most practical type of vibration enhancement and is used in single-phase flow.
- **Electrostatic fields:** These fields are applied in many different ways to dielectric fluids. The electrostatic fields can be directed to cause greater bulk fluid mixing in the vicinity of heat transfer surfaces.
- **Injection:** This method involves the supplementation of gases to a flowing liquid through a porous heat transfer surface, or by injecting another liquid into the liquid upstream.

4. Heat transfer enhancement through nanofluids:

In industrial processes, thermal properties of liquids play an important role in heating as well as cooling applications. The thermal conductivity is an important physical property in heat transfer that decides the heat transfer performance of the liquid. Simple heat transfer fluids have a lower thermal conductivity compared to nophores, so they are not suitable for very cold applications. Scientists had been annoying to improve the poor thermal behaviour of these conventional heaters by using solid additives. It is done on the basis of the classical effective medium theory of mixtures for effective properties of the fluid mixture. Tuning fine the solid suspensions to the millimetre and micrometre sizes for getting more heat transfer performance has failed. It is caused by corrosion of engine components, low heat conductivity, particle absorption, particle blockage, excessive pressure drop. Etc.

The thermal conductivity of the main liquid is increased by the addition of neonate. Due to the small particle size, nanotubes are easy to penetrate into the liquid, channel blockage, and erosion along the channel wall are no longer a problem when using nanoscale. All the physical mechanisms of material have a critical scale below which the properties of the material can change totally. Nowadays nanotechnology offers chemical and physical routes to prepare nanometersized particles. Normalized thermal conductivity is also recognized as effective thermal conductivity value gained by separating the overall thermal conductivity of the nanofluid from the base fluid. In the recent improvements, the production of particles with Nano sized (nanoparticles) can be achieved.

5. Existing research works:

1. **Prajapati *et.al* (2019)** In this article, heat transfer and fluid behavior are investigated numerically in parallel, small, high-pressure air ducts at different heights. Seven different cases were examined with changes in height from 0.4 to 1.0 m. A full ambient closed heat sink (normal configuration) of 1.1 mm is the case, while the other six heat sinks maintain a space between the fin top surface and the cover wall. It had experimental that the proposed design of heat sink facilitates different heat dissipation capacity in addition to characteristics of fluid flow. The result predicted that the temperature distribution, the pressure drop, the heat transfer coefficient, and the velocity profile clearly show that heat transfer increases with increasing fin height, but the heat sinks with shorter fin height (0.4 - 0.6 mm) had reveal low heat transfer potential. It was establish that height of 0.8 mm showed a maximum heat transfer, which was higher than the blown height of 0.9 mm and 1.0 mm.
2. **Hussain *et.al* (2019)** In this article, the study builds a validated liquid crystal (CFD) model in comparison with investigational data from the literature showing the influence of flow direction and filler profile on the thermal properties of the heat sink flat type. In particular, the fluorescence spectra with the filler profiles were compared to the normal design (smooth fins with no fill forms), and acceptable consequences were detected. The consequences of this study show that the reference temperature along with the radiative heat resistance is lower for the proposed design. Consequently, the developed method has the potential to be used to recover the thermal performance of the heat sink and thus to mature more well-organized cooling technologies.
3. **Dawei Yang *et al.* (2017)** studied numerically and experimentally the cooling performance of single-phase array microchannel heat sinks with different pin-fin configurations such as triangle, square, pentagon, hexagon, and circle. The deionized water

was allowed to pass through staggered 218 pin fin configuration for a different configuration in which the hexagon pin fin had the low blocking effect of fluid along with UCTS of 4.27% . It showed larger heat transfer rate.

