Effect Of Turbulators On Plate-Fin Heat Sink For Heat Transfer Enhancement-Through Computational Fluid Dynamics

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***Abstract*—The performance of the heat sink mainly depends on the design, working fluid, base temperature and flow behavior of the fluid. Since many decades many of the researchers and academicians have put their efforts to enhance the performance of heat sink. With the development of technologies and the miniaturization of electronic equipment's heat generation inside the electronic devices becomes the major concern. This put direct pressure on researcher to have a high specific heat transfer heat sink. So, in the same order here in this work, new design of plate fin heat sink with turbulator was proposed to enhance their performance. Different design of turbulators were placed in between the plate fins heat sink. Effect of different design of turbulator on heat sink performance with change in Re number was analyzed. Through CFD analysis flow behavior of fluid, velocity variation and pressure drop inside the duct was evaluated. Through numerical analysis it was found that, with the use of turbulator the performance of heat sink gets significantly enhance as compared to simple plate fin heat sink. Out of different design of fins, square shape of fins shows the better performance as compared to others.**

***keywords* -Computational Fluid Dynamics(CFD),plate-fin heat sink, turbulators, heat transfer,**

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 varied: Heat sinks are one of the most common forms of thermal management in technology, machinery, and even in natural systems. These components are so ubiquitous that they're easy to overlook, even by those who are familiar with the technology.As far as history goes, the field of electronic cooling does not have a very long past. A rather quick look through my personal reference material that is strictly geared towards cooling electronics had at the earliest some US Navy documents from the 1950s. Comparing the solution techniques available today to those available then shows that we have both much better tools and harder problems (although I still like to refer to the suggested heat transfer coefficient value of ~10 W/m2-K for natural convection when not much else is known). Perhaps because of the shorter history and the tendency of engineers working in this field always being exposed to the latest and greatest electronics, the electronics cooling community sometimes doesn't venture out and learn from related fields. When we start solving problems without doing significant research, we can live in a fairy tale world where we think that our problems are strictly unique to us. There can be a benefit of taking some time to examine the past and finding out that other smart engineers have often looked at similar problems and may have relevant information that would help us with understanding. The use of heat exchange theory provides a good example where there is a possible benefit from thinking about the problems, we are solving from more than one viewpoint.

Since the resistance can vary with the coolant velocity, information about how Rth varies with velocity may be provided. The coolant temperature of reference is the inlet temperature. While this approach is convenient, there isn't much need to think about using a minimum amount of coolant and other constraints such as noise and prime power to move the coolant may dictate the flow rate. Engineers that come from an avionics background typically consider that the coolant will change temperature as the waste heat is added. Often, the coolant flow rate is specified in terms of flow rate per KW of heat such that the temperature rise of the coolant from inlet to exit is constant for different electronic assemblies. The mindset is to use the coolant as efficiently as possible because additional coolant is either not possible or very expensive. One of the potential benefits of applying heat exchanger theory to electronics cooling is that it can provide one way of looking at efficiency. Moffat provides a good discussion on heat exchanger theory applied to air-cooled heat sinks and general heat exchanger theory can be found in most heat transfer textbooks [While the theory was mostly developed to deal with two fluids, a bounding case where one of the fluid temperatures did not change (such as with condensation or evaporation) simplifies the equations and can be representative of heat sinks used to cool electronics.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 is an increased contact area between the working fluid (air) and the material surface. Here in this work, the effect of placing different shapes of turbulator in the longitudinal direction of the plate-fin heat sink on heat transfer was analyzed. It also analyzes the effect of placing the turbulator in the transverse direction of the heat sink.

II.SOLID MODEL AND MESHING

For making the solid model of the heat sink as considered in Saravana kumar et.alsame geometric parameters were considered asmentioned in the paper. The geometric parameters considered for a solid model of the heat sink are.Length of the heat sink-100 mm, width of the heat sink-92 mm, height of heat sink-31 mm, length of the plate fins-25 mm, thickness of fins-2 mm, pitch of fins-8 mm, turbulator dimension (width*thickness*height)- 2*1*25 mm^3. Based on above mention geometric conditions of the plate-fin heat sink solid model was made in Ansys design modular. The solid model of the plate-fin heat sink is shown in the below figure.

