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Numerical Heat Transfer Analysis through Triangular Fins

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ABSTRACT

The challenge posed by high heat fluxes in electronic components makes thermal management an essential element in the development of these systems, which are driving conflicting needs for high performance as well as reduced power consumption, size, and weight. Although many new cooling technologies such as cooling by heat pipes, cold water, and even by liquid nitrogen have been proposed and adopted, air cooling by heat sink is still a commonly used solution for thermal management in electronic packaging due to its low cost, availability, and reliability factors. The main objective of this study is to investigate numerical study of the thermal performance of triangular fin heat sink. Finite volume method based CFD software, Ansys FLUENT, will be used as the tool to solve the current problem. This study will be performed with variable thermo physical parameters to find the optimum values to control the temperatures in safe range.

KEYWORDS: Numerical study, Thermal management, Triangular fin, CFD software

1. INTRODUCTION

In present era, the cooling of electronic chips to have optimum performance is becoming more and more challenging. The major reason for failure of electronic device or system is due to overheating or thermal mismanagement. Whenever the electronic circuitry is powered on and electric charge flows through it, heat gets generated due to I2R losses or Joule heating (I Current, R- Resistance). This heat has to be dissipated effectively so has to make these electronic devices reliable and operate in upright condition. In most of the cases dissipation of this heat naturally may not maintain the operating temperature of these electronic devices below the threshold value because of the processing capabilities that they have to deal with. This requires external attachments to boost up the heat transfer process. One such attachment is the use of heat sink. we can see the electronic applications such as integrated circuits such as graphic card, audio area, chip sets, control processing unit (CPU) and hard disk drives are making a high effort to give the best outcome but as high working conditions lead to heat dissipation which must be reduced to an extent within less span of time and without increasing other difficulties for the system. Various heat dissipation solutions in the form of heat sinks are being presented with innovative design, having better metallurgical options. Most widely accepted heat sink designs of triangular and pin fin heat sink with aluminum as are the feasible material choice. A heat exchanger is a machine that transfers the heat of a fluid to one or more other fluids with different temperatures. As a result, the heat exchangers are implemented in all industrial and commercial usages, and even those aspects of normal life that are related to energy transfer. Each living creature is somehow equipped with a heat exchanger. Heat exchangers are manufactured in very small and very huge sizes. The smallest heat exchangers (less than one we used for super conduct or electronic applications, guiding missiles controlled by the thermal source, etc. The biggest heat exchangers (more than1000MW) are implemented in large power plants as boiler, condenser or cooling tower. Heat exchangers are widely used in different industrial units like power plants, refineries, metal molding and glass industries, food a systems for buildings, gas congestion industries, land, sea and space vehicles, and finally electronic industries. The current research focuses on the optimization of triangular fin type, aluminum structured heat sink, using innovative computational and simulation tool, ANSYS software.

2. LITERATURE REVIEW

It describes about the literature review of the triangular fin heat sink. In this we considered twenty journals. We want to analyze the triangular fin heat sink with different convection regimes. The twenty journals are explained as follows:

