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A Literature Review on Effect of Use of Turbulators On Plate Fin Heat Sink For Heat Transfer Enhancement

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***Abstract*—In this survey paper we discuss the different fin configuration for heat sink design. The present study carries out numerical computations of the plate-circular pin-fin heat sink and provides physical insight into the flow and heat transfer characteristics. The governing equations are solved by adopting a control-volume-based finite-difference method with a power-law scheme on an orthogonal non-uniform staggered grid. The coupling of the velocity and the pressure terms of momentum equations are solved by the SIMPLEC algorithm. The plate-circular pin-fin heat sink is composed of a plate fin heat sink and some circular pins between plate fins. The purpose of this study is to examine the effects of the configurations of the pin-fins design. The results show that the plate-circular pin-fin heat sink has better synthetical performance than the plate fin heat sink.**

Keywords- Heat sink Perforated fins rectangular edge fin Thermal efficiency enhancement

I. INTRODUCTION

A heat sink is a component that increases the heat flow away from a hot device. It accomplishes this task by increasing the device's working surface area and the amount of low-temperature fluid that moves across its enlarged surface area. Based on each device's configuration, we find a multitude of heat sink aesthetics, design, and ultimate capabilities. A heat sink (also commonly spelled heat sink) is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature. In computers, heat sinks are used to cool CPUs, GPUs, and some chipsets and RAM modules. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light-emitting diodes (LEDs), where the heat dissipation ability of the component itself is insufficient to moderate its temperature. Each heat sink is valuable in applications that may have varying: Heat sinks are one of the most common forms of thermal management in technology, machinery, and even in natural systems.

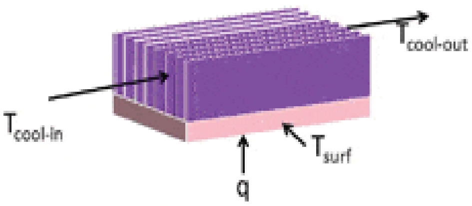

Fig. 1. Simple heat sink

These components are so ubiquitous that they're easy to overlook, even by those who are familiar with the technology. We'll address the basic working principles involved in heat sinks, introduce active and passive heat sink configurations, and discuss how some users implement heat sinks in their applications. A heat sink is designed to maximize its surface area in contact with the cooling medium surrounding it, such as the air. Air velocity, choice of material, protrusion design and surface treatment are factors that affect the performance of a heat sink. Heat sink attachment methods and thermal interface materials also affect the die temperature of the integrated circuit. Thermal adhesive or thermal paste improve the heat sink's performance by filling air gaps between the heat sink and the heat spreader on the device. A heat sink is usually made out of aluminium or copper.

1.1 Plate Fin Heat Sink

Plate-fin heat sinks as implied by their name are heat sink geometries that have their extruded fins running across the entire length of the base in the form of a plate. These types of heat sinks are the most commonly used in electronic devices. Heat sinks with plate fins can be modeled in different shapes and can also be arranged in different forms to force the direction of flow. Plate-fin heat sinks usually cover a larger surface area across the base of the heat sink. Hence, generally has a larger area for heat transfer since there's an increase contact area between the working fluid(air) and the material surface.

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1.2 Pin Fin Heat Sink

Heat sinks with pin fin extrusions are widely used based on the ability to increase their surface area through the increase in the number of pins. Pin fin extrusions are usually layered across the base of a heat sink in a specified order or pattern so as to enhance airflow. One advantage of using pin fins over plate fins is that the direction of flow does not necessarily need to be precisely defined since all sides could work as an inlet though or outlet. In most cases depending on geometry, there is a direction of flow inlet and outlet that increase the performance of the pin fin heat sink and should be taken into account when mounted on the object to be cooled.

1.3 Geometry Heat Sink

With improved methods of manufacturing, manufacturers and researchers are able to manufacture objects of different shapes and dimensions. With geometry being a factor that affects the performance of heat sinks, the ability to manufacture heat sinks of different exotic geometries enables both thermal engineering and researchers to optimize heat sinks based on geometry modification. In this study, different heat sink geometries are analyzed under the same conditions and compared to each other based on their thermal performance and cost of operation. The exotic geometries in this study were modeled based on knowledge from fluid dynamics and heat transfer to better improve heat sink performance.

