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Steady State Thermal Analysis of Rectangular Fin with Different Cavities

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Abstract* – *Fins are used to increase the rate of heat transfer. Generally, the material used for the application of fins is aluminum alloys. In this project the steady state thermal analysis of rectangular fin with and without cavities on the fin surfaces by using Ansys Workbench 14.0. The temperature distribution and total heat transfer rate through the rectangular fin with and without cavities on the fin surfaces was calculated for different fin materials like Copper, Aluminum and Brass. Steady state thermal analysis of rectangular fin, and a specified base temperature condition. Considering rectangular fin of different length conducts heat away from its base at 500^{0}K and transfers it to a surrounding at 300^{0}K through convection. The convection heat transfer coefficient is 12 W/m^{2}K.Thermal conductivity of the fin material is specified. A constant temperature condition is applying at the base of the fin convective boundary conditions are using at the tip of the fin. Comparative study was done among the fin material used to find out the best material under the conditions. Steady state temperature distribution is investigating.

Keywords— Cavity, Extended Surface, Heat Transfer, Thermal Performance, Simulation.

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I. INTRODUCTION

Fins 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. Other applications include IC engine cooling, such as fins in a car radiator. It is important to predict the temperature distribution within the fin in order to choose the configuration that offers maximum effectiveness. This exercise serves as a visualization tool for evaluating the effect of shape on fin effectiveness, efficiency, and temperature distribution. In many heat transfer applications, it is desirable to increase the surface area that is available for the heat transfer process; this is particularly true when one desires to dissipate heat to a low conductivity medium such as air. There are three mechanisms by which heat transfer can take place. All the three modes require the existence of temperature difference. The three mechanisms are.

1. Conduction,
2. Convection
3. Radiation

II. PREVIOUS WORK

Pradeep Singh, Harvinderlal,Baljit Singh Ubhi[1] had investigated the heat transfer performance of extended surface or finned surface. Design of fin with various extensions such as rectangular extension, trapezium extension, triangular extensions and circular extensions has been considered for the analysis. The heat transfer performance of extended surfaces with same geometry having various shapes of extension and without extension has been compared. About 5% to 13% enhancement in heat transfer can be obtained with these various extensions on fin as compare to same geometry of fin without these extensions. In this thermal analysis, temperature variation along the length of fin at which heat flow occur through the fin is analyzed. Extensions on the extended surface or finned surfaces are used to increases the surface area of the fin in contact with the ambient fluid flowing around it. Since, the surface area increases, it tends to increase the heat transfer due to convection. Thus there will be an increase in overall heat transfer due to conduction and convection.

Shivdas S. Kharche&Hemant S. Farkade[2] had investigated the effect of placing notch on the finned surface. Different shapes of notched such as rectangular, triangular etc. has been designed on rectangular fin array. Natural convection heat transfer for fin without notch and notched fin had been investigated theoretically and experimentally. The central position on the fin array becomes ineffective to heat transfer because of single chimney flow pattern. On the central position, the heated air rises upward and in that case already hot air is present so there is a notched portion so that fresh air can move across that. By performing the experimentation, it has been observed that average heat transfer coefficient for fin with notched portion results in high heat transfer coefficient value as compared to fin without notched portion. Also copper material results in high heat transfer as compared to aluminum.

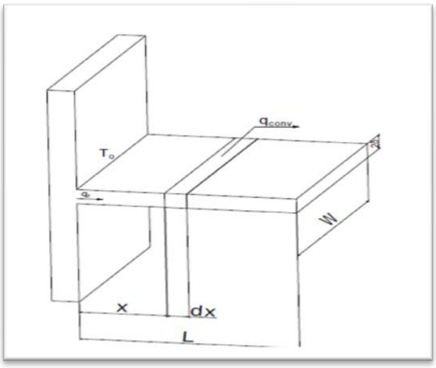
Patro. P, Patro. B and Barik. A. K [3] had performed computational investigation for the conjugate heat transfer of pin fins inside a rectangular cavity. Triangular and circular pin fins has been considered for the CFD analysis. With high air velocity at inlet, the temperature of the bulk fluid present outside the extended surface increases in case of both fin due to the fact that high air velocity tends to increase the convective heat transfer. Conjugate heat transfer means conduction, convection and radiation effect has been considered. Up to certain limit, the velocity of air can be increased. It is so because high velocity tends to increase the pressure drop which result in decreased thermal performance of the fin. The streamlines obtained by the simulation shows that at particular velocity there is an improved mixing and more recirculation of air. Circular pin fin perform far better than triangular pin fin in terms of thermal performance such as heat transfer etc. and pressure drop across the pin fins.