Ikram Ullah et. al. [1] proposed that the objective of this research is to examine the efficiency of moving, porous, and triangular fins while also analyzing the improvement in heat transfer. The impact of different dimensionless characteristics such as porosity, radiation conduction, Peclet number, and thermo-geometric parameters Surface temperature, convection conduction, and their effects on the effectiveness of movement are examined. Triangular, porous fins. Both numerically and analytically, the model is studied utilizing DTM.**Mr. Ranjeet H. Basugade et.al. [2]** Described that due to the high thermal resistance supplied by gases in general, it is especially vital to increase the performance of heat exchangers using gas as the working fluid. The triangular fins can be used to increase the surface area density of plate heat exchangers, which can be used to make up for the poor heat transfer qualities of gases. Moreover, a promising Utilizing longitudinal vortex generators is a method for improving heat transmission. **Mir Waqas Alam et. al. [3]** discussed for a central processing unit, heat sinks' cooling capacity is crucial (CPU). In this work, simulation has been used to investigate the thermo fluid behavior of the designed micro-pin-fin heat sink. The heat sink is mounted on a triangular cylinder chip of a CPU. Air cooling techniques include utilized to extract heat. This numerical study takes fin and inlet turbulence intensity (TI) into account. Effect of the micro-pin-diameter fin's (D) on how well the heat sink perform Application of the Turbulent SST Model to capture the system is experiencing turbulence. **Mohamed A. Alfellaget.al.[4]proposed** in the current research, a conjugate heat transfer model was used to numerically examine the impact of an inclined slotted plate-fin mini-channel heat sink with triangular pins on laminar convection heat transfer and fluid flow. A parametric analysis of the heat sink's hydrothermal performance using the slots and pins were designed geometrically. Variations in the height were used to conduct the investigation. Of the inclination slot, its angle, and the placement of the pin in relation to the slot's leading edge. **Tehmina Ambreen et. al. [5]** discussed the Lagrangian-Eulerian approach is used to explore the combined effects of pin-fin shape change and the use of Nano fluid coolants on heat transfer and fluid flow properties of a heat sink. Square, round, and triangular cross-sectioned micro pin-fins' staggered array is analyzed for the parametric range of 570 Pa to 2760 Pa in terms of pressure. **Younes Menni et.al. [6]** Did this work involved in two-dimensional analysis of air, a fluid with constant properties, flowing into a rectangular channel with staggered cascaded rectangular triangular fins (CRTFs). The governing flow equations used to represent the incompressible steady fluid and turbulence include continuity, momentum, turbulence, and energy equations. **Mathanraj. V et. al. [7]** says a number of experiments were conducted to examine and contrast the heat transfer in a counterflow arrangement for examining with and without the use of longitudinal triangular fins. The test portion is a copper-made horizontal annular tube. A 1000 mm long tube having an inner diameter of 15 mm and an outside diameter of 19 mm. using a triangular fin with a base diameter of 9 mm, a height of 8 mm, and a thickness of 2 mm Current research. **Munther Abdullah Mussaet. al. [8]** discussed a large triplex-tube heat exchanger (TTHX) with internal longitudinal fins that incorporate phase-change material (PCM) is used in latent heat thermal energy storage (LHTES) systems. This heat exchanger was experimentally designed, tested, and evaluated. The PCM was completely cemented employing both-sides freezing as the primary technique while being affected Discharging temperature was 65 °C on average**. Sandhya Mirapalli et. al. [9]** described that the fins that are affixed to the surface can promote heat transmission by convection between a surface and the fluid surrounding it. The heat transfer via borders, walls, or other continuous solids dispersed into the environment or surroundings to keep the system operating in a stable state. In numerous technical applications required a lot of heat to be lost from confined spaces. By adding fins, the raising the surface's effective area will increase the heat. **Shadlaghani. A et.al. [10]** Aims the goal of this study was to identify a suitable pattern that would enable a more effective design of the heat sink fins. Forced convection was the studied heat transmission process, and flow was thought to be monotonous and stable. The shape of the fin cross section and its dimensions were designed to