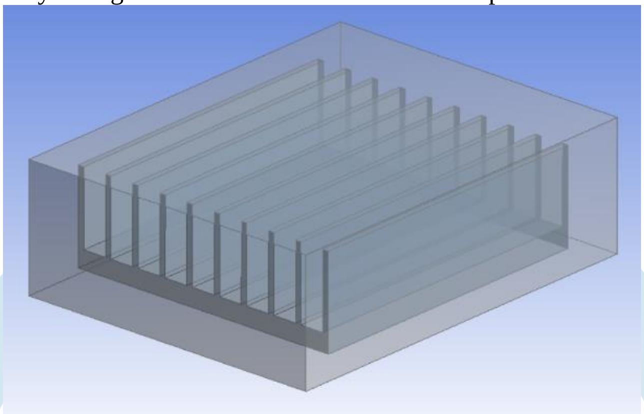

Fig 1. Plate-Fin Heat Sink

For performing the numerical analysis of the heat sink, discretization of the heat sink into the number of different elements was done. To check the grid independency, heat sink geometry was discretized with different numbers of elements and calculated the heat transfer coefficient for Re – 1013. Through numerical analysis, it is found that with 231032 elements with 61566 numbers of nodes, the optimum result is coming. So, it is concluded that after increasing the number of elements to 231032, there is no such change was observed during the work. For further analysis, 2310 elements were considered during this work. The meshing of the solid model plate-fin heat sink without turbulators is shown in the below figure

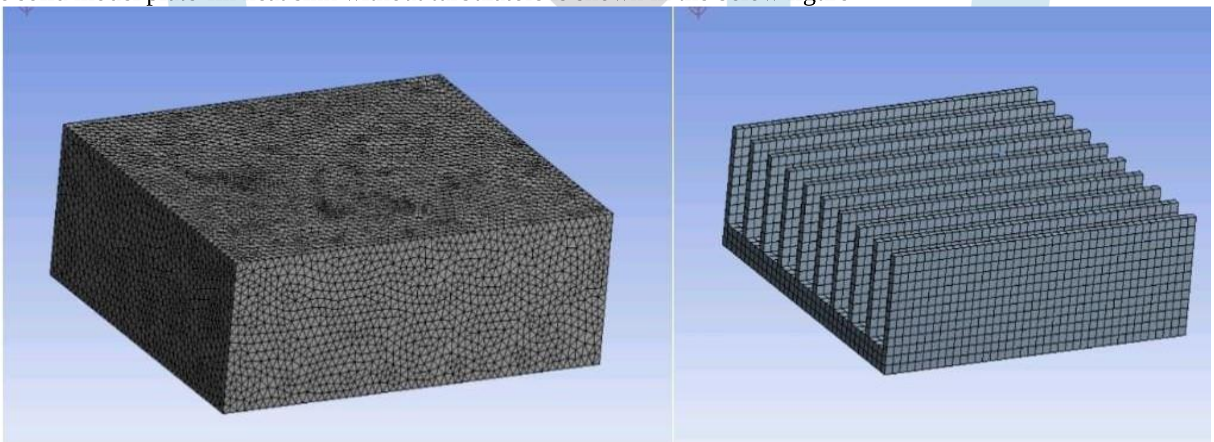

Fig2. Mesh of the Heat Sink.

In this case, the hexahedral shape of the element is used to do the mesh of the heat sink. For the enhancement of results and better numerical analysis, it is necessary to have mesh refinement in critical zones of the heat sink. Refinement was also done in the area of two different medium contact regions. After mesh refinement name selection of different components of the heat sink was done.

III. BOUNDARY CONDITION AND SOLUTION METHOD

To validate the numerical analysis of the heat sink, the same boundary conditions were considered as considered by Saravana Kumar et al. at the inlet, the air inlet temperature is 300 K. whereas 80 W heat was considered during the numerical analysis. No-slip conditions were also considered inside the wall of the heat sink. Here it selects the coupled base second-order upwind methods for the CFD analysis of plate fins heat sink.

IV. PLATE FIN HEAT SINK WITHOUT BAFFLES

For validation, numerical analysis of heat sinks without baffles was done at different Reynolds numbers. For analysing the effect of change in Reynolds number four different number was considered during the work that is 1013, 1793, 2706, and 3309.According to Reynolds numbers velocity of air at the inlet, and the heat sink was calculated, and the velocity of air at the inlet for different Reynolds numbers is 0.822, 1.45, 2.19, and 2.68 m/s.

