Heat Transfer Enhancement and Thermal Performance of Extended Fins

Sunil S, Gowreesh S S, Veeresh B R

Abstract: A fin is an extended surface which is used to increase the rate of heat transfer by connecting to the heating surface. The heat transfer rate can be increased by convection process and also by increasing surface area by means of extended surfaces. In the present analysis effect of increase in total surface area to improve the rate of heat transfer is studied. Thermal Analysis is performed for various perforated fin extensions with varied diameter. The analysis is carried out using commercially available finite element analysis software. Analysis called steady state thermal has been used to find out the temperature variations and heat flux of the fins.

Keywords: extended surface, increase, process variations, temperature, be increased

I. INTRODUCTION

In this chapter we have discussed basic heat transfer, modes of heat transfer, importantly natural convection has been discussed and heat transfer through extended surfaces or fins and various methods of increasing heat transfer are discussed. Extended Surface (Fin) are used to enhance convective heat transfer in a wide range of engineering applications and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly applied for heat management in electrical appliances, such as computer power supplies or substation transformers and other applications include IC engine cooling, Fins in Automobile radiator. Extensions on the finned surfaces is used to increases the surface area of the fin. When the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface as compare to fin without the extensions provided to it. The concept of heat transfer through perforated in fin array also one of the method to improve the heat transfer character. The efficiency and rate of heat transfer in perforated fin is compared to the fin with extension. The various types of extension provided on fin array such as (a) Rectangular fin with 20mm*5 perforation, (b) Rectangular fin with 20mm*7 perforation, (c) Rectangular fin with 3mm cut out, and (d) Rectangular fin with 20mm perforation and 3mm cut out.

A. Heat transfer and thermodynamics

Transfer of energy, mass, momentum etc has been included in the study of transfer phenomenon and these are all recognized as a single discipline of fundamental importance on the basis of thermodynamic forces and fluxes.

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Hence the transfer of such unified phenomena occurs due to a force of concentration gradient, temperature gradient, velocity gradient etc.

B. Heat transfer by extended surfaces or fins

The rate of heat transfer is given by

$$q= hA\,(T_{surface}-T_{ambient})$$

where q = coefficient of convective heat transfer.

h = convective coefficient.

A = Surface area.

T_s = Surface temperature.

T_a = ambient temperature.

To increase the convective heat transfer the following methods are used

- Increase the temperature difference (T_s-T_a)
- By increasing the coefficient of heat transfer (h).
- Increase the surface area (A).

Increasing h may require the installation of pump or fan or replacement is need for existing one with larger one. Hence alternative method for increasing the rate of heat transfer is increasing the surface area by giving extensions or perforations to the fins.

II. LITERATURE REVIEW

Nitish Kumar Jha, et. Al. (2015) Had investigated the heat transfer through extended surfaces. Fin with various extensions like fin with rectangular cavity, fin with triangular cavity, fin with trapezoidal cavity, and fin with semicircular cavity are considered for the analysis and the results are compared with the fin without cavity. About 2% to 21% of heat transfer enhancement has been recorded for fin with cavity. Fin with rectangular cavity provides more heat transfer as compared to fin without cavity. In thermal analysis the temperature variations of all the fin without cavity and fin with cavity has been analysed and the heat transfer has been calculated and percentage of variation in heat transfer has been recorded. Effectiveness of fin with rectangular cavity is more compared to fin without cavity.

V. Karthikeyan, et. al. (2015) had studied the rate of heat transfer for various extended surfaces. Fin with various extensions and different perforations are designed and analysed the results are compared with fin without extensions. As a result heat transfer through fin with rectangular extension is higher compared to other type of extension. Fin with rectangular extensions provide 13% to 21% more enhancement of heat transfer. Fin with rectangular extension has more effectiveness compared to fin with various extensions.

Shital B. Salunkhe, et.al. (2015) In this paper the heat transfer has been analysed on the outer surface of the longitudinal finned tubes of different material such as copper, Aluminium with silver coating and Aluminium with

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nickel coating. Experiment is based on flow velocity. It is observed from the experimental results that the coefficient of convective heat transfer is enhanced with increase in air velocity and surface area. After comparing they concluded that coating affects heat transfer rate and heat transfer coefficient and copper is having high heat transfer coefficient as compared to other material specimen.