maximize the heat transfer rate in a certain physical situation while taking into account a fixed fin volume. **Akashnil Kayal et. al. [11]** talk about any heating or cooling system must include fins. Its main function is to enhance heat transfer.The many fin properties, including fin tip and base among others, the temperature, fin array, fin efficiency, and fin efficacy Others were investigated to determine how they impact fin efficacy, financial efficiency, and a practical algorithm This will provide flexible analytical and design capabilities and be put to use in transformers and freezers. **Shinde Sandip Chandrakant et. al. [12]** says that there are two types of cooling systems used in all engines: liquid cooling and air cooling. Liquid cooling is the more common of the two types of engine cooling systems. Because of its ability to reject a lot of heat, the preferred method of cooling a small capacity engine is it has a significantly more straightforward cooling system design both lighter and less expensive using an air-cooled engine For heat, annular fins with various fin profiles are utilised.transfer improvement, hence it's crucial for an efficient use of fin profiles in air-cooled engines gain improvement in heat transfer. **Mohd. Parwez Alamet. al. [13**] designed using CFD and varying air velocity of 2-4 m/s, the performance of a tube-type heat exchanger with fins of various shapes and varying fin pitch and thickness has been examined in the present work. Aluminum makes up the pin fin tube type heat exchanger, and air serves as the free stream fluid. **Gaurav Krishnayatra et.al.[14]** proposed that in the current case study, an unique axial finned-tube heat exchanger's thermal performance of the fins is examined and forecasted using a machine learning regression technique. Effects of changing the convective heat transfer coefficient, material, fin thickness, and fin spacing on the overall efficacy and efficiency have been examined and discussed. The k-Regression analysis use the machine learning technique nearest neighbor (k-NN) to forecast The outputs for thermal performance and the outcomes demonstrated remarkable prediction accuracy. **Ayush Bopcheet.al. [15]** Discussed that Al2O3 nanoparticles are used as the base fluid together with water and ethylene glycol to analyses the heat sink using five different Reynolds numbers. For numerical calculations using the single phase model, Ansys Fluent is employed. Experimental data with various Reynolds number values are used to validate the results. **Abhishek Mote et. al. [16]** aims in this study, CFD software is used to analyses heat transmission through finned surfaces. The heat transfer over the fins under the heat exchanger was simulated using CFD software. There are two different air speeds surrounding the fins. Based on experiment there was a time when several researchers conducted research. Using CFD software was a time-consuming task. **Hiba K. Mohsenet. al. [17]** discussed that electronic equipment frequently has a heat sink attached to it in order to remove extra heat. It cools circuit components by releasing surplus energy.in order to avoid overheating and premature failure of a component and improved component performance and dependability. The geometries of extrusion either flat-plate fins or pin fins are present on the heat sink. **Tianji Zhuet. al. [18]** proposed that latent heat thermal energy storage (LHTES) has received more and more attention in the Thermal energy storage field due to the large heat storage density and nearly constant temperature during phase change process. However, the low thermal conductivity of phase change material (PCM) leads to poor performance of the LHTES system. In this paper, the research about heat transfer Enhancement of PCM using fin tubes is summarized. **Evangelos Bellos et.al.[19]** talk about enhancing heat and flow is a vital tool for creating extremely effective, small, and affordable devices. The goal of this analysis is to thoroughly examine the implementation of various fin forms on the internal side of a tube with the intention of enhancing flow and heat. While the application of circular, rectangular, and triangular fins is studied, the reference empty tube also research. **Rahul Guptaet. al. [20]** says that the second-largest two-wheeler market in the world is in India. Due to its resilience and longevity, the motorcycle category has had notable growth patterns during the past four to five years among the three segments (motorcycles, scooters, and mopeds) of the Indian two-wheeler market. Balance, even on slick roads. Air-cooling is employed in Indian motorcycles because of the decreased Engine cylinder blocks are lightweight and easily constructed.