Fig. 2 The geometry of Heat Sinks

1.4 Different types of heat sink

The source generates heat.

- This source may be any system that creates heat and requires the removal of said heat to function correctly, such as: Mechanical- Electrical- Chemical- Nuclear- Solar- Friction

Heat transfers away from the source.

- Heat pipes can also aid in this process, but we'll cover those components separately. In direct heat sink-contact applications, heat moves into the heat sink and away from the source via natural conduction. The heat sink material's thermal conductivity directly impacts this process. That's why high thermal conductivity materials such as copper and aluminum are most common in the construction of heat sinks.

Heat distributes throughout the heat sink.

- Heat will naturally travel through the heat sink via natural conduction moving across the thermal gradient from a high temperature to a low-temperature environment. This ultimately means that the heat sink's thermal profile will not be consistent. As such, heat sinks will often be hotter towards the source and cooler towards the sink's extremities.

II. LITERATURE REVIEW

In this section discuss the different previous work presented by different research in the field of heat sink.

Mauro, A. W., et.al (2010), In this research work presented flow boiling saturated CHF data in a multi-micro channel copper heat sink have been collected with three HFC refrigerants: R134a, R236fa and R245fa. The test section was fed by a singular system with one central inlet and two outlets, called split flow, which provided much better performance in terms of CHF attainable compared with the single inlet/outlet system (and also reduced the pressure drop). For all the tests carried out, the saturated CHF increased with mass velocity. For R236fa and R134a, an increase of saturation temperature resulted in a slight decrease of CHF, while the inlet subcooling provided a moderate positive effect on CHF. For R245fa the effect of saturation temperature and inlet subcooling tended to be negligible. The highest CHF values have been reached with R134a (330 W/cm2 for G = 1500 kg/m2 s). With this fluid it was possible to achieve higher flow rates with the test facility, thanks to its lower two-phase pressure drop. On the other hand, making the comparison over the same range of mass velocity, R245fa yielded CHF values comparable with R134a. The experimental data were compared with five prediction methods, including one numerical method [1].

Koşar, et.al. (2010), In this research work presented unstable boiling was studied in three different micro-pin fin heat sinks. Pressure signals and flow images were acquired under unstable boiling conditions, which were accompanied by severe temperature fluctuations. The main conclusions drawn from this study are: Similar to parallel micro channel array, flow instabilities are of concern during flow boiling in micro-pin fin heat sinks. Onset of boiling was accompanied by considerable flow instabilities in all the tested micro-pin fin heat sinks with a corresponding increase in surface temperature. For water, the magnitude of the pressure drop fluctuations before and after unstable boiling was not significant regardless the shape of the pin fin. Peak to peak pressure drop fluctuations remain small compared to the time averaged pressure drop for all the devices For R-123, a drastic change is observed in the pressure signals with the initiation of unstable boiling, and a sharp increase in the magnitude peaks of the FFT profiles becomes apparent. Moreover, not only the spectrum peak increases significantly but the side-lobe energy also significantly increases after the inception of unstable boiling, which is an indicator of rapid bubble growth instability. For the devices operated with water (both circular and hydrofoil shaped micro-pin fin devices), no significant change is observed in the FFT profiles with unstable boiling. Upstream compressible volume instability rather than rapid bubble growth instability prevails under these unstable boiling conditions [2].

Dogruoz, et.al (2010), In this research work presented with the invention as well as implementation of advanced electronics, smaller, compact, low weight, and low cost devices with aggressive thermal performances are demanded. In order to respond to this need, advanced thermal materials have been developed. Although these materials are relatively new, novel applications start to utilize them to meet certain design requirements. In this research work presented, four different advanced materials were studied as well as aluminum and copper as baseline materials. Authors developed a design of experiments for our simulations with 343 cases in total to understand conduction and convection resistances of extruded heat sinks in a natural convection environment. Simulations were carried out via commercially available CFD software by taking advantage of the tool's periodic boundary condition capability. In simulating the test cases, effect of the convection has also been studied by changing the heat sink base temperature. Pareto charts presented the relationships and strengths for both conductive and convective thermal resistances, as well as minimum fin temperatures [3].