4. **Xiao-Hu Yang *et al.* (2017)** presented in their papers, briefly about the flow and thermal modelling in comparison with liquid metal and water in which liquid metal has extraordinary flow and thermal performance. The predicted data and the actual experimental data provided similarity in performance, which validated the numerical method. The better prediction of pressure drop and pumping power was based on flow resistance and friction factor. Liquid coolant exhibited good cooling performance since it had high thermal conductivity. Hence, the study showed that the rates of liquid metal, when compared with water, showed thermal resistance 60% more than water, and also less power consumption of only about 43%.
5. **Sung-Min Kim & Issam Mudawar *et.al* (2017)** focused on the thermal design of MCHS with an inlet in saturated conditions. Here pressure drop and heat transfer coefficient were calculated using predictive methods. The predictive tools such as dry out incipience and premature heat flux and two-phase critical flow limited considerable heat sink performance. A parametric research was conducted based on these tools to track the change of maximum heat flux corresponding to volumetric flow rate. Using the heat transfer coefficient pressure drop and maximum bottom wall temperature was evaluated. Deep microchannel increased the heat flux and decreases pressure drop and producing an unfavourable effect on the bottom wall temperature.
6. **Anurag *et al.* (2016)** proposed a new analysis of different inlet and outlet flow arrangements. The cross sections taken were rectangular, rectangular with semicircle and divergent- convergent. All of these were microchannel are made up of copper material. The CFD analysis found that the divergent-convergent had better heat transfer than the other two cross-sections. Comparing those two, the rectangular with semicircle had better heat transfer than a rectangular section.
7. **Lei Chai *et al.* (2016)** studied numerically the heat transfer in microchannel heat sink with offset ribs on sidewalls considering laminar flow. The different offset ribs used were rectangular, backward triangular, forward triangular, semi-circular and isosceles triangular. It was smaller velocity difference in y-direction which caused better mixing of hot water near the wall and the cold water in the centre of the microchannel. Heat sink with forwarding triangular, semi-circular and isosceles triangular offset ribs had slightly better heat transfer performance than the heat sink with rectangular and backward triangular ribs. Also, a heat sink with semi-circular and isosceles triangular showed the least pressure drop. They also investigated the laminar flow and heat transfer characteristics in the interrupted microchannel heat sink with ribs in the transverse microchannel. The different rib configurations in the experiment were rectangular, backward triangular, diamond, forward triangular and ellipsoidal. They found that periodic thermal layer developing flow was accountable for the substantial heat transfer enhancement.
8. **Anbumeenakshi et.al (2016)** In this study, they had investigated through series of experiments on the common effects of nanofluids and uneven heat on the cooling effect of microchannel sinks. The microscopic radiation that is considered in this study distributes 30 rectangles with a 0.727 millimetre diameter. In the experimental experiments, three machines of the same extent were used. Uneven heat is provided by opening two of three heaters at the same time. The maximum temperature of the pulse rays is lowest when the chipper is placed above the flow.
9. **Benjamin Herrmann-Presents *et al.* (2016)** studied numerical simulation of cooling microchannel through the spiral radial flow of fluid. The factors such as height, inlet angle, and fluid were varied to study the effects. The rotational flow of fluid induced the fluid to move over the heat exchanging surface. When the microchannel height was reduced, it resulted in the merging of boundary layers and entrainment effect.
10. **Assel Sakanova *et al*. (2015)** achieved a study with the new shape of the microchannel. The study dealt with the unique shape of the microchannel by bringing out the wavy type of microchannel with 25µm, 50µm, and 75µm amplitude. The wavy structure was supplementary scrutinised by varying the volume flow rate with three altered concentrations of nanofluid. The performance was increased by increasing the amplitude and decreased wavelength which provides low thermal resistance and comparable pressure drop. However, the replacement of water fluid with Nanofluid effect is not affected by the wavy channels.
11. **Duangthongsuk et.al (2015)** In this article, they had tested the thermal conductivity and flow characteristics of the heat sinks with shapes like circular and square pin (MCFHS and MSFHS) with SiO2, dispersed in DI water having fractional volumes of 0.2, 0.4 and 0.6% of the sound strength. The description is the impact of needle structure, particle concentration, and flow rate of heat exchanger and pressure drop across the test site. It is assumed that the coefficient of heat emission increases with increasing the concentration of particles and Reynolds numbers. Finally, it would suggest that the use of square shaped heat sinks should be avoided when case comes to circular shaped structure of fins.
12. **Jang et.al (2014)** This article optimized a radial heat sink pin–fin having a fin-height profile. Natural convection and heat transfer from radiation have been taken into account and experiments are conducted to confirm digital models. Among the different height patterns, the outer field shows the best cooling. The variability of the various parameters is studied to determine the design variables, the outer height of the shaft, the difference between the height of the lens and the number of bars. Efficiency is optimized to reduce heat and mass resistance. In total, the cold radiation efficiency of rounded rays with a needle-height profile shows an improvement of more than 45%, while maintaining a mass that is comparable to plate heat.
13. **Jingru Zhang *et al.* (2013)** investigated on the fluid flow to remove heat from two different cross-sections, a straight and a U-shaped channel. Both are made of silicon material as a substrate with the microchannel base plate made out of polydimethyl siloxane (PDMS). They found that the thermal resistance and pressure drop are better in U-shaped channel than the straight and also the heat transfer rate is better in the U-shaped channel.
14. **Navin Raja *et al.* (2013)** scrutinised the heat transfer enhancements in the trapezoidal cross-section with laminar flow characteristics. They initially considered various base fluids like water, Ethylene Glycol (EG), oil and glycerine with Nano sized diamond particles of 2% substrate materials like copper, aluminium, steel, and titanium. They conducted percentage enhancement test in trapezoidal cross-section, and they obtained 98.15% results in thermal resistance which were found to be the mixture of glycerine with diamond nanoparticles. It could naturally increase the cooling performance of the MCHS assisted by the high viscosity glycerine.

15. **Matthew D Byrne *et al.* (2012)** conducted an experiment varying concentration values to the volume of CuO and the second factor was the use of surfactant CTAB as suspension enhancer. In this experiment, the hydrodynamic and thermal performances of seven fluids were determined. The microchannel heat transfer evaluation showed an increase in the performance of pure water to 10% by adding a surfactant and a particular increase of smaller concentration values. Even the surfactant also caused smaller improvements of heat transfer. So it provided a dispersion of nanoparticles in the fluids. The absence of a suspension, enhancer led to agglomeration and settling.

6. Conclusion

Through literature survey it is found that micro channel heat sinks are very important in the area of high specific heat transfer. With the development of technology, the size of the equipment is reducing day by day, which increases the heat generation rate inside the system. So, to overcome this problem compacted microchannel heat sink come in to picture. Since few years' rigorous research work is going to increase the specific heat transfer capacity of microchannel heat sink.

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