Pardeep Singh, et. al (2014) They had studied the design and analysis for heat transfer through fin with various extensions. The heat transfer through fin having same geometry but various extensions provide 5% to 13% increase in rate of heat transfer when compared to fin without extensions. Rate of heat transfer through fin with rectangular extensions is higher than other type of extensions. Temperature is minimum at the end of fin with rectangular extensions as compared to fin with other types of extensions.

Mukesh Didwania, et. al. (2013) In this paper they have analysed the pressure loss and heat transfer for different shape of fins with rectangular duct. Rectangular fin, cylindrical fin are used for analysis. The purpose of this study is to find out the optimum dimensions and shapes for rectangular longitudinal fins, cylindrical pin fins by including transverse heat conduction. As a result after analysis they have concluded that heat transfer rate is maximum for circular fin and minimum for rectangular fin. Pressure loss is minimum for circular fin and maximum for rectangular fin in the duct. Air gets maximum temperature in case of circular fin.

A. Conclusions from literature review

- According to the literature review mentioned above rate of heat transfer can be increased by increasing the surface area.
- In one of the above papers fin with rectangular extension enhance more heat transfer.
- The temperature at the fin end is less for fin with rectangular extension.
- Hence in this project the various perforation and cutout is given to increase the heat transfer.

III. METHODOLOGY

In this chapter we are going to introduce the basic features of mechanical. The rectangular fin with various extensions and perforations are considered for analysing the heat transfer characteristics. This is done by using the steady state thermal analysis where temperature variations and total heat flux are analysed and the solutions are compared with existing model and validated for better results. So following steps shows the methodology used for analysing the results using thermal analysis.

A steady state thermal analysis can be described in the context of 4 main steps i.e.

1) Preliminary decisions
- What type of analysis has to be done
- What type of model it is.
- Selection of elements.

2) Pre-processing
- Importing model in IGS file.
- Defining and assigning material properties to the model.
- Meshing the geometry
- Applying boundary conditions
- Analyzing results

3) Solving
- Solve the model

4) Post processing
- Review the results
- Checking and Validation of result.

IV. DESIGN OF MODEL

Figure shows the front view and side view 2D image of base line model which has been considered as a reference model for the analysis.

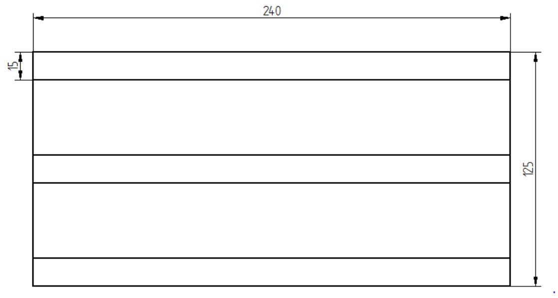

Fig 1: Front view

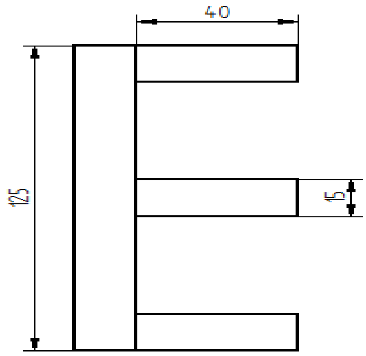

Fig 2: Side view

A. Designing of fin arrays with solid works

In this section solid model of various type of fins with perforations and cut out has been shown like existing model, rectangular fin with 20mm*5 perforation,20mm*7 perforation, 3mm cut out, 3mm cut out and 20mm perforation.

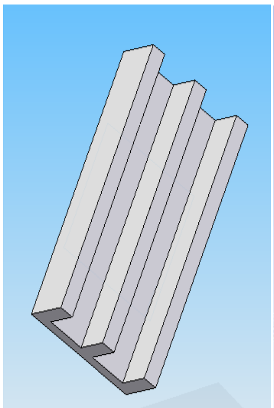

Fig 3: Base line model

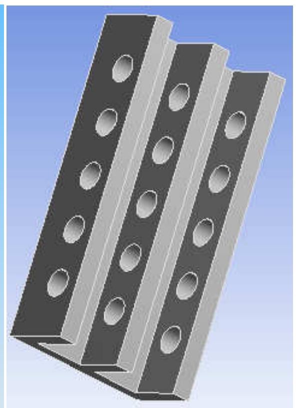

Fig 4: Rectangular fin With 20mm*5 perforation

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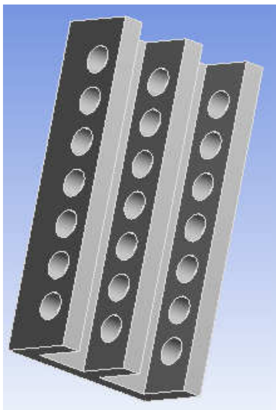