Chein,, et.al (2010), In this research work presented copper foam fabricated using the electroforming technique was employed as the heat-sinking material. Because of the special flow characteristic of fluid flow in the copper foam and enlarged heat transfer area, the copper foam heat sink has better performance as compared with those of single-channel, plate-fin and pin-fin heat sinks. The measured results also indicated that the thermal resistance of copper-foam heat sink decreases with the decrease in porosity which can be controlled by the electroforming time [4].

Liu, et.al (2011), In this research work presented, two micro staggered square high pin fin heat sinks with different channel sizes were fabricated. Using deionized water as working fluid, the performance of pressure drop and heat transfer in staggered square long micro pin fins were experimentally studied. The main conclusions include:1) For both heat sinks, the pressure drop increased with the Rec number. The flow friction factor transition phenomenon appeared at Rec 300. 2) Both heat sinks exhibited huge heat dissipation capability. The experimental data showed that, for the type 2 heat sink, the heat dissipation could reach 2.83 106 W/m2 at the flow rate of 57.225 L/h and the surface temperature of 73.4 C, and, therefore, meet the demand of high power heat removal. The heat dissipation increased with the flow rate for a fixed surface temperature while the increasing rate decreased with the flow rate. 3) The Nusselt number increased with the fin Reynolds number. For both heat sinks, the heat transfer was over predicted by the previous correlations. Therefore, we presented new correlations for the average Nusselt number prediction. The Nusselt number varies as Re0.61. 4) The heat resistance decreased with the pressure drop. The deceleration rate was faster for the small pressure drop and slower for the large pressure drop [5].

Reyes, et.al,. (2011), In this research work presented the effect of tip clearance on micro-channel flow based thermal control systems when, owing to engineering design restrictions, the flow itself cannot be considered as fully developed. The study has accounted for two parameters of practical interest, namely the heat transfer and the pressure drop (which is related to the pumping power). Four configurations involving a tip clearance have been analyses and compared to a baseline configuration of micro-channel flow without tip clearance. The height of the square section micro-channels was 500 mm. Tip clearances of 250 mm, 500 mm, and 1000 mm were considered. One additional configuration with the channels perpendicular to the main flow and a tip clearance of 500 mm was studied. For each configuration, six different volume flow rates were considered. These flow rates, in the case of the baseline configuration, led to Reynolds numbers in the range from 416 to 2600. The main conclusion of the work been presented is that implementation of tip clearance in active micro-channel based thermal control systems is an attractive option form the practical industrial application standpoint owning to two arguments: The added manufacturing cost is negligible since most of the manufacturing complexity is associated the micro-machining of the micro-channels, while the top wall can be easily set at a lower or higher height. The deterioration in heat transfer caused by the tip clearance is small while the savings in pumping power are large. In our study, for the optimum tip clearance height, the heat transfer (at the lowest volume flow rate, Re ¼ 416) was 83% of the baseline configuration. However, the required pumping power was only 18% of the baseline case. The advantage of introducing a tip clearance can also be illustrated noting that the required pumping power can almost be halved maintaining the thermal efficiency [6].

Yu, et.al. (2011), In this research work presented numerical analyses were conducted to optimize a radial heat sink adapted to a circular LED light. Experiments were performed to validate the numerical model, and the agreement was good. To determine the optimum model, three types of heat sink (L, LM and LMS models) were compared and the LM model exhibited superior thermal performance. Parametric studies were performed to compare the effects of three geometric parameters (number of long fins, long fin length and middle fin length) and an operating parameter (heat flux) on the thermal resistance and average heat transfer coefficient for the heat sink array. As the number of long fins, middle fin length and long fin length increased, the thermal resistance and average heat transfer coefficient decreased. It was found that optimum values of the geometric parameters existed for maximizing heat transfer performance, i.e., minimizing thermal resistance. Finally, the heat sink geometry (number of long fins,long fin length and fin length ratio) was optimized using a CCD and an EA. By varying weighting factors, Pareto front was investigated with respect to heat flux. Pareto front showed trade-off between minimal thermal resistance and minimal mass of heat sink. It was found that it was impossible to optimize both thermal performance and heat sink mass at the same time, and there existed upper limit to the ratio of weighting factors (x1/x2).