DhanawadeHanamant,K.N.Vijaykumar&Dhanawade Kavita[4] had investigated the performance of heat transfer across the fin arrays by the use of circular perforation on the extended surface. Circular holes have been designed through fin surface. Model without perforation and model with circular perforation has been compared. The simulation is performed with the help of ANSYS Fluent. Extended surface with circular perforation results in heat transfer enhancement as compare to solid fin arrays without perforation. CFX is used to set the boundary condition for the natural convection phenomena around the fin surface. The simulation result obtained is validated experimentally. Also fin with circular perforation results in improvement in average Nusselt number.

Description And Specification of Fin

- As fins are introduced to enhance heat transfer from a base which is at high temperature, rectangular fins are considered for analysis. Life and effectiveness can be improved with effective cooling. The air cooling mechanism is mostly dependent on the fin size. The heat is conducted through the fin and converted to air through the surfaces of the fins. Insufficient removal of heat from base plate will lead to high thermal stresses and lower engine efficiency.

- The rectangular fin as shown in Fig. with 'L' as the length of the fin, 't' as thickness of the fin and 'W' width of fin and assuming the heat flow is unidirectional and it is along length and the heat transfer coefficient 'h' on the surface of the fin is constant.



- Fig.1 Rectangular fin Specification
- Where,
- k = Thermal Conductivity, W/mK
- Ac= Cross Section Area of fin, m^2
- m= Fin Parameter $\sqrt{hP/KA}$
- P= perimeter of fin, (2W+2t)
- θ_0= temperature difference, K

h= heat transfer coefficient, W/m^2K

Table.1 Properties of Fin Materials

S. No.	1	2	3
Fin Material	Copper	Aluminum	Brass
Thermal Conductivity of fin material W/mK	400	237	111
Ambient Temperature ^{0}K	300	300	300
Base Plate Temperature ^{0}K	500	500	500
Heat Transfer Coefficient W/m^2K	12	12	12

A. 3d fin model dimensions

The fins with various cavities are design with the help of 3D modeling software Solid Edge ST5 with following fin dimensions.

