

Heat Transfer Enhancement and Thermal Performance of Extended Surfaces with Cavity

Nitish Kumar Jha ¹, Kailash B A ²

P.G. Student, Department of Thermal Power Engineering, VTU RC Kalaburagi, Karnataka, India¹

Assistant Professor, Department of Thermal Power Engineering, VTU RC Kalaburagi, Karnataka, India²

ABSTRACT: Heat transfer rate increases by using different shape of extension but it results in increase in cost of the material. Different shape of cavity can be utilised to increase the rate of heat transfer which can also reduce the cost of manufacturing. In the present work thermal analysis is carried out for different shape of cavity on extended surface using Ansys-MultiPhysics software. The simulation is carried out using the CFX of ANSYS 14.5. Thermal analysis is performed and temperature variations with respect to distance at which heat flow occur through the fin is analyzed. In this study, different shape of cavity such as rectangular, semicircular, trapezoidal and triangular has been considered on the rectangular extension. Fin without cavity has been compared with fin with different shapes of cavity. Heat transfer rate, efficiency and effectiveness for all the geometry calculated analytically and numerically using simulation. Heat transfer rate for fin with rectangular cavity has got more heat transfer rate than all the remaining geometry.

KEYWORDS: Extended surface, Cavity, Heat Transfer, Thermal Performance, Simulation.

I. INTRODUCTION

A fin is a surface that extends from an object to increase the rate of heat transfer to and from the environment by increasing convection. Different shape of cavity is used to increase the surface area of the fin with the fluid flowing around it. Types of cavity provided on fin are (a) Rectangular Cavity, (b) Triangular Cavity, (c) Trapezoidal Cavity, (d) Semicircular Cavity.

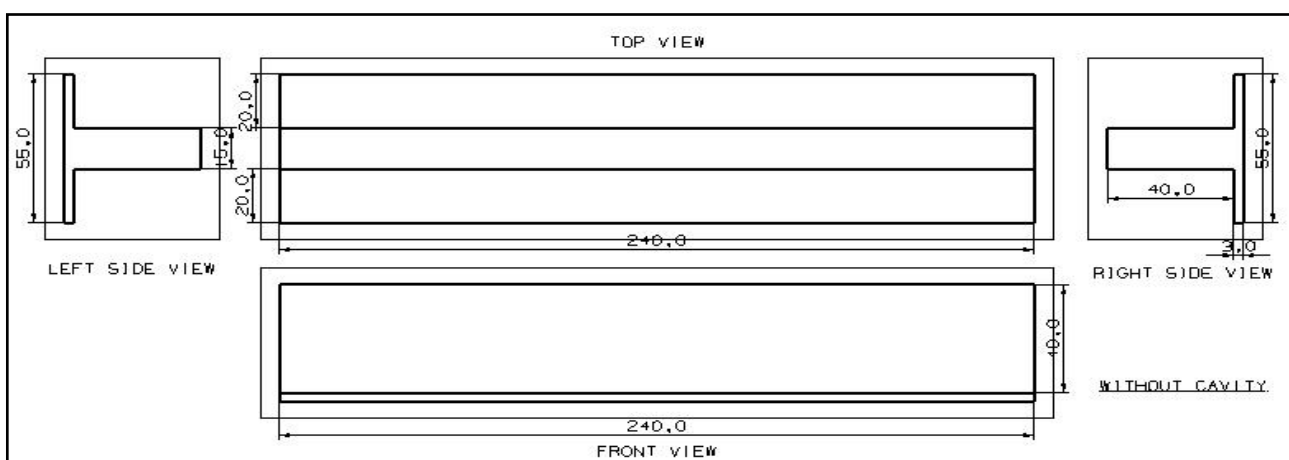


Fig. 1 2-D diagram of Fin without Cavity

The above figure shows the two dimensional representation of solid fin without cavity. Different side view has been represented to understand the overall structure of the fin.