Fig 5: Rectangular fin with 20mm*7 perforation

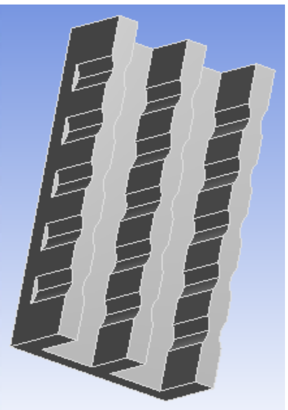

Fig 6: Rectangular fin with 3mm cut out

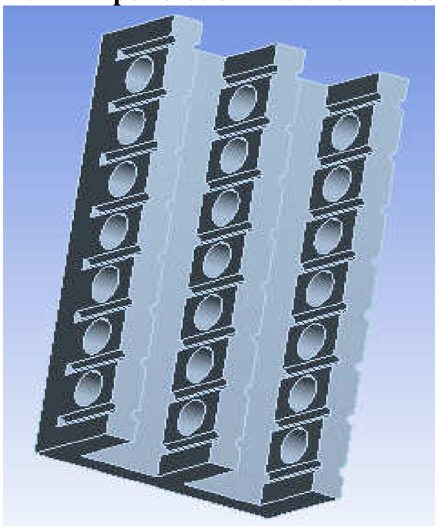

Fig 7: Rectangular fin with 20mm perforation and 3mm cut out

B. Import the geometry

Before importing the model geometry we have to check and set the unit systems to metric (m, kg, N, s, V, A) then the model geometry should be imported, the model should be in IGS format.

C. Mesh generation

In this section the meshed models are shown for fin with different diameter of perforation and cut out. Meshing is carried out by using mechanical physics preference along with fine relevance centre.