Base Plate Dimension

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Length = 240mm

Width = 55mm

Height = 3mm

Fin Dimension

Length = 240mm, Width = 15mm, Height = 40mm

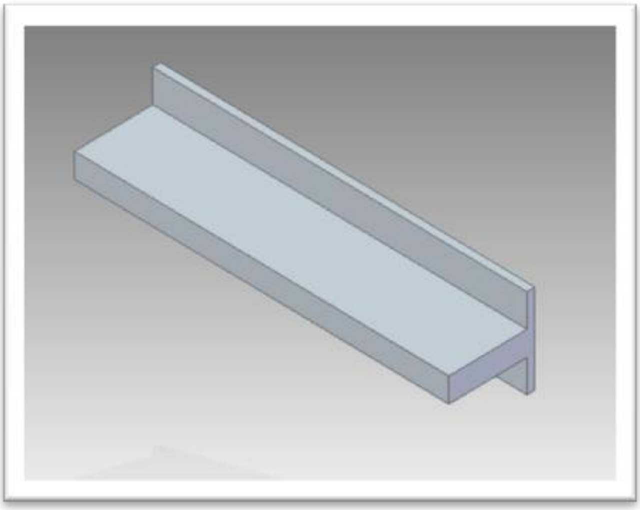


Fig.2 3D ISO Fin Drawing

B. Meshed Model of Fin

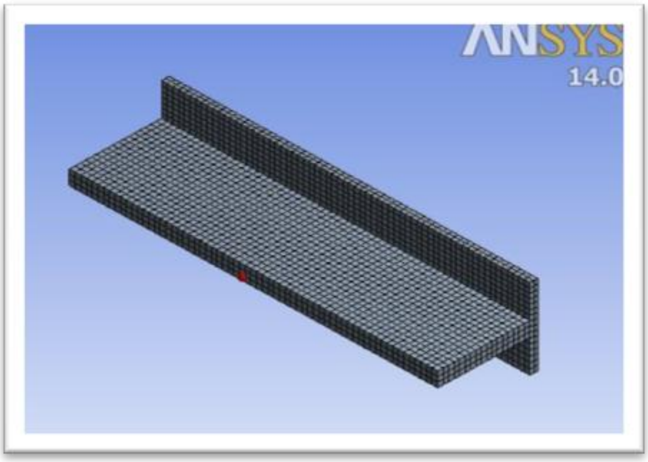


Fig. 3 Meshed 3D Model of fin without Cavity

After the creation of 3D model in solid edge ST5 the next process is to go for steady state thermal analysis using Ansys workbench 14. Import the 3D model file in IGS format so that meshing can be performed. In the present case Hex dominant solid185 type of element has been used and detail information on meshed assembly as shown in Table 4.1.Steady state thermal analysis is performed using ansys workbench 14.

Table.2 Detail Information about Meshed Fin

Object Name	**Rectangular Fin**
Length Unit	Millimeters
Bodies	1
Nodes	6310
Elements	3262

Boundary Conditions

A. Temperature & Convection Boundary Condition

Assigning boundary conditions to the meshed model

Materials for the model are selected as Copper, Aluminum and Brass. Thermal conductivities of materials are 400 W/m^{0}C, 237W/m^{0}Cand 111 W/m^{0}C.