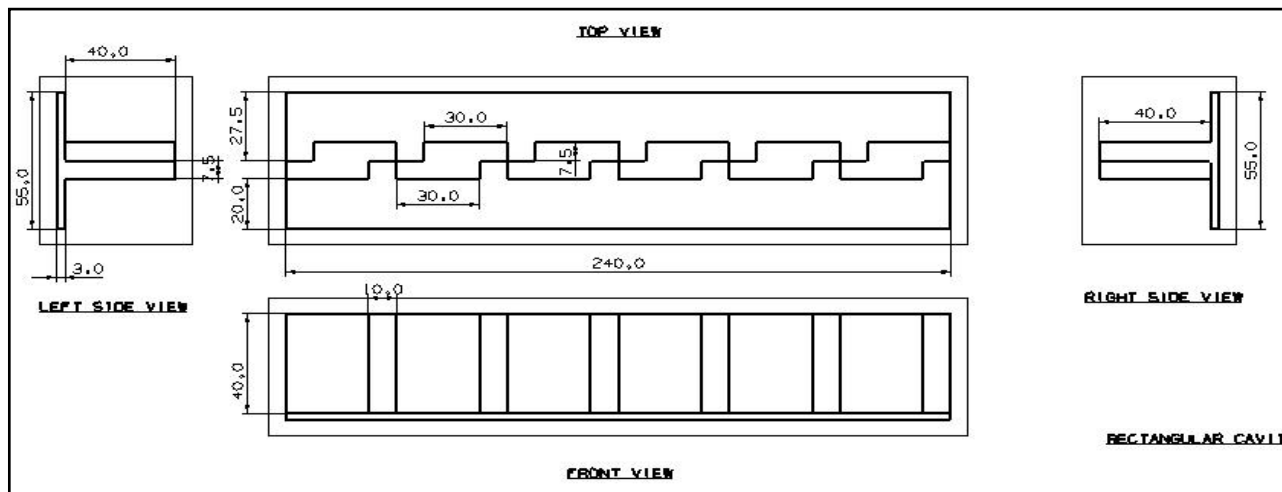


Fig. 2 2-D diagram of Fin with Rectangular Cavity.

The above figure shows the solid fin with rectangular cavity which will enhance the heat transfer. Like that different shape of cavities has been considered for the analysis.

II. LITERATURE REVIEW

Pardeep Singh, Harvinder Ial, 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 is used to increases the surface area of the fin in contact with the ambient fluid flowing around it. Since, the surface area increases, it tend 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 aluminium.

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 a 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.

Dhanawade Hanamant, 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

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

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.

III. DESIGN AND ANALYSIS OF FIN WITH CAVITY

A. Designing of Fin with unigraphics.

The fin with various cavity are design with the help of design software unigraphics (NX6) by using different tools available.

Base plate dimension:-

Length = 240mm, Width = 55mm, Height = 3mm

Fin dimension:-

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

B. Analysis of fin for heat transfer with simulation software

After the creation of design the next process is to go for steady state thermal analysis using ANSYS 14.5. Import the design file in design modeller so that meshing can be performed. Steady state thermal analysis is performed using CFX component.

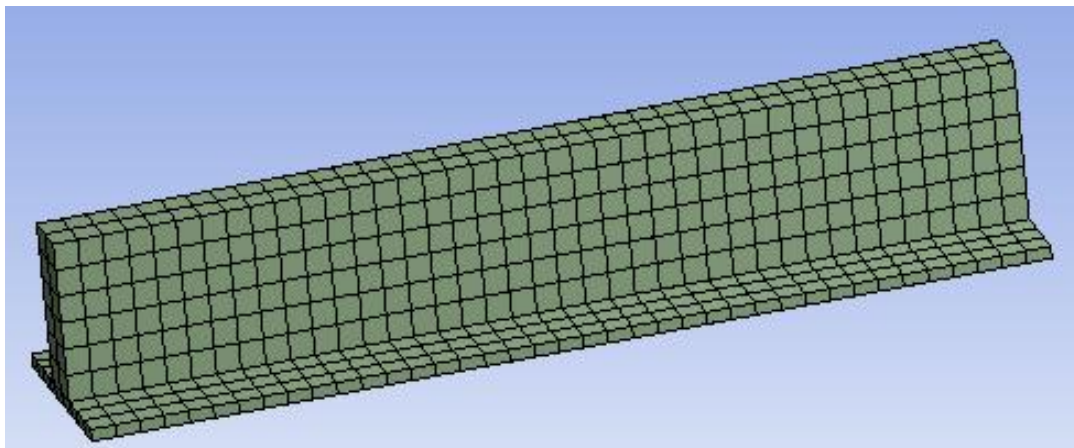


Fig. 3 Meshing of fin without cavity.