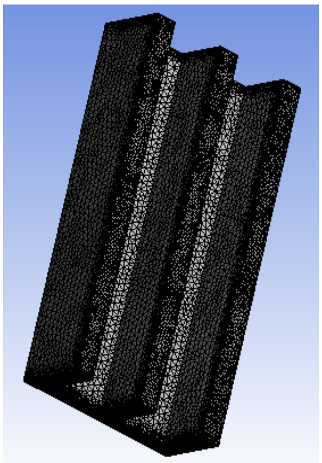

Fig 8: Model 1

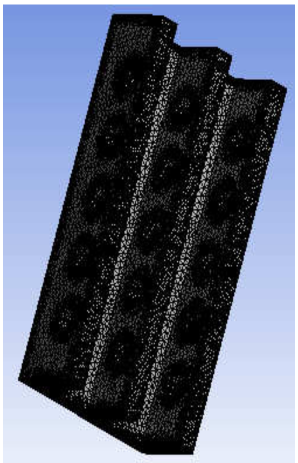

Fig 9: Model 2

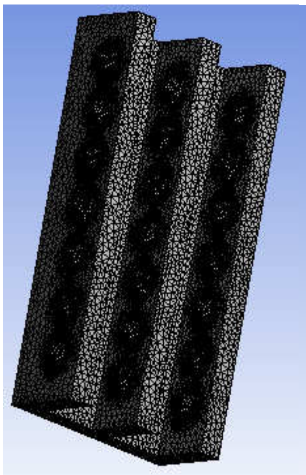

Fig 10: Model 3

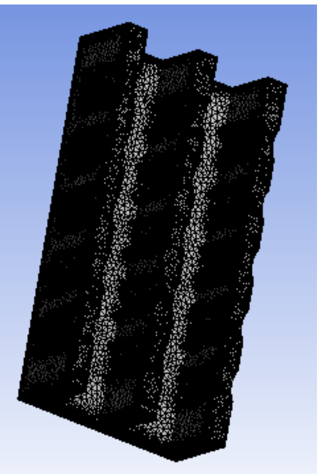

Fig 11: Model 4

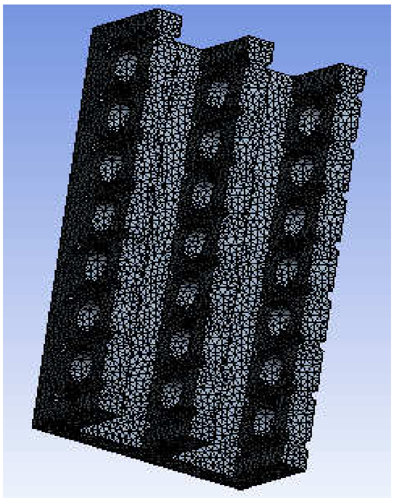

Fig 12: Model 5

D. Applying boundary conditions and assigning material properties

Aluminium has been selected for the analysis as a material which is economically good and also there is high rate of heat transfer and dissipation in this material.

Thermal conductivity, k=167 W/m^{0}c.

Thermal instantaneous coefficient expansion = 23.1*10^{-6} /k.

Base plate temperature = 55 ^{0}c.

Heat transfer coefficient = 83 W/m^2 ^{0}c

Ambient temperature = 30^{0}c.

Density = 2.70 g/cm^3

Young's modulus = 70000 Mpa

Poisson ratio = 0.35

V. ANALYSIS AND RESULTS

In this chapter first we have the material properties and boundary conditions. Then we have the temperature and heat flux analysis, graphs for temperature distribution, heat flux, rate of heat transfer.

A. Analysis

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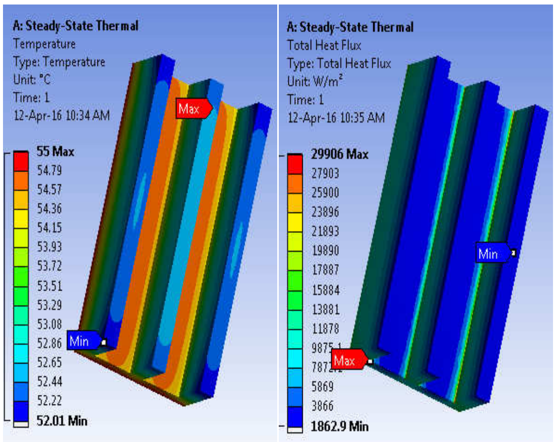

