Steady state analysis of thermal fins having different cross sections

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Abstract

Various researches are being done on the design of thermal fins so as to improve their effectiveness and efficiency while reducing their weight or manufacturing cost. This work is related to one such analysis. In this work steady state analysis using ANSYS is done on fins having different types of cross sections viz. rectangular, triangular and elliptical. The length, width and area of cross section of these fins are identical while maximum thickness varies to compensate for the area of cross section. The initial and all other conditions are same for the analysis of these fins and the only difference is in their shape. Finally tip temperature and heat flux at base is plotted, while effectiveness and efficiency was compared. The software used to create models was CATIA V5.

Keywords

ANSYS, Simulation, Effectiveness, Efficiency, Fin.

1.Introduction

Every machine or device in this modern world somehow releases the heat like IC Engines, processors etc. Cooling of these heat emitting/generating devices or machines at some required rate becomes essential in some cases, so as to protect the device or machine from the ill effects of accumulation of heat or to improve its performance.

This task is mainly done by the thermal fins. Techniques involved in heat transfer might be passive techniques (where geometry plays the important role), active techniques (where output power is used to increases the heat transfer rate) or compound technique (where more than one technique is used)[1-3]. In this paper passive technique is used to analyse the fins.

1.1 Types of the fin

Owing to the shape of the fins, fins can be of different types viz. triangular fin, rectangular fin, trapezoidal fin, pin fin, drop shaped fin etc.

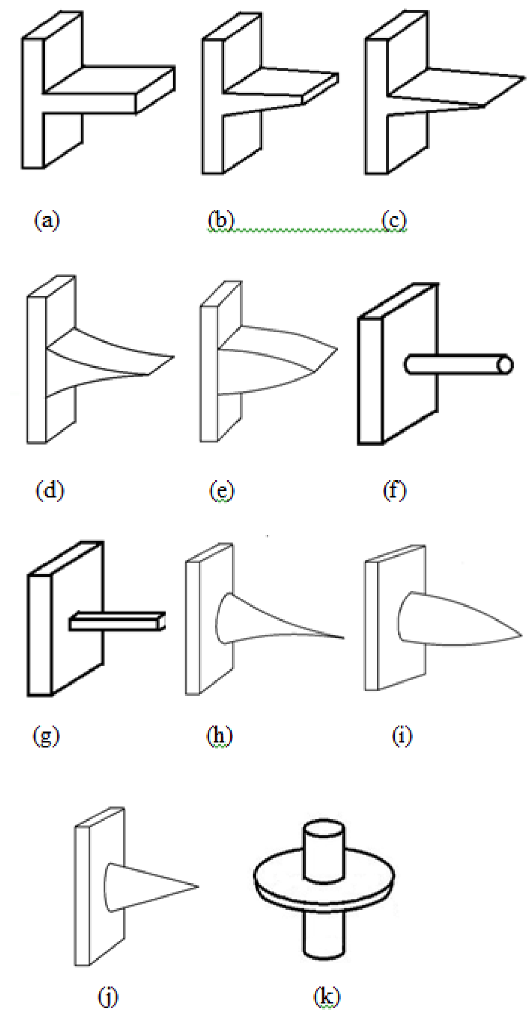

Figure 1 Types of the fin: (a) Rectangular fin, (b) Trapezoidal fin, (c) Triangular fin, (d) Concave parabolic fin, (e) Convex parabolic fin, (f) Circular pin fin, (g) Square pin fin, (h) Concave parabolic pin fin, (i) Convex parabolic pin fin, (j) Conical pin fin and (k) Annular fin

2.Methodology

Virtual model of the fins having different cross sections viz. rectangular cross section, triangular cross section and elliptical cross section would be created using CATIA V5. Further these models are saved as filename.igs file, so that these virtual models can be imported in ANSYS workbench. On ANSYS workbench a “Steady State Thermal” standalone system would be created by the respective tool of ANSYS. After importing the geometry appropriate meshing is done and Aluminium Alloy is applied as the material of the part body. Later initial conditions and other boundary conditions are applied and solved for the temperature distribution and total heat flux. Finally the tip temperature distribution, heat flux at base, effectiveness and efficiency of these fin are compared and conclusions were drawn.