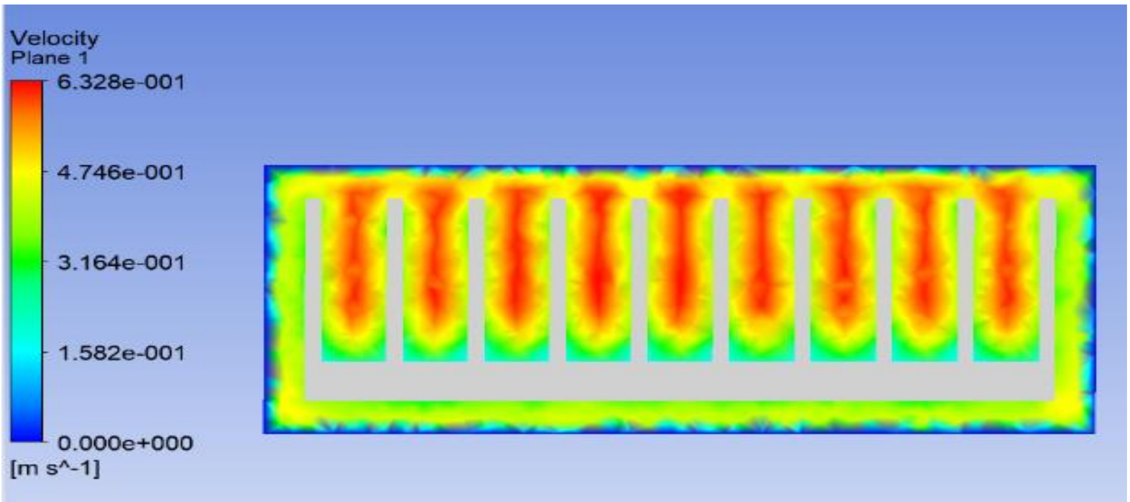

Fig 3. Variation of Velocity in The Transverse Direction of Heat Sink AtRe – 1013

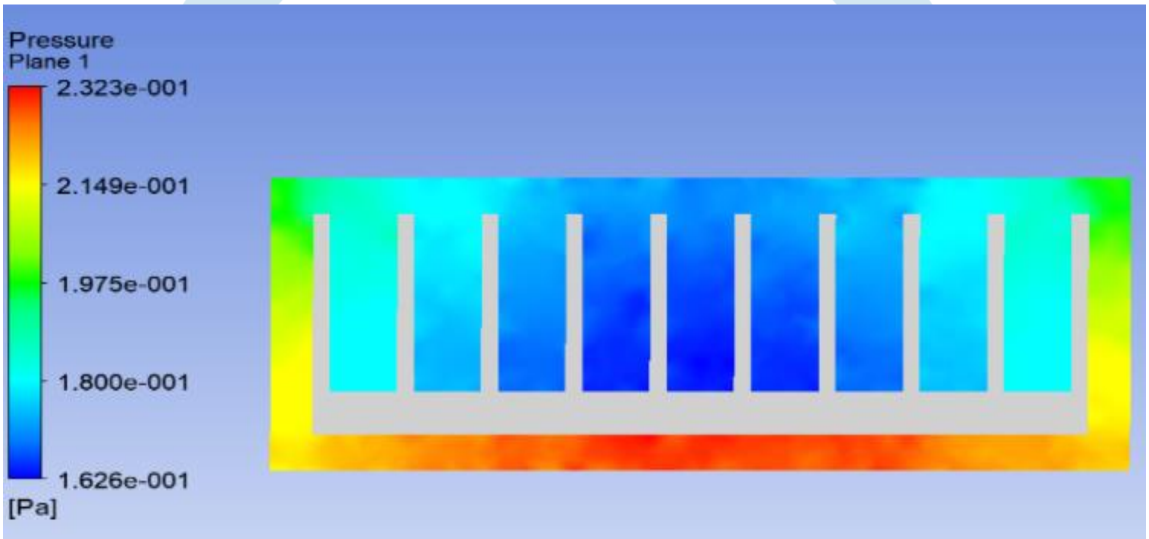

Fig4. Variation of Pressure in The Transverse Direction of Heat Sink at Re – 1013

The above figure shows the velocity variation at the central plane of the heat sink. From the contour, it was observed that thevelocity of air is maximum in the middle of the channel. The value of the Nusselt number and pressure drop for different Reynolds numbers calculated through numerical analysis is mentioned in the below table. Through the table, it was found that with the increase in Re number for a simple plate-fin heat sink the heat transfer gets increases. Whereas by increase the Re number pressure drop gets also increases.

V.VALIDATION OF NUMERICAL ANALYSIS OF PLATE-FIN HEAT SINK WITHOUT TURBULATOR

After computing the significance of the Nusselt number and pressure drop for plate-fin heat sink at different Reynolds through CFD analysis, it is then compared with the experimental results performed by Saravana kumar et.al.