By considering all the above-mentioned journals, as per our knowledge we observed that different types of fins are considered and it should be done in the natural or forced convection only and some of the fins are compared with each other. Here we are doing the thermal analysis of a Triangular fin heat sink with convection regimes such as natural convection, forced convection, with and without radiation.

3. *METHODOLOGY*

This chapter discuss about the methodology and step by step procedure for the design and analysis of triangular fin heat sink. First, we took the steady state thermal analysis and we give the material selection. We designed the sketch in the geometry with specific dimensions that are mentioned below. After the sketch is modeled, we did mesh to that sketch with default size. Here we choose Aluminum as the heat sink material.

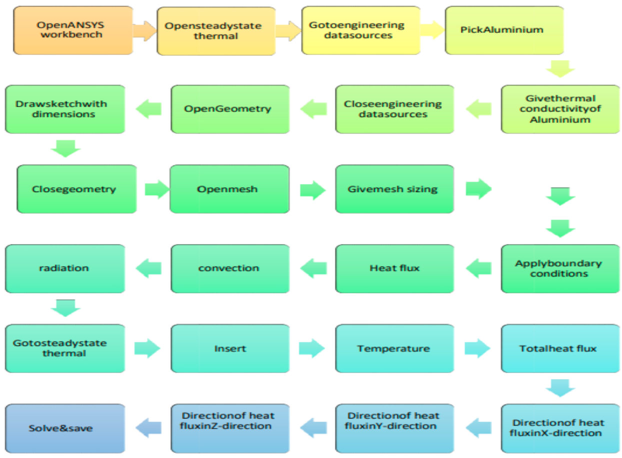


FIG: 1: FLOW CHART

Fig: 1 shows the flow chart of analysis

4. *ANALYSIS*

By performing the analysis, we got different temperature contours and are mentioned as follows: Fig 2 shows the resulted temperature of a triangular fin heat sink. Here the minimum temperature is 26.976 ^{0}C, average temperature is 26.988^{0}C and the maximum temperature is 27 ^{0}C.

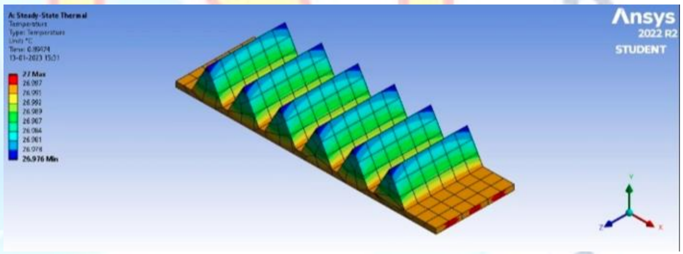


Fig: 2: Temperature

Fig 3 shows the total heat flux of the triangular fin heat sink. Here the minimum heat flux is 60.243W/M2, average heat flux is 270.30W/M2 and the maximum heat flux is 540.38W/M2.

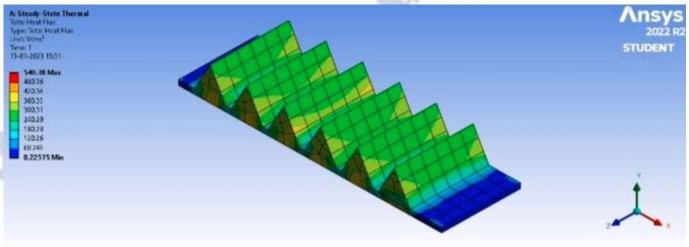


Fig: 3: Total Heat Flux

The X – direction of heat flux is as shown in the Fig 4. Here the minimum heat flux is -346.98 W/M2, average heat flux is -26.77 W/M2 and the maximum heat flux is 293.44W/M2 .

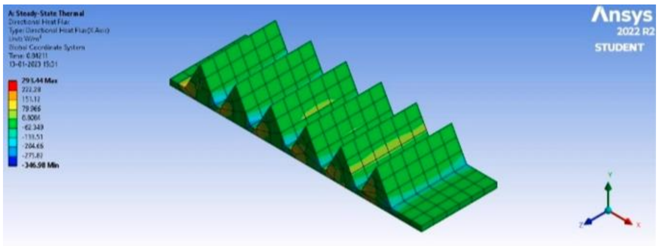


Fig: 4: X-DIRECTION OF HEAT FLUX

The Y – direction of heat flux is as shown in the Fig 5. Here the minimum heat flux is -189.09W/M2, average heat flux is 350.56W/M2 and the maximum heat flux is 539.65W/M2