C. Assigning load and constraint to the meshed model

Material for the model is selected as Aluminium.

Thermal conductivity of material – 237 W/mK.

Ambient temperature – 300K

Base plate temperature – 500 K

Heat transfer coefficient – 12 W/m²K

D. Result from Analysis

After the generation of mesh and assigning of load and constraints next step is to run the simulation for the model. Temperature distribution along the length of the fin has been shown which is used to calculate the heat transfer.

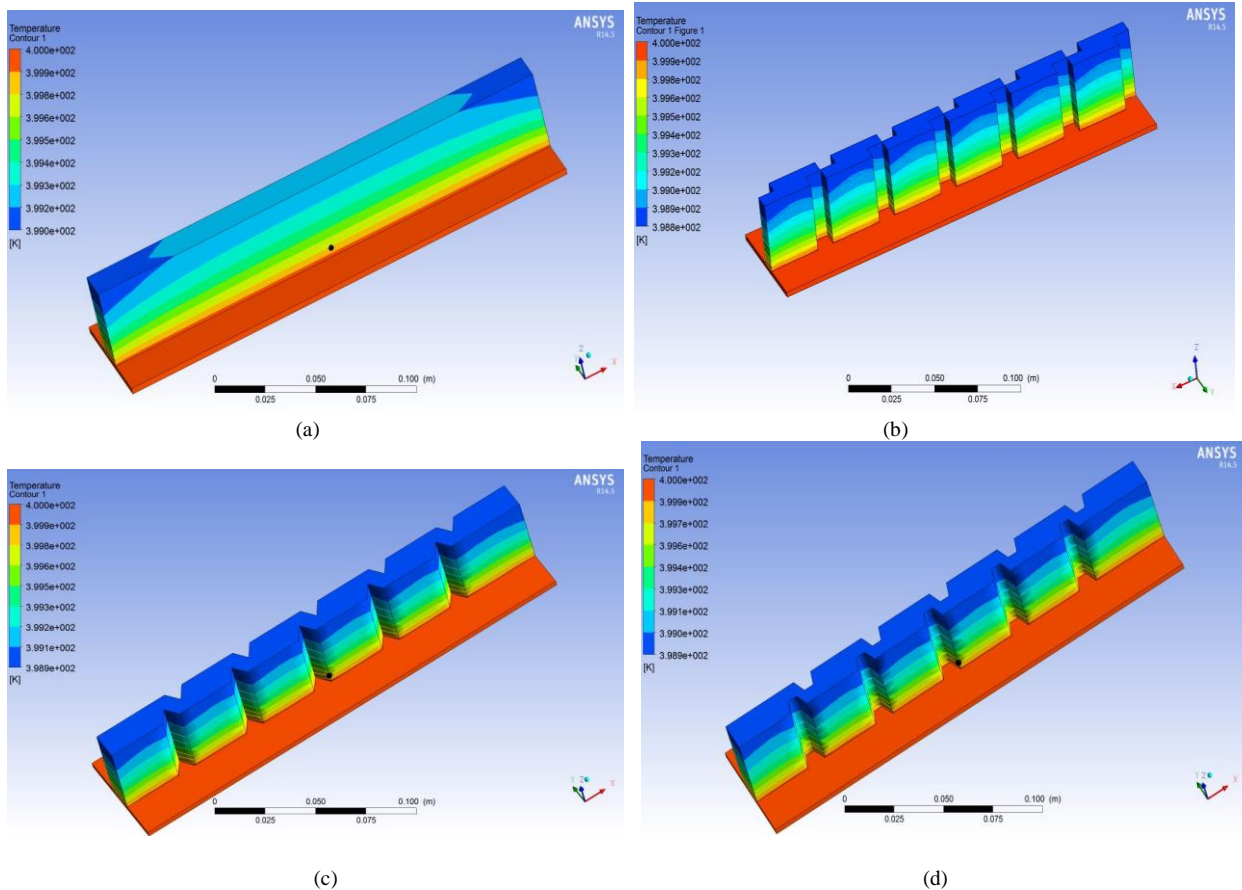


Fig. 4 Temperature Contour for different design consideration. (a) Fin without cavity (b) Fin with rectangular cavity (c) Fin with triangular cavity (d) Fin with trapezoidal cavity

The temperature distribution along the length of the fin has been observed by the steady state thermal analysis with the help of application package ANSYS 14.5.