Ambient temperature – 300^{0}K

Base plate temperature – 500 ^{0}K

Heat transfer coefficient – 12 W/m$^{2\,0}$C

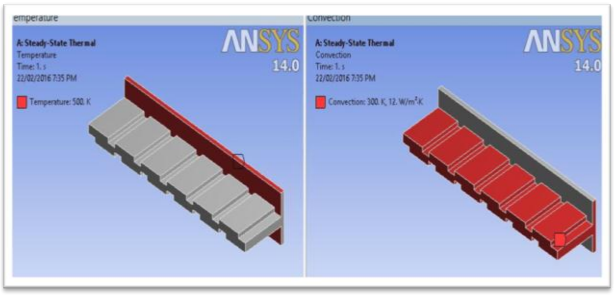


Fig.4 Boundary Conditions

Analysis Results And Discussions

Temperature and Heat Flux Distribution along the Fin

A. Length of fin 50mm without Cavity

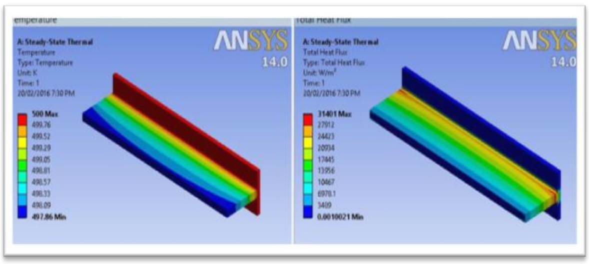


Fig.5 Temperature and Heat Flux (W/m^2) Variation for Copper Fin

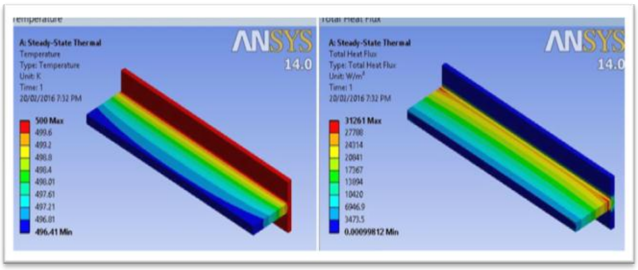


Fig.6 Temperature and Heat Flux (W/m^2) Variation for Aluminum Fin

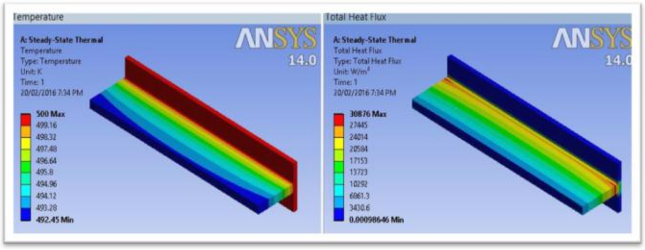


Fig. 7 Temperature and Heat Flux (W/m^2) Variation for Brass Fin

B. Length of fin 50mm with Semicircular Cavity

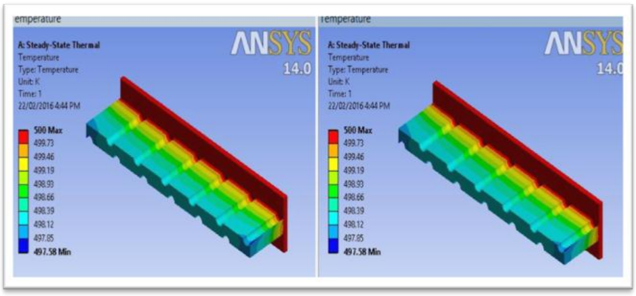


Fig.8. Temperature and Heat Flux Variation for Copper Fin

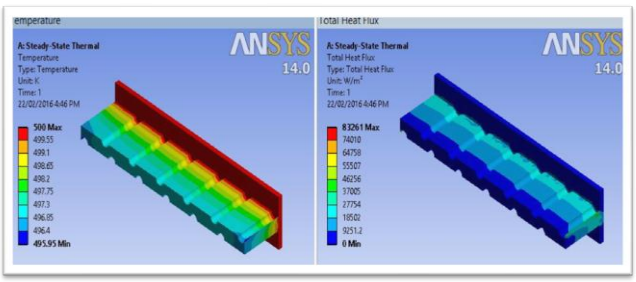


Fig9. Temperature and Heat Flux Variation for Aluminum Fin

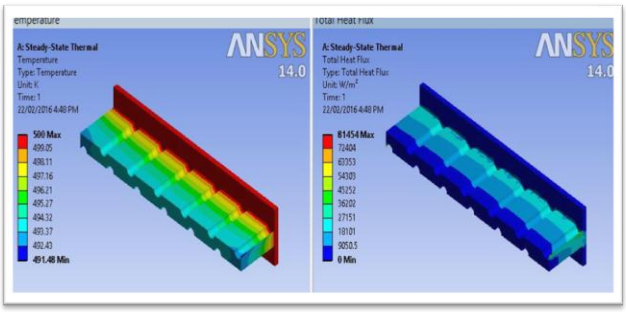


Fig4: Temperature and Heat Flux Variation for Brass Fin

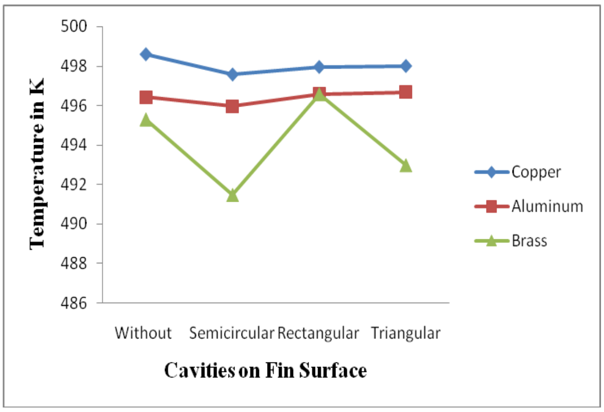
Table.3 Comparison of Temperature Variations along the length of fin

Sl No	Length of Finin mm		Fin with different types of Cavities							
			Without Cavity		Semi-Circular Cavity		Rectangular cavity		Triangular Cavity	
			T in ^{0}K	q_x w/m2	T in ^{0}K	q_x	T in ^{0}K	q_x	T in ^{0}K	q_x
1	50mm	Copper	498	31401	497	85137	497	35693	498	26897
2		Aluminum	496	31261	495	83261	496	35523	496	26787
3		Brass	495	30876	491	81454	496	35521	492	26482
1	60mm	Copper	498	30438	496	81837	497	42369	497	39383
2		Aluminum	495	35152	494	81993	495	42137	495	39562
3		Brass	493	35509	489	81731	491	41500	490.	38957