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Chen, et.al (2012), In this research work presented a 3D heat sink model for the dynamic simulation of heat dispersion process. Based on the developed 3D model, we have analyzed the distinction between the plate- and pin-fin heat sinks explicitly and systematically. Simulation results show clearly that the pin-fin heat sink can lead to much better heat dispersion than plate-fins, mainly due to the providence of a larger heat dispersion area. Authors also observed from the 3D simulation results that the plate-fin heat sink presents a significantly contorted temperature distribution compared with the pin-fin heat sink. The effects of pin fin diameter, fin numbers and air approaching velocity on optimal conditions and the overall performance of the pin-fin heat sinks have been investigated thoroughly. The thermal analysis has shown obviously that these key factors have nonlinear and interacting effects on entropy generation rate. To optimize the cylindrical pin-fin heat sinks, a real-coded genetic algorithm is applied for both the in-line and staggered arrangements. The entropy generation rate, which takes account of the air resistance and thermal resistance simultaneously, is adopted as the objective function to be minimized. The obtained optimal results has revealed that the proposed optimization approach is superior to existing methods, which provides less entropy generation rate while at the same time maintaining considerably lower air-approaching velocity [8].

Kota, et.al (2012, May), In this research work presented 3D numerical simulations and experiments of high velocity, transitional flow through a dimpled channel were conducted, reminiscent of conditions in future high performance air-cooled heat sinks (e.g., centrifugal heat sinks). Ease of manufacturability and implementation of microscale dimples (200 μm depth and 1000 μm footprint diameter) was also demonstrated in the paper. It was found that the performance of dimples, in addition to depending on the flow regime, also depends on the velocity and the flow development characteristics (here, dimples in aerodynamically fully developed flow region were found to yield better thermal performance compared to those in the developing region). Under the considered operating conditions of transitional flow (Re of 1650) in a narrow channel (0.8 mm wide) with a high flow velocity (17 m/s), dimple depth relative to the channel width was found to be a key design parameter that governs the overall performance. In addition, dimple depth and spacing also have a significant impact on the performance, especially with their impact on the pressure drop, and vortex strength and interaction. A right selection of these parameters is crucial to reap the maximum benefit of using dimples. Geometry optimization was performed using design of experiments with response surface analysis, and the optimum geometry was found to be application dependent. In addition to the practical conditions surrounding electronics, it was observed that dimples themselves will also result in premature flow transition in internal flows and must be considered during simulations for an accurate performance prediction [9].

Wang, et.al (2013), In this research work presented adopted a combined optimization procedure, including a simplified conjugate-gradient method and a completely three-dimensional nano fluid-cooled MCHS model, to look for opti-mal geometric structure for a silicon-based MCHS. Three parameters, channel number N, channel aspect ratio a, and width ratio of channel to pitch b, server as search variables and are optimized simultaneously under fixed inlet volume flow rate, fixed pumping power, and fixed pressure drop, respectively, with the total thermal resistance RT as objective function. Water-based Al2O3 nano fluid with 1% particle volume fraction is assumed to be the coolant of the MCHS. The MCHS has Lx = 10 mm, Ly < 1 mm, Lz = 10 mm, and d = 0.1 mm. The coolant inlet temperature and heat flux are Tin = 293 K, qw = 100Wcm2. The optimal geometric structure is closely dependent on the constraint condition. The optimal design has N = 134, a = 6.39, and b = 0.37 with thermal resistance of 0.0876 KW1 for fixed volume flow rate of 200 cm3 min1, N = 51, a = 5.69, and b = 0.62 with corresponding thermal resistance of 0.1059 KW1 for fixed pumping power of 0.05 W, N = 37, a = 4.38, and b = 0.59 with thermal resistance of 0.0760 KW1 for fixed pressure drop of 20 kPa. The optimal geometric structure is different under various inlet volume flow rates, various pumping powers, and various pressure drops. Larger N and smaller b should be adopted when nano fluid cooled MCHS operates under fixed inlet volume flow rate, however, smaller N and larger b should be adopted when nanofluid-cooled MCHS operates under fixed pumping power or under fixed pressure drop. The improvement in cooling performance of nanofluid- cooled MCHS is attributed that optimal geometric structure increases inlet flow velocity and effective thermal conductivity of nanofluid, which enhances convective heat transfer between nanofluid and channel wall [10].