2.1 Material applied for the fins

Aluminium alloy: These are alloys in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc. 6061 is a precipitation-hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S", it was developed in 1935[3-7]. It has good mechanical properties, exhibits good weld ability.

2.2 Geometry of the fins

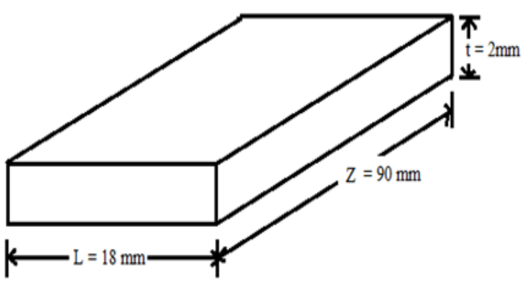

Figure 2 Dimensions of the rectangular fin

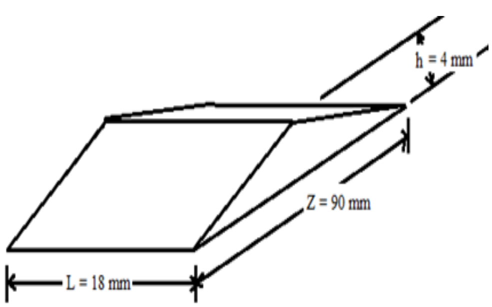

Figure 3 Dimensions of the triangular fin

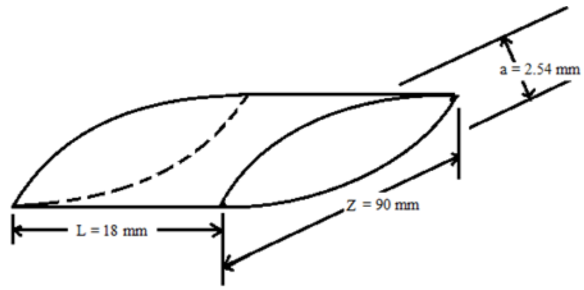

Figure 4 Dimensions of the elliptical fin

Table 1 Dimensions of the fins

S. No.	Dimension type	Rectangular fin	Triangular fin	Elliptical fin
1.	Length (mm)	18	18	18
2.	Width (mm)	90	90	90
3.	Maximum Thickness (mm)	2.0	4.0	2.54
4.	Area (mm^2)	180	180	180

Apart from the dimensions given above a base of dimension 8mm x1 mm was also added in the model.

2.3Boundary conditions applied

Table 2 Value of the basic boundary conditions

S. No.	Parameter	Value	
1.	Material	Aluminium alloy	
2.	Heat transfer coefficient	40	W/m/^{0}C
3.	Base Temperature	1500	^{0}C
4.	Ambient Temperature	30	^{0}C

2.4Basic mesh details

Table 3 Values of basic parameters of the meshes

S. No.	Parameter	Rectangular fin	Triangular fin	Elliptical fin
1.	Mesh type	Hex20	Tet10	Tet10
2.	Nodes	13612	18791	30631
3.	Elements	2278	10368	19173
4.	Element quality	0.9513	0.74396	0.75749

3.Results

Following 3-D and 2-D results were obtained by the simulation of the various fins