Fig 13: Temperature contour and heat flux for Model 1

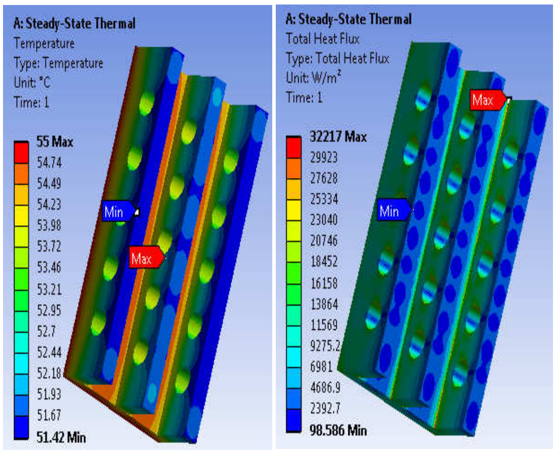

Fig 14: Temperature contour and heat flux for Model 2

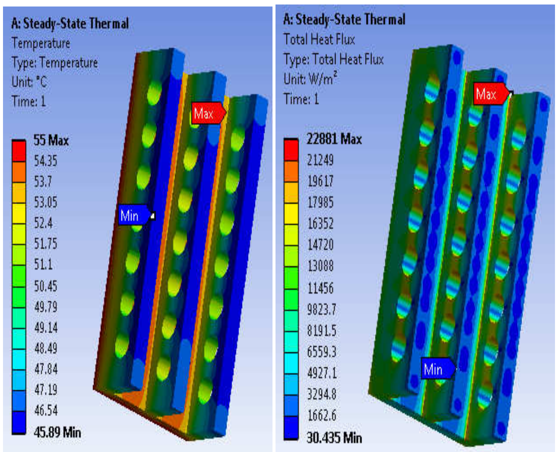

Fig 15: Temperature contour and heat flux for Model 3

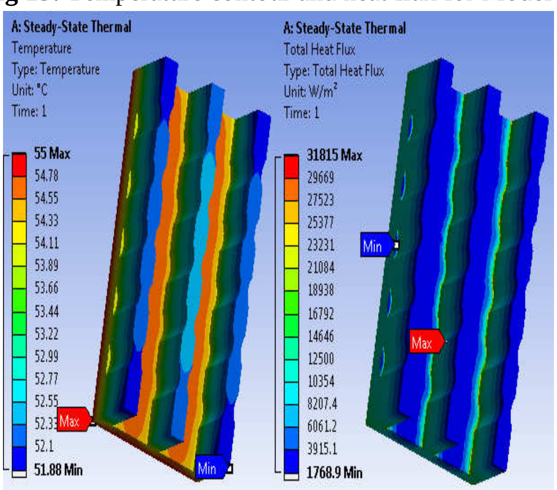

Fig 16: Temperature contour and heat flux for Model 4

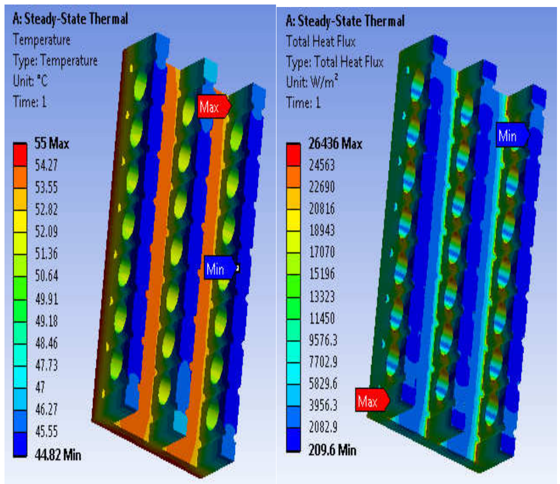

Fig 17: Temperature contour and heat flux for Model 3

Following table shows the temperature contour, maximum heat flux, minimum heat flux and rate of heat transfer for each model compared with base line model.

Table 1: Temperature variation and heat flux

S.N	Rectangular fin profiles	Tempe -rature variati ons	Maxi-mum heat flux	Minim-um heat flux
1	Model 1	52.01	29906	1862.9
2	Model 2	51.42	32217	98.586
3	Model 3	45.89	22881	30.435
4	Model 4	51.88	31815	1768.9
5	Model 5	44.82	26436	209.6

Table 2: Rate of heat transfer for all models

S.N	Rectangular fin with profiles	HT w	Increase in HT W	percentage increase in HT %
1	Model 1	194.53	-	-
2	Model 2	204.3	9.77	5.02
3	Model 3	225.89	31.36	16.12
4	Model 4	234.77	40.24	20.68
5	Model 5	260.28	65.75	33.79

B. Results and discussions

The temperature distribution, maximum and minimum heat flux are recorded by analysis for fins with various perforations.

By using the heat transfer governing differential equation the rate of heat transfer is calculated for fin of finite length. The enhancement of heat transfer for fin without extension and perforation is recorded. Increase in heat transfer for fins with various perforations are compared with Base line model. The graphs are plotted for temperature distribution, max and min heat flux and rate of heat transfer for all models.