Fin Temperature Variation Graphs with Different Cavities on Fin

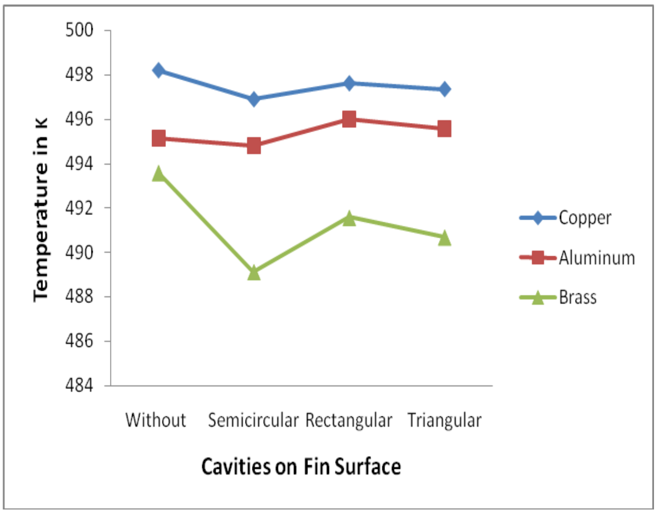
A. 50mm Fin Length

Graph 1 shows the variation of fin temperature with different cavities on fin surface for various fin materials. However it is concluded that rectangular fins with semicircular cavity having Brass fin material shows more heat transfer rate on 50mm fin length.



Graph.1 Variation of Fin Temperature with Different Cavities

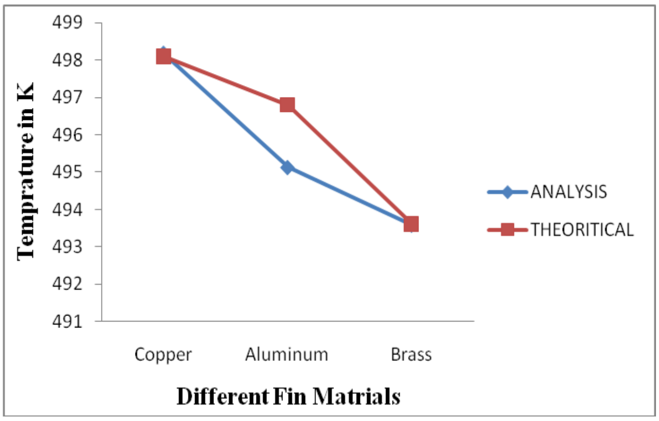
B. 60mm Fin Length



Graph.2 Variation of Fin Temperature with Different Cavities

Graph 2 shows the variation of fin temperature with different cavities on fin surface for various fin materials. However it is concluded that rectangular fins with semicircular cavity having Brass fin material shows more heat transfer rate on 60mm fin length.

C. Comparison Graph between ANSYS Results an Theoretical Values of Fin Temperature



Graph.3: Comparison of Theoretical &Ansys Analysis Results

In this project an attempt is made to compare the fin tip temperatures obtained by theoretical calculations made from the basics of Heat transfer to the values obtained from simulation software ANSYS Workbench -14. A constant cross section is considered for all materials. In simulation analysis a solid Brass Rectangular fin shows much heat transfer at the end (tip) of the fin than result obtained from experimental values.

CONCLUSION

In the present work an attempt is made to find the heat transfer rate, temperature, distribution and fin efficiency, heat flux for a solid rectangular fin with different materials and fin length and following conclusions made.

- The use of fin with cavity provides efficient heat transfer
- Fin with cavity provide almost 2% to 21% of heat transfer enhancement as compared to fin without cavity.
- Fin with brass semicircular cavity results in highest heat transfer enhancement up to 21% as compared to other fin configuration.
- Effectiveness of rectangular fin with rectangular cavity is more as compared with fin without cavity.
- Use of cavity on extended surface reduces the weight of material thus there will be decrement in cost of manufacturing of fin.
- Temperature at the end of fin with semicircular cavity is minimum as compared to other design specification hence heat transfer is maximum.

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Heat Transfer-A Basic Approach by M. Necati Ozisik - Professor, Mechanical and aerospace engineering, North Carolina State University

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