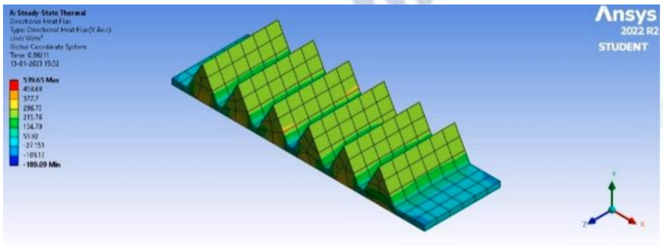


Fig: 5: Y-DIRECTION OF HEAT FLUX

The Z – direction of heat flux is as shown in the Fig 6. Here the minimum heat flux is -154.53W/M2, average heat flux is -9.1003e-008 W/M2 and the maximum heat flux is 154.53W/M2 .

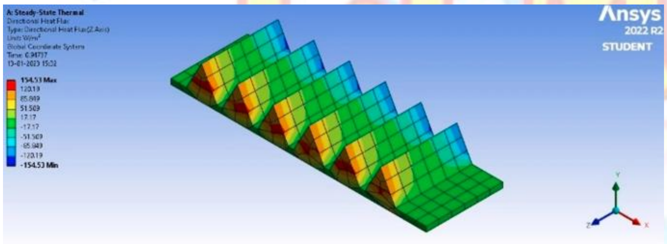


Fig: 6: Z-DIRECTION OF HEAT FLUX

5. RESULTS AND DISCUSSION

This chapter discusses about the simulation results. Here we got different temperature Results for different input parameters, those are explained as follows:

Simulation Results:

In this analysis of fins, we got results of nearly10, 000 different temperatures for different Convection regimes and radiation. Here all the fins are of same length, also same height and the Boundary conditions are applied as same to all the fins. So, we considered one fin here. The node Numbers from base plate to top of the fin is 167, 168, 169, 170. All the temperatures are in ^{0}C. Table 1 shows about the temperature results from natural convection to forced convection by considering the radiation as emissivity is 0.45.

Table 1 Radiation of 0.45

NODE NUMBER	S. NO.	h = 5 W/m2 K	h =10 W/m2 K	h = 25 W/m2 K	h = 50 W/m2 K	h = 100
167	1	79.739	79.591	79.169	78.524	77.412
168	2	79.294	78.897	77.763	76.044	73.122
169	3	78.942	78.348	76.656	74.108	69.825
170	4	78.676	77.933	75.824	72.661	67.387

Table: 2 shows about the temperature results from natural convection to forced convection by Considering the radiation as emissivity is 1.

Table: 2 with Radiation

NODE NUMBER	S. NO.	h = 5 W/m2 K	h = 10 W/m2 K	h = 25 W/m2 K	h = 50 W/m2 K	h = 100 W/m2 K
167	1	79.611	79.466	79.053	78.421	77.328
168	2	78.949	78.561	77.453	75.772	72.905
169	3	78.426	77.847	76.197	73.707	69.51
170	4	78.031	77.308	75.253	72.165	67.003

Table3 shows about the temperature results from natural convection to forced convection by considering without radiation.

Table: 3 without Radiation

NODE NUMBER	S. NO.	h = 5 W/m2 K	h = 10 W/m2 K	h = 25 W/m2 K	h = 50 W/m2 K	h = 100 W/m2 K
167	1	79.846	79.696	79.266	78.61	77.482
168	2	79.584	79.178	78.022	76.272	73.303
169	3	79.376	78.769	77.042	74.444	70.086
170	4	79.218	78.459	76.304	73.076	67.706

Table: 4 shows the temperature results for different emissivity's as 0.05, 0.25, 0.45, 0.85. These are the temperature values for the emissivity's by considering natural convection.