T Saravanakumar, D Senthil Kumar (2019), In this study, PFHS with and without baffles are experimentally studied at various heat source and wind velocity. The temperature distribution and thermal resistance on Heat sink has been studied using CFD analysis and compared with experimental results. The difference of thermal resistance between experimental study and CFD analysis is around 4.75%. Based on the findings, the thermal resistance is reduced with increasing Reynolds number but it increases pressure drop. The turbulator attachment reduces thermal resistance, thermal resistance of PFHS without baffles is high than with baffles. But the baffle inserts will increase pressure drop in the cooling flow medium due to flow obstruction. This baffle insert design heat sink can be used wherever highest transfer is required in limited space. This higher pressure drop leads to no improvement in the profit factor. Hence baffle dimensions may be changed accordingly so that the air obstruction and pressure drop will be minimized to some extent, which will help to increase the profit factor (J) [34].

Idris Al Siyabi et.al., In this research work explore the effect of the PCM heat sink has been compared to a non-PCM heat sink. Also, the variation of PCM thickness, melting temperature and the two PCM concept have been studied inthis work for power ratings ranging between 1.0 W to 2.0 W. The variations in the heat sink temperature and the PCM melting profile with time have been used to analyze the system performance. The following is concluded from this work:

- Two PCM techniques with arrangement of RT50–RT55 increases the thermal regulation period by110 min and 130 min as compared to RT50 and RT55, respectively. Using RT50–RT55, the heat sink temperature at the end of the operation is reduced by 10.3 _C and 6.1 _C as compared toRT50 and RT55, respectively, for 2.0W.
- Two PCMs with the arrangement of RT58-RT47 reduces slightly the maximum temperature as compared to RT47–RT58.
- As PCM thickness increases from 30 to 60 mm, the thermal regulation period increases by 50 min and 35 min for 1.5 W and 2.0 W power ratings, respectively. As the PCM melting temperature increases from 47 (RT47) to 58 _C (RT58), the thermal regulation period increases from 30 to 70 min for 2.0W. However, the heat sink temperature also increases from 63 to 74 _C. [35]

M. Karamia et.al. In this research, the steady-state incompressible fluid flow in a micro pin fin heat sink with the baffles was investigated. Modelling ,meshing, and analysis of laminar flow in the range of 50≤Re≤250were performed using ANSYS Fluent. Three different baffles (single segmental baffle, double segmental baffle, triple segmental baffle) were used. The length of the baffles was investigated in four dimensions, which formed four different overlaps namely 60%, 40%, 20%, and 0%.The results showed that creating baffle between pin fins has a great influence on the heat transfer rate. Their effect on low Reynolds numberis insignificant and increases with higher Reynolds. The average fluid velocity was checked to find the reason for this difference. The pressure drop is another parameter that is important in micro channels and micro pin fin heat sinks and we reviewed it in this research. The highest-pressure drop is related to double segmental baffle and a 40% overlap, which increased pressure drop by 77% in Reynolds number 250 compared with the micro pin fin heat sink without a baffle. The results show that the baffle has a significant effect on the micro pin fin heat sink heat transfer rate. The micro pin fin heat sink with double segmental baffle had the best performance in the heat transfer rate. The heat transfer rate in a 20% overlap and Reynolds number 250 is 47.37% higher than the heat sink without baffle. The lowest heat transfer rate in this baffle was at Reynolds number 50 and 20% overlap (4. 7% higher than the micro pin fin heat sink without a baffle). The micro-pin fin with a triple segmental baffle in a 60% overlap and Reynolds number 250 has a30.4% increase in heat transfer rate compared with micro pin fin heat sink without a baffle. The heat transfer rate of micro pin fin heat sink with a single segmental baffle in a 0% overlap and Reynolds number250 is 26.76% higher than the micro pin fin heat sink without a baffle[36].