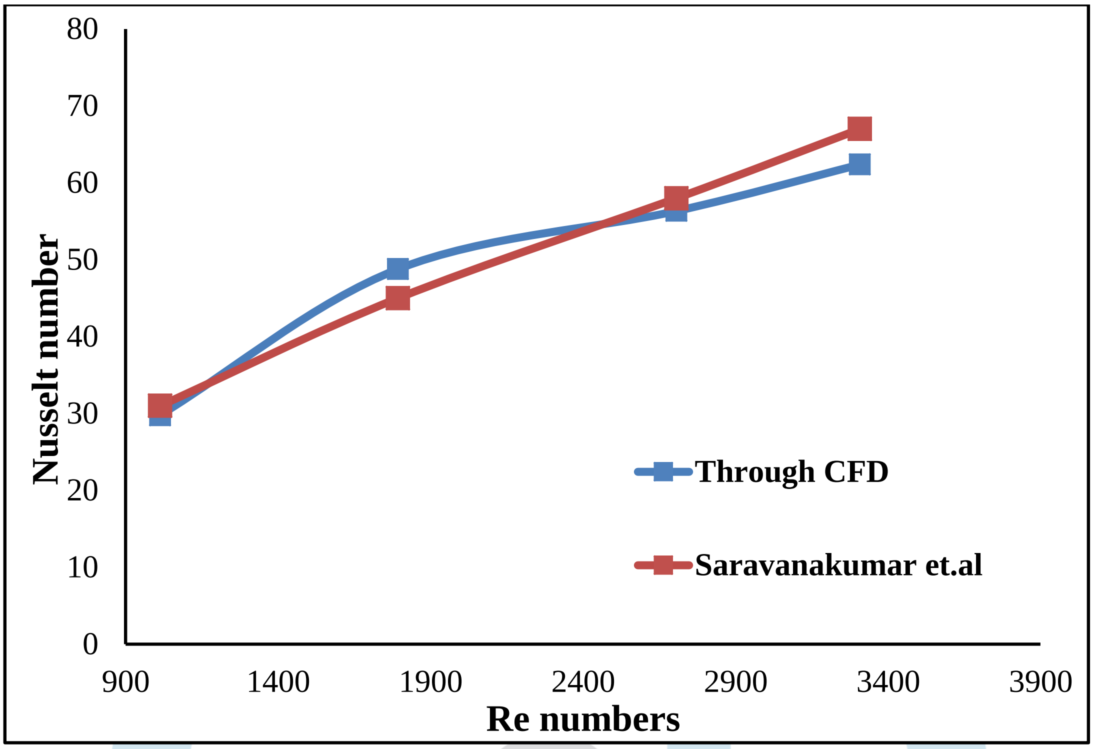

Fig 5. Comparison of the Value of Nusselt Number

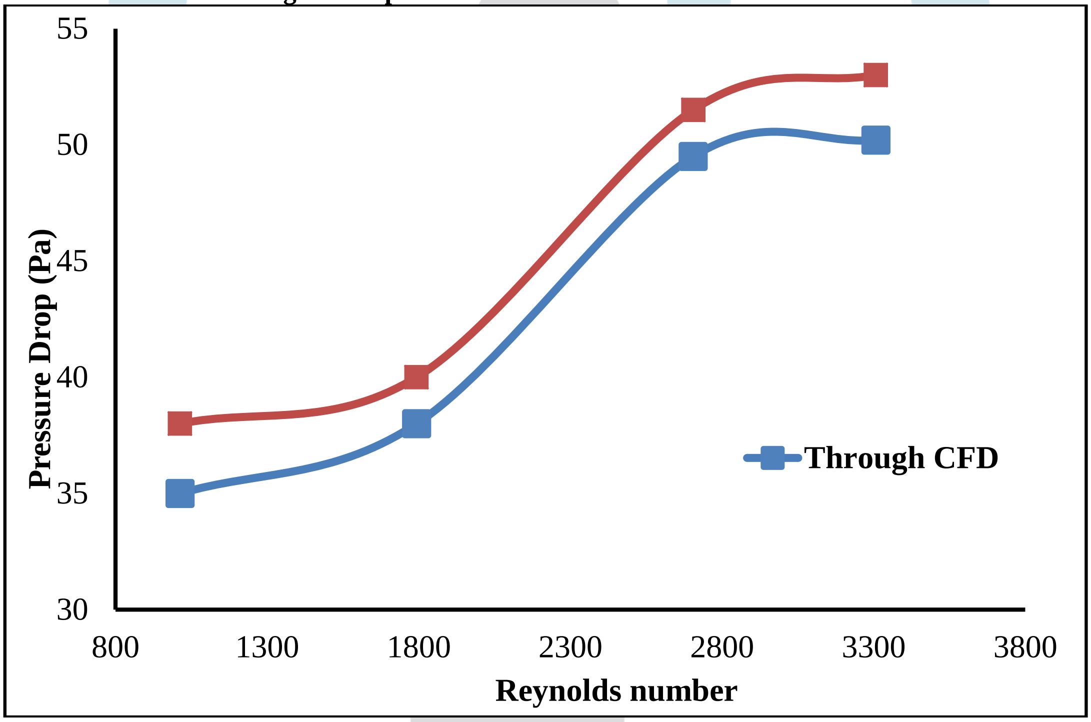

Fig 6. Comparison of Pressure Drop at Different Reynolds Number

VI. RESULT AND DISCUSSION

After comparing the value of the Nusselt number, the value of Pressure drop inside the heat sink was also analyzed and compared in the below table with the experimental result performed by Saravana Kumar et.al (1). Through comparison of pressure drop and Nusselt number, it is found that the result obtained through CFD analysis is near to the values obtained through experimental analysis performed by Saravana Kumar et.al and it is coming to under 10% error to it is concluded the CFD analysis of Plate fins heat sink is correct. From the above graph, it is found that the value of pressure drop inside the Plate fin heat sink without baffles at different Reynolds numbers is coming near to the values calculated through experimental analysis. The error is under 10% which shows the accuracy and correctness of the CFD analysis of plate-fin