Table: 4 Emissivity for natural convection

NODE NUMBER	SL. NO	E = 0.05	E = 0.25	E =0.45	E =0.85
167	1	79.833	79.782	79.731	79.631
168	2	79.549	79.41	79.273	79.003
169	3	79.324	79.116	78.911	78.506
170	4	79.153	78.893	78.637	78.132

Table: 5 shows the temperature results for different emissivity's as 0.05, 0.25, 0.45, 0.85. These are the temperature values for the emissivity's by considering forced convection.

Table 5.1.5 Emissivity for forced convection

NODE NUMBER	SL. NO	E = 0.05	E =0.25	E =0.45	E =0.85
167	1	77.475	77.439	77.406	77.339
168	2	73.285	73.193	73.105	72.932
169	3	70.061	69.927	69.8	69.549
170	4	67.675	67.511	67.356	67.049

Table: 6 shows the temperature values for the emissivity by considering with radiation and without radiation.

Table: 6 with and without radiation in natural convection

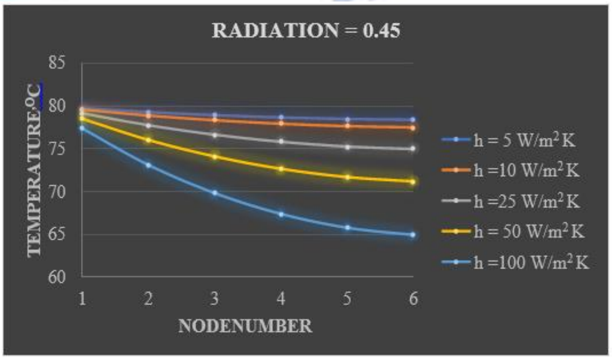
NODE NUMBER	SL. NO	E =0	E =1
167	1	79.846	79.594
168	2	79.584	78.903
169	3	79.376	78.357
170	4	79.218	77.945

Table: 7 shows the temperature values for the emissivity by considering with radiation and without radiation.

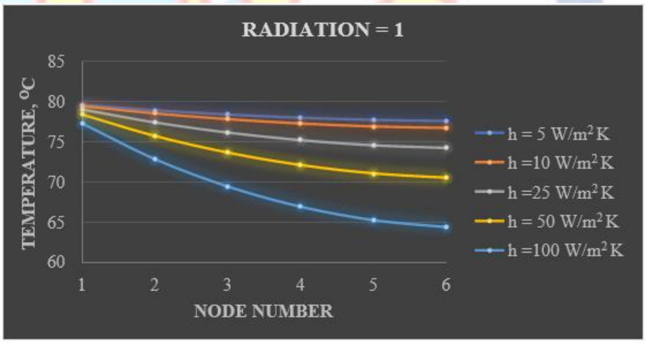
Table: 7 with and without radiation in forced convection

NODE NUMBER	SL. NO	E =0	E =1
167	1	77.482	77.314
168	2	73.303	72.868
169	3	70.086	69.456
170	4	67.706	66.935

The graph for temperature drop on various conditions is shown below: The Graph 1 shows the temperature drops for the different convections. In this graph the X–axis shows the node number and the Y–axis shows the temperature. It is the graph for the different convections by considering the radiation as 0.45. Here the blue line shows the temperature drop for convection of 5 W/m2 K, orange line shows the temperature drop for convection of 10 W/m2 K, grey line shows the temperature drop for convection of 25 W/m2 K, yellow line shows the temperature drop for convection of 50 W/m2 K and the light blue line shows the temperature drop for the convection of 100 W/m2 K.