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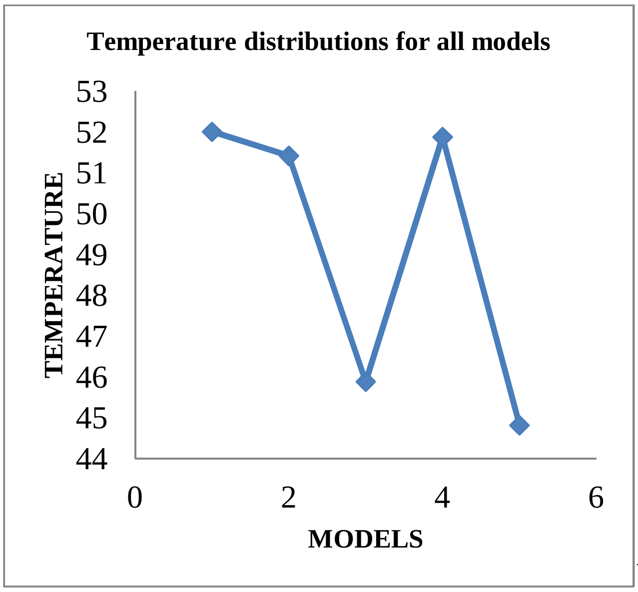
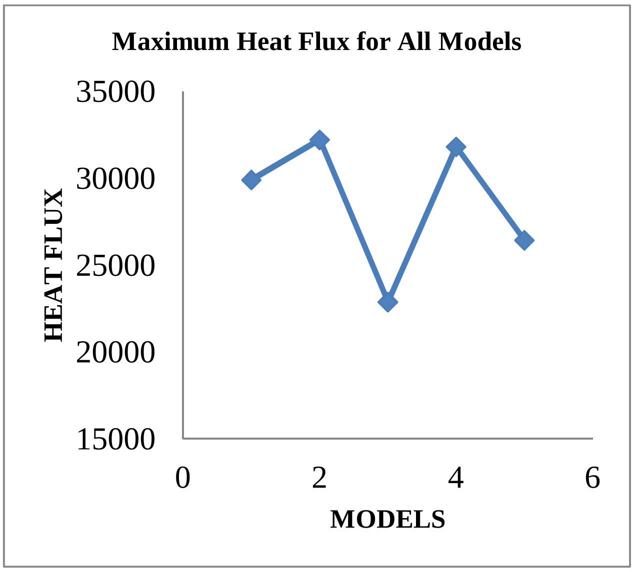
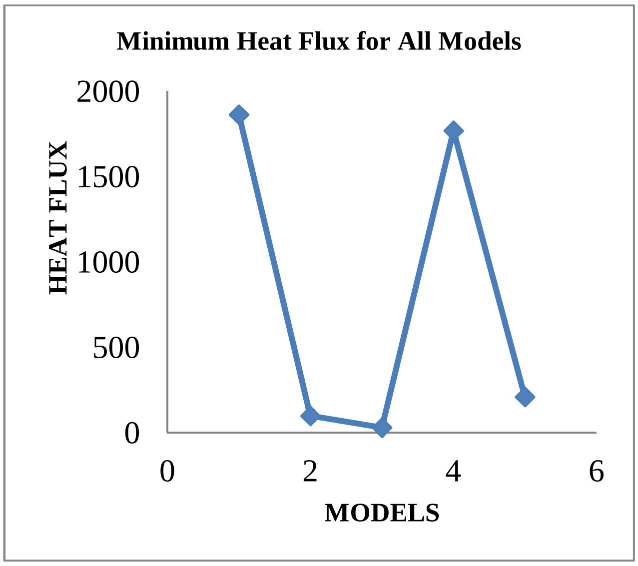


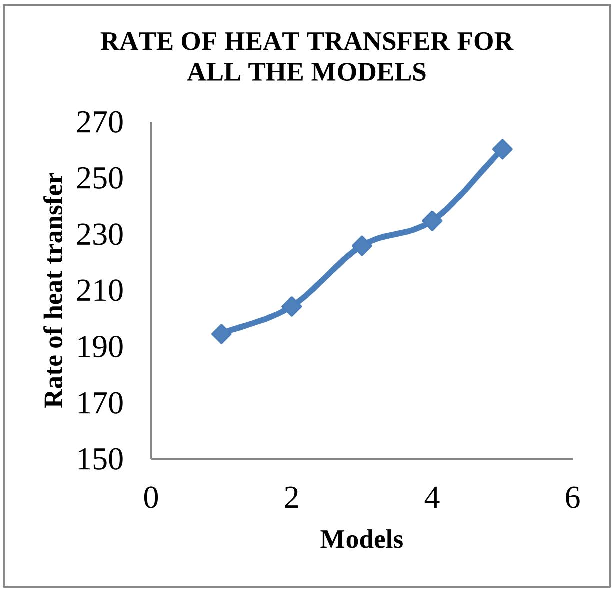
Graph 1: Temperature distributions for all models



Graph 2: Maximum heat flux for all models



Graph 3: Minimum heat flux for all models



Graph 4: Rate of heat transfer for all models

VI. CONCLUSIONS

- Heat transfer through Rectangular fin with 20mm perforation and 3mm cutout is higher than other type of fins when results are compared.
- Temperature at the end of rectangular fin with 20mm perforation and 3mm cutout is minimum compared to other type of fins.
- The maximum heat flux is observed for Model 2.
- The minimum heat flux is observed for Model 3.
- Rectangular fin with 3mm cutout and 20mm perforation provide 33.79% of heat transfer enhancement compared to other models.

A. Scope of future work

- Further analysis can be carried out for forced convection.
- The results may vary for forced convection heat transfer.

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