heat sink without baffles. After validating the CFD analysis of the heat sink, for the further enhancement of heat sink heat transfer, here in this work different shapes of turbulators were used in between plane fins.

VII. THE SQUARE SHAPE OF TURBULATOR

In this case, the square shape of turbulators was considered during the work, square shape turbulator with 4 mm^2 cross-sectional areas. The solid model of the heat sink with a square shape turbulator is shown in the below figure.

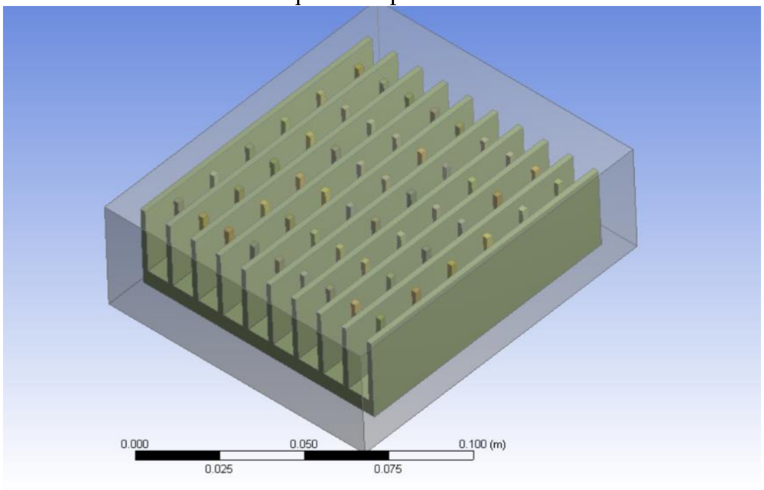

Fig 7. Heat Sinks Have the Square Shape of Turbulator.

VIII. COMPARISON OF DIFFERENT SHAPES OF TURBULATORS

After analyzing the effect of different shapes of turbulators inside the plate-fin heat sink, a comparison of different shapes of turbulators at different Re numbers was done. the comparison was mainly done based on the Nu number and pressure drop inside the heat sink for different turbulator geometry at different Re numbers. The comparison of the value of the Nu number for different Re numbers is shown in the below table.