TABLE-1
COMPARISON OF TEMPERATURE VARIATION ALONG THE LENGTH OF FIN.

	$T_b=500K \quad h=12W/m^2K \quad T_\infty=300K$				
Length of Fin (mm)	Fin with different types of cavity (Temperature in K)				
	Rectangular	Triangular	Trapezoidal	Semicircular	No cavity
5	499.338	499.427	499.365	499.423	499.567
10	498.917	499.063	498.966	499.090	499.286
15	498.558	498.757	498.630	498.810	499.044
20	498.254	498.502	498.351	498.573	498.835
25	498.008	498.292	498.123	498.380	498.672
30	497.824	498.124	497.947	498.228	498.540
35	497.689	498.007	497.816	498.116	498.437
40	497.450	497.859	497.703	497.914	498.365

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

IV. RESULT AND DISCUSSION

Heat transfer calculated by using the heat transfer governing differential equation for the fin of finite length and loses heat by convection.

$$Q = \theta_0 \sqrt{hPkA} \left[\frac{\sinh mL + \left(\frac{h}{mk}\right) \cosh mL}{\cosh mL + \left(\frac{h}{mk}\right) \sinh mL} \right]$$

Where, T_0 = base plate temperature in Kelvin, T_∞ = Environment temperature in Kelvin, L= Length of fin in meter
 $m = \sqrt{hP/kA}$, P= Perimeter of cross-sectional area of fin in Meter, A= Cross-sectional area of fin in (m²)
 k= Thermal Conductivity of material in W/mK., Q = Heat transfer in Watt.
 A_t = total area of fin surface in m², $A_{fin\ base}$ = total area at the fin base in m²

TABLE 2
COMPARISON OF HEAT TRANSFER FOR DIFFERENT SHAPES OF CAVITY AT PARTICULAR BASE PLATE TEMPERATURE

Types of Cavity	$T_b=500K \quad h=12W/m^2K \quad T_\infty=300K$		
	Heat Transfer (W)	Increase in Heat Transfer (W)	% increase in Heat Transfer
Without Cavity	57.29	-----	-----
Rectangular	69.36	12.07	21.07
Triangular	63.96	6.67	11.64
Trapezoidal	66.19	8.90	15.53
Semicircular	58.89	1.60	2.79

The above table shows the heat transfer through fin with different shape of cavity at particular base plate temperature of 500 K. Fin with rectangular cavity provides sufficient increase in heat transfer as compared to fin without cavity. Cavity on the extended surface increases the surface area exposed to the environment which results in increase in heat transfer due to convection.

V. CONCLUSION

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 rectangular cavity results in highest heat transfer enhancement up to 21% as compared to rectangular fin without cavity.
- 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 rectangular cavity is minimum as compared to other design specification hence heat transfer is maximum

REFERENCES

- [1] Pardeep Sing, Harvinder lal, Baljit Singh Ubhi., "Design and Analysis for Heat Transfer through Fin with Extensions" IJIRSET (An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 5, May 2014.
- [2] Shivdas S. Kharche & Hemant S. Farkade, "Heat transfer analysis through fin array by using natural convection", IJETAE – ISSN 2250-2459, Volume 2, Issue 4, April 2012.



ISSN(Online) :2319-8753

ISSN (Print) : 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

- [3] Patro. P, Patro. B and Barik. A. K, "CFD simulation of a conjugate heat transfer problem in a rectangular cavity", International journal of thermal technologies, Vol. 2, No. 2(june 2012), ISSN 2277 – 4114
- [4] Dhanawade Hanamant, K.N. Vijaykumar &Dhanawade Kavita, "Natural convection heat transfer flow visualization of perforated fin arrays by CFD simulation", IJRET eISSN:2319-1163
- [5] Heat Transfer- A Basic Approach by M. Necati Ozisik - Professor, Mechanical and aerospace engineering, North Carolina State University.