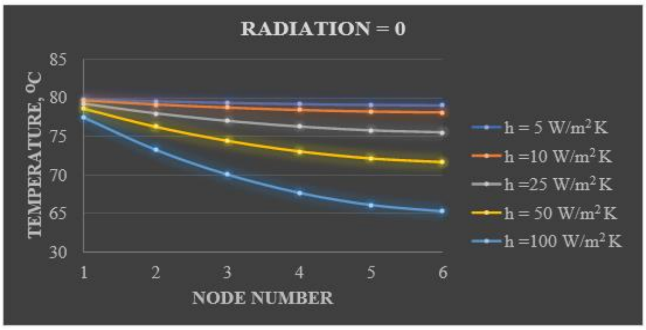
Graph: 1 considering radiation of 0.45



Graph: 2: Film coefficient with radiation

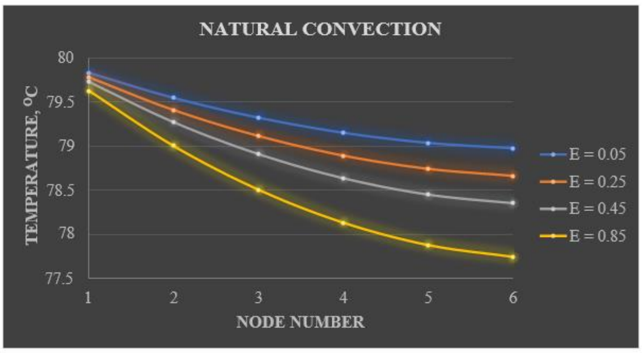
The Graph: 2 shows the temperature drops for the different convections. In this graph the X–axis shows the node number and the Y–axis shows the temperature. It is the graph for the different convections by considering the radiation as 1. Here the blue line shows the temperature drop for convection of 5 $W/m^2 K$, orange line shows the temperature drop for convection of 10 $W/m^2 K$, grey line shows the temperature drop for convection of 25 W/m^2 K, yellow line shows the temperature drop for convection of 50 $W/m^2 K$ and the light blue line shows the temperature drop for the convection of 100 $W/m^2 K$.

The Graph: 3 shows the temperature drops for the different convections. In this graph the X – axis shows the node number and the Y – axis shows the temperature. It is the graph for the different convections by considering without radiation. Here the blue line shows the temperature drop for convection of 5 $W/m^2 K$, orange line shows the temperature drop for convection of 10 $W/m^2 K$, grey line shows the temperature drop for convection of 25 $W/m^2 K$, yellow line shows the temperature drop for convection of 50 $W/m^2 K$ and the light blue line shows the temperature drop for the convection of 100 $W/m^2 K$.



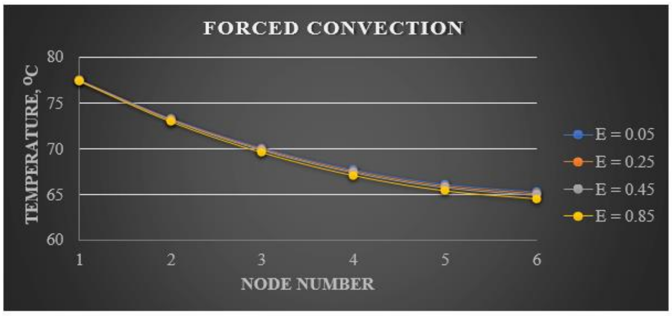
Graph: 3 Film coefficient without radiation

The Graph: 4 shows the temperature drops for the different emissivity's. In this graph the X – axis shows the node number and the Y – axis shows the temperature. It is the graph for the different emissivities by considering natural convection. Here the blue line shows the temperature drop for emissivity of 0.05, orange line shows the temperature drop for emissivity of 0.25, grey line shows the temperature drop for emissivity of 0.45 and yellow line shows the temperature drop for emissivity of 0.85.