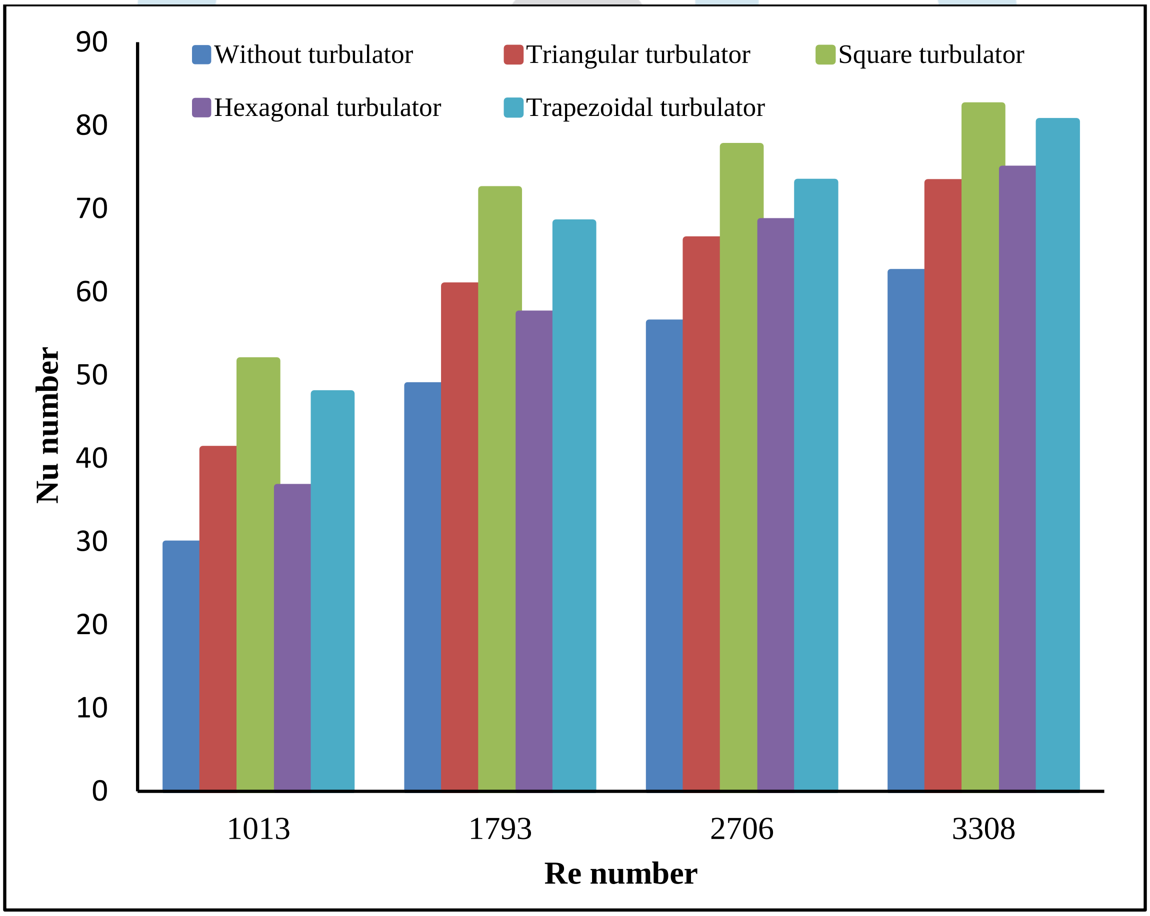

Fig 8.Comparison of the Value of Nu Number for Different Shapes Of Turbulator.

From the above graph, it is found that the heat sink with a square shape of turbulator shows the maximum value of Nu number as compared to other shapes of turbulator for each case of Re number. From the above graph it is found that with the use of turbulator, the pressure drop inside the heat sink is more as compared to without turbulator heat sink. But with the change in the shape of turbulator there is a very marginal change in pressure drop for different shapes of turbulators.

IX. COMPARISON OF DIFFERENT HEIGHTS OF TURBULATOR

After evaluating the performance of the heat sink having turbulators on the adjacent walls of the plate fin with different heights, a comparison was done. The performance of the heat sink was compared based on the Nusselt number and pressure drop.