Marina Astanina, et.al., The process of hydro gravitational convection of the liquid with a temperature-dependent viscosity in a closed porous two-dimensional enclosure having a heat-conducting and heat-generated element with a copper heat sink on the lower adiabatic boundary of the cavity has been examined numerically with the help of non-dimensional stream function, vorticity and temperature variables. A numerical simulation has been conducted in a broad range of the governing parameters suchas geometry characteristics of the heat sink, viscosity, and time. The distribution of isolines and integral characteristics of heat transfer has been received. It has been demonstrated that geometry characteristics of the heat sink play the main role in the process. For example, a rise of the thickness of the radiator fins from 0.06 to 0.24 characterizes an increment of the average heater temperature upto 28%, while a growth of the length of the adiabatic sections on the vertical walls from 0 to 1 leads to an increase in the temperature within the energy source at about by ten times. A rise in the fins number has the non-monotonic effect, namely, the convective motion strength and average heater temperature are reduced for a rise on n from 1 to 3 (namely the liquid circulation rate decreases at about 63% and average heater temperature reduces at about 41%), while these average parameters are increased when n rises from 3 until 5 (namely, the liquid circulation rate increases at about 27% and average heater temperature rises at about 21%). Therefore, the fins number n = 3 can be considered as an optimal value of fins number characterizing low heater temperature. Taking into account the temperature dependent viscosity with exponential law one can find a physical nature for the results of mathematical modelling with intensification of the convective flows within the cavity. The cooling system with a copper heat sink is a good way for management of heat removal from the energy source. As a rule, such systems have a high thermal conductivity and heat capacity which provide effective heat removing.

III. TURBULATORS EFFECT

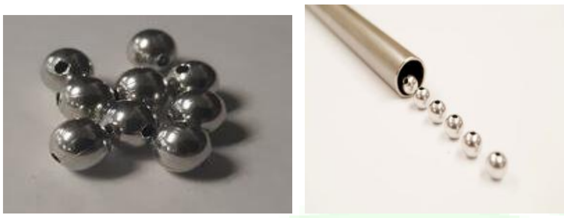
Turbulators play an important role in heat sink. In fin tube heat exchangers, the fluid (gas/water/glycol/ refrigerant/etc.) circulating through the coil’s tubes is extremely important for the coil’s overall performance – it’s half the battle, along with airside heat transfer. The degree to which the fluid contacts the tube walls affects the coil’s performance and influences a system's overall efficiency – the more the fluid comes into contact with the tube wall, the better – and more economical – the heat transfer.One method used by coil manufacturers to increase the efficiency of heat transfer equipment – particularly in applications involving fluids with low velocity, high-viscosity, or both – is by creating turbulence within the heat exchanger’s tubes. By doing so, turbulent flow is achieved, which, relative to the less energetic laminar flow, makes for increased contact with tube walls.

There are four common types of turbulators seen in heat exchanger:

A. Ball,
B. Twisted Tape,
C. Spring,
D. Matrix.

Ball Turbulator

Ball turbulators are true to their name – small balls, usually made from aluminum, used to affect the flow of the working fluid in a given coil. They do so by taking up space within the tube, increasing velocity by reducing volume



Ball Turbulator (b) Coil with Ball Turbulator
Fig. 3 Ball Turbulator

In the above fig. 3 shows the ball turbulator, the turbulators covered in this post, ball turbulators are the most effective, as they best reduce the internal surface area of the tube. However, with that reduced surface area comes the highest pressure drop of the four turbulators discussed in this piece. Like several other elements of heat transfer, the expression "if some is good, more is better" does not apply, as an optimal balance between pressure drop and ideal turbulence must be attained.