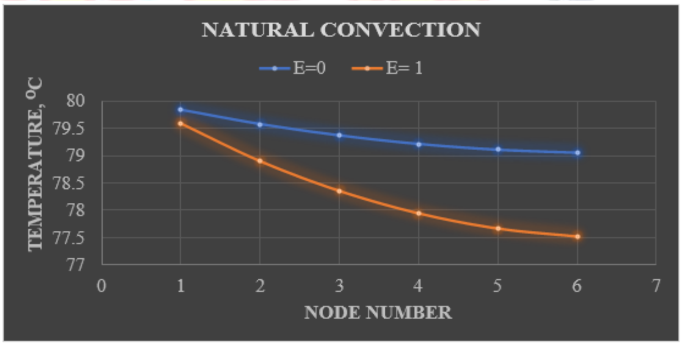
Graph: 4 Radiation in natural convection

The Graph: 5 shows the temperature drops for the different emissivities. In this graph the X – axis shows the node number and the Y – axis shows the temperature. It is the graph for the different emissivities by considering forced convection. Here the blue line shows the temperature drop for emissivity of 0.05, orange line shows the temperature drop for emissivity of 0.25, grey line shows the temperature drop for emissivity of 0.45 and yellow line shows the temperature drop for emissivity of 0.85.



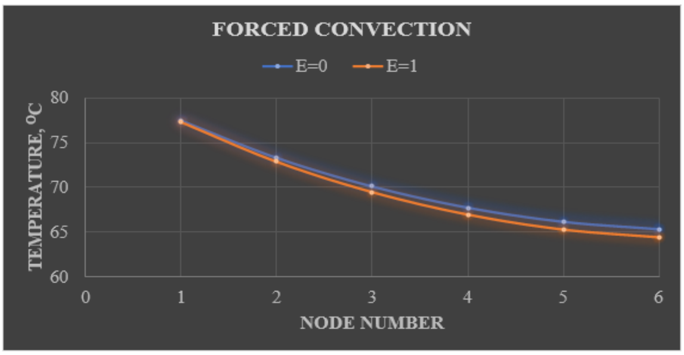
Graph: 5 Radiation in forced convection

Graph: 6 shows the temperature drop for the natural convection by considering with radiation and without radiation. Here node number is taken on X –axis and the temperature is taken on Y – axis.

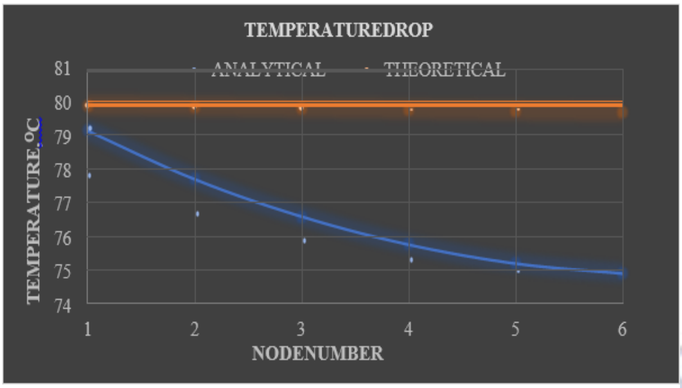


Graph: 6 with and without radiation in natural convection

Graph: 7 shows the temperature drop for the forced convection by considering with radiation and without radiation. Here node number is taken on X –axis and the temperature is taken on Y – Axis.



Graph: 7 with and without radiation in forced convection



Graph: 8 Temperature drop between analytical and theoretical values

The theoretical and numerical results on the bases of temperature difference for straight plate fin heat sink are plotted as shown in **Graph: 8** between theoretical and numerical results, a slight difference between 0.87 to 5% is observed. Overall, the numerical results show good agreement with numerical result. Hence, the model could be usedforthermalanalysis.

6. CONCLUSION

In this study, triangular fin heat sink is modeled and steady state thermal analysis is done by using ANSYS workbench. It is investigated under different convection regimes such as free and forced convection and with radiation and without radiation. The results are presented in the form of temperature, total heat flux and direction of heat flux. In this we also calculated the theoretical results. On comparison between the theoretical and simulation results there is difference between 0.57 to 5% is obtained. By considering all the above conditions the heat transfer will takes place more in forced convection when compared with the natural convection. Hence we concluded that the heat transfer should takes place maximum under forced convection.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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