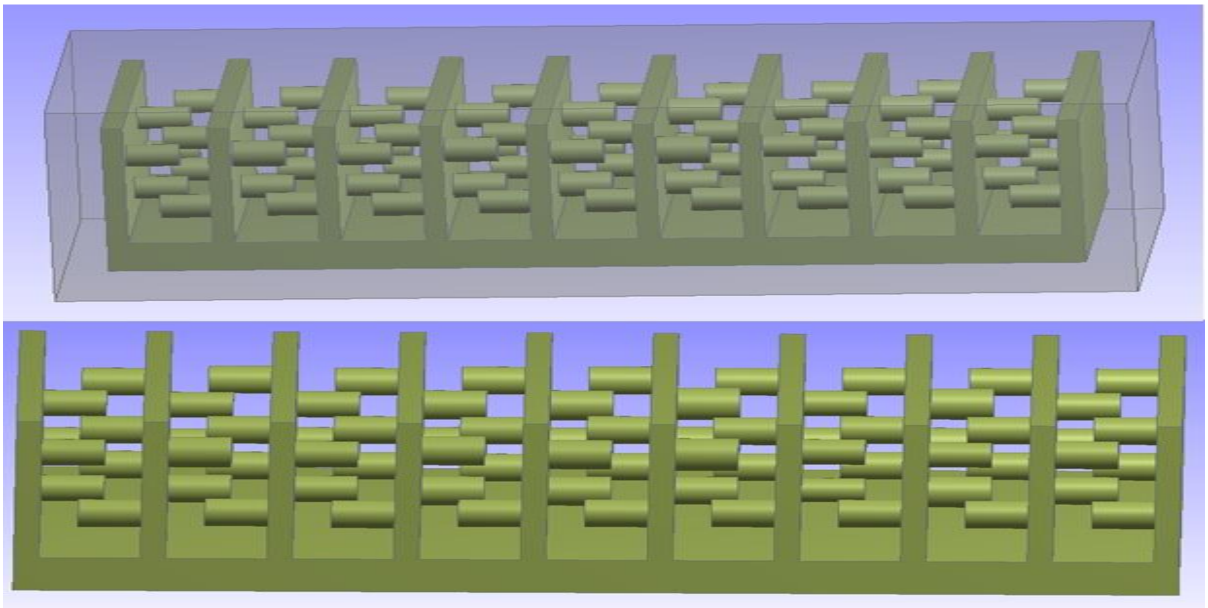

Fig.9. Effect of Placing Turbulators on The Wall of The Fins in Heat Sink

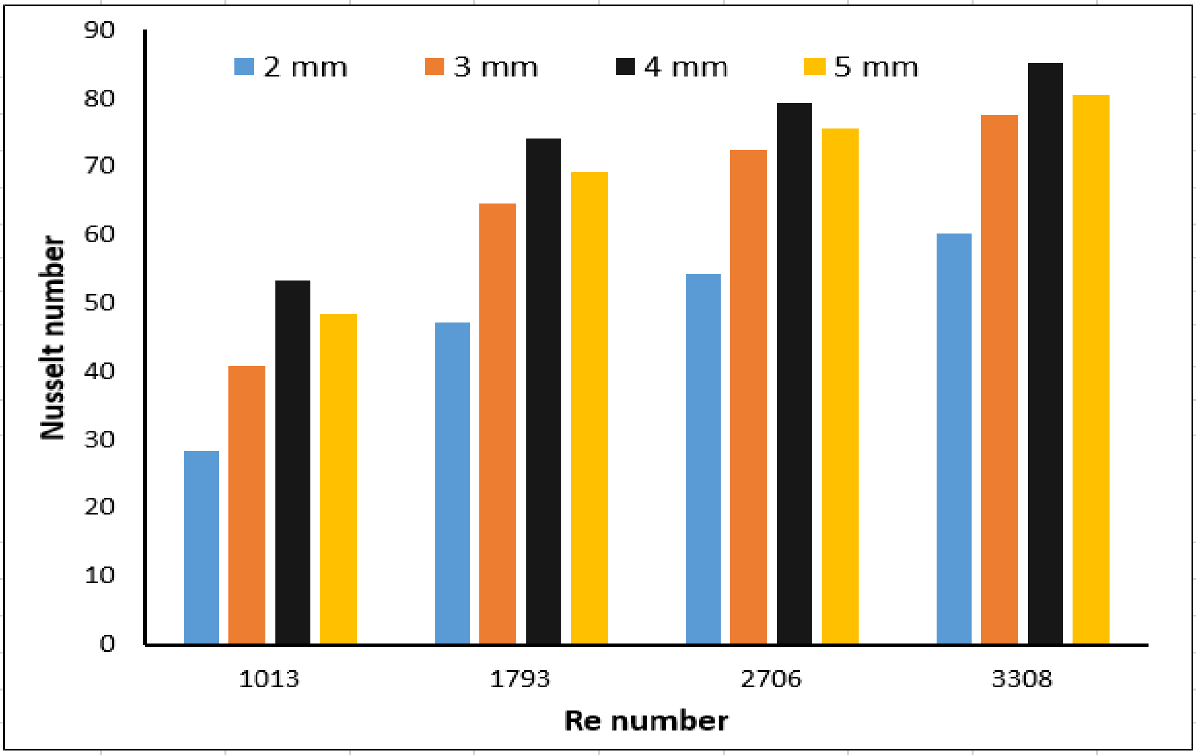

Fig 10. Comparison of the Value of Nusselt Number for Different Heights of Turbulator