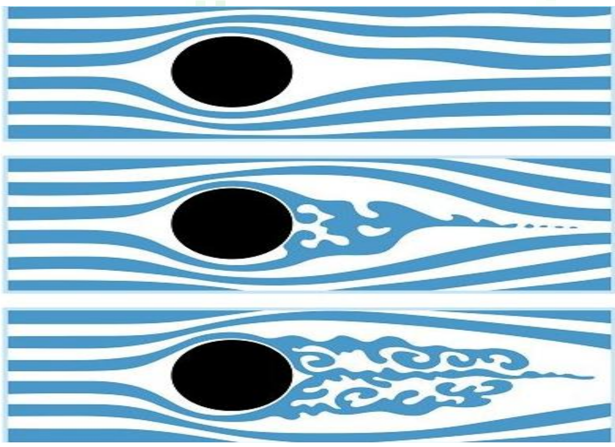


Fig. 4 Turbulator CFD analysis

With regard to cost, ball turbulators are fairly inexpensive, but should be purchased to stock if used regularly to best realize the value.

Spring turbulator

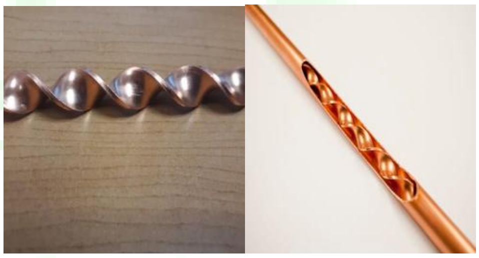
Another example of the excellent naming abilities of its creators is the spring turbulator, which is a coiled spring. They're sold as tightly wound coils (picture a small-diameter slinky) and then stretched out inside the tube (picture a ruined small-diameter slinky). Small hooks at either end of the tube, combined with a snug fit within the tube's internal diameter prevent the spring from returning to its original shape and establish contact between the spring and tube wall.

(a) Spring Turbulator (b) Tube wall with Ball Turbulator
Fig. 5 Spring Turbulator

Spring turbulators create a wave-like motion, directing fluid energy up and down more so than imparting spin. This motion channels the fluid toward the tube walls, eating into the boundary layer and improving heat transfer. They can be made from a number of materials, but ours are typically made from brass, and they offer an excellent balance of relatively low cost and good performance. Like ball turbulators, springs' value is best realized when ordered in bulk and stocked for specific diameter tubes.

Twisted tape turbulator

These helically shaped rods are inserted into heat exchanger tubes, where they create turbulence. They create turbulent flow in a method similar to that of a spring turbulator, but not identical, and can be made from any number of materials.



(a)Twisted Tape Turbulator(b) proto type Turbulator
Fig. 6. Twisted Tape Turbulator

These helically shaped rods are inserted into heat exchanger tubes, where they create turbulence. They create turbulent flow in a method similar to that of a spring turbulator, but not identical, and can be made from any number of materials.

Twisted tape turbulators essentially bisect the tube's internal diameter, coming into contact with the tube wall, where they create turbulence and channel the flow away from the tube's center outward to the boundary layer. This makes the fluid nearer the wall more turbulent than in the center, which is desirable, as the bulk of the heat transfer occurs in this region of the tube.

Twisted tape turbulators' performance is marginally better than spring turbulators, but the price is much greater, and costs add up quickly depending on number of tubes. Lead time for twisted tape turbulators is longer as well, as each turbulator must be made according to the tubes' specific lengths. The customer can also specify the number of twists per foot, depending on the required level of turbulence.

Matrix turbulator

The matrix turbulator consists of a twisted wire rod adorned with thin wire loops along its length. Typically made from stainless steel, these devices serve as static mixers, churning the fluid and imparting turbulence.

(a)Matrix Turbulator (b) Matrix type Turbulator with Coil

Fig. 6 D.Matrix Turbulator

Like twisted tape, these must be made custom for each coil, resulting in higher cost. Contributing to that higher cost and - high performance - is the fact that the configuration and density of the matrices can be changed to meet the needs of a given application.

IV. CONCLUSION

In this experiment the primary goal is to study the performance of heat sink with different orientation of the fin. The experimental and numerical study will be performed. The main objective of this study is to find better configuration of a heat sink which can work smoothly even after the temperature inside the component exceeds the IGBT permissible temperature. Best optimized configuration of given heat sink will be found. This will be achieved with the help of experimental & numerical study

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