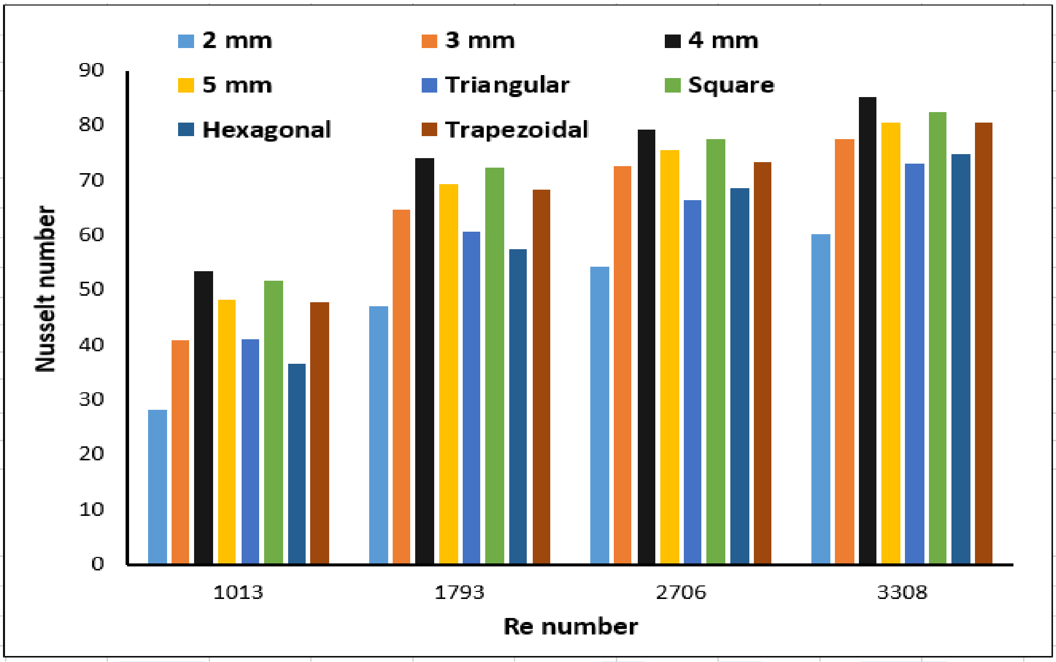

Fig 11. Comparison Of theValue ofNusselt Number forTurbulators Placed inA Different Position

Through comparison, it was found that with an increase in height of the turbulator up to 4 mm, the value of the Nusselt number gets increases whereas for 5 mm height it starts decreasing. The pressure drops inside the heat sink get increases with an increase in height of the turbulator. Through CFD analysis it was found that in the case of turbulator placed on the fins, 4 mm height turbulator shows the maximum heat transfer as compared to other heights of the fins. After evaluating the performance of the heat sink turbulators placed on the base plate and the surface of fins comparison was done.

X. CONCLUSION

- The effect of different shape of the turbulator place on the base plate of the heat sink was analyzed through CFD using Ansys Fluent.
- It is fond that turbulators with rectangular shape shows the higher Nu number, this means the heat transfer is higher than the other shape of turbulators having same cross-sectional dimension.
- Heat sink having turbulators shows the higher heat transfer as compared to heat sink without turbulator. This shows the significance of use of turbulators in plate fin heat sink.
- It is found that with the use of turbulator, the pressure drop inside the heat sink is more as compared to without turbulator heat sink. But with the change in the shape of turbulator there is a very marginal change in pressure drop for different shapes of turbulators.
- To analyze the effect of changing position of turbulators, turbulators were also place on the besides wall of the plate fins.
- Most commonly used circular shape of turbulators having same cross-sectional area with staggered arrangement was considered during the numerical analysis of heat sink having turbulators at the besides wall of the plate fins.
- Through CFD analysis it is found that turbulators placed on the wall of the fins having 4 mm height shows higher heat transfer as compared to all heat sink having turbulators place on the base plate.
- The value of pressure drops for turbulators placed on the fins is significantly lower than the turbulator placed on the base plate of the heat sink.
- Overall, it can say that the heat sink with turbulators placed on the adjacent wall of the plate-fin heat sink shows better performance as compared to the turbulator placed on the base place of the sink

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