3.1Temperature distributions

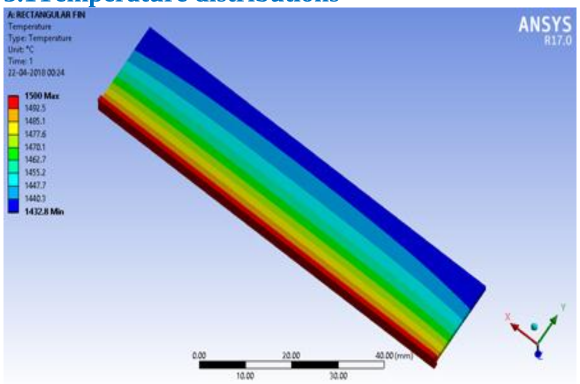

Figure 5 Temperature distributions for the rectangular fin

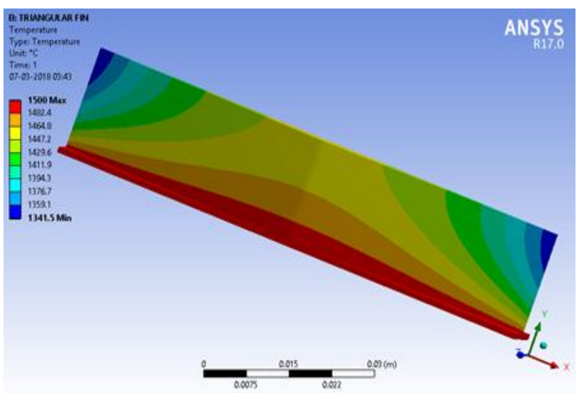

Figure 6 Temperature distributions for the triangular fin

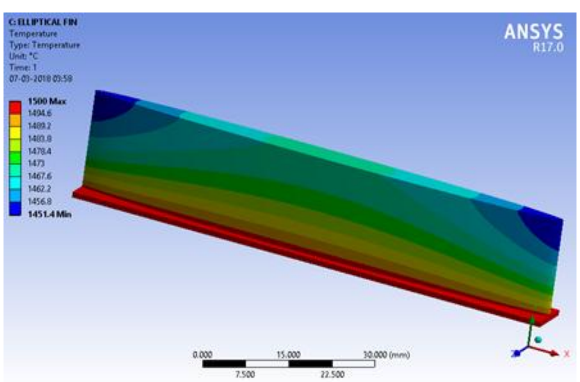

Figure 7 Temperature distributions for the elliptical fin

3.2Total Heat Flux Distributions

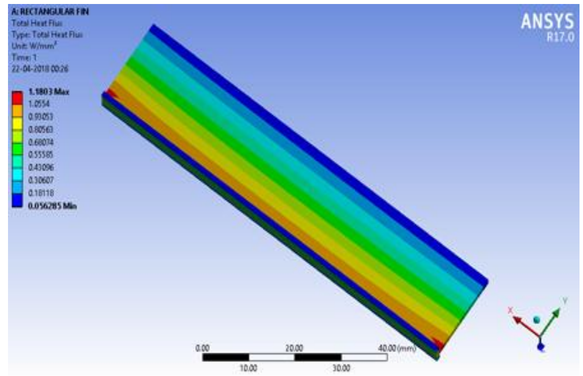

Figure 8 Total heat flux distributions for the rectangular fin

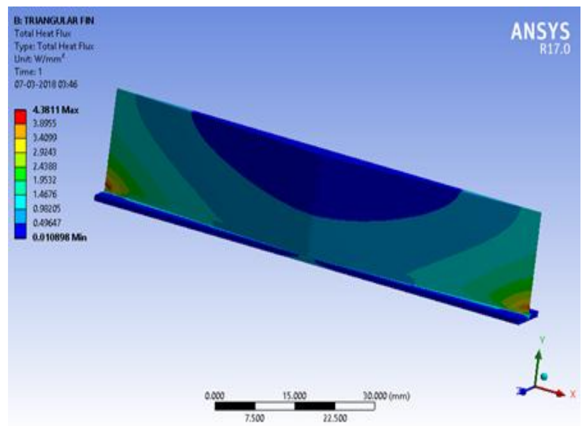

Figure 9 Total heat flux distributions for the triangular fin

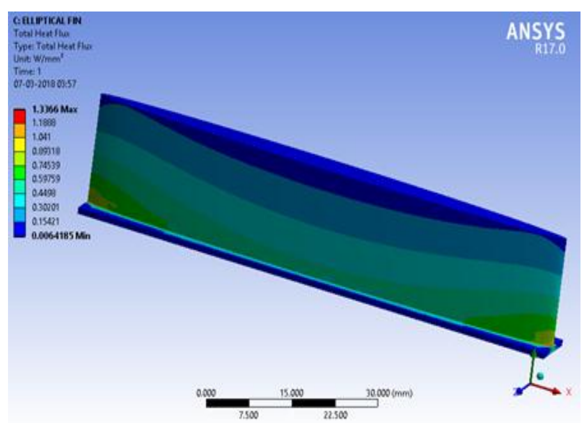

Figure 10 Total heat flux distributions for the elliptical fin

3.3Tip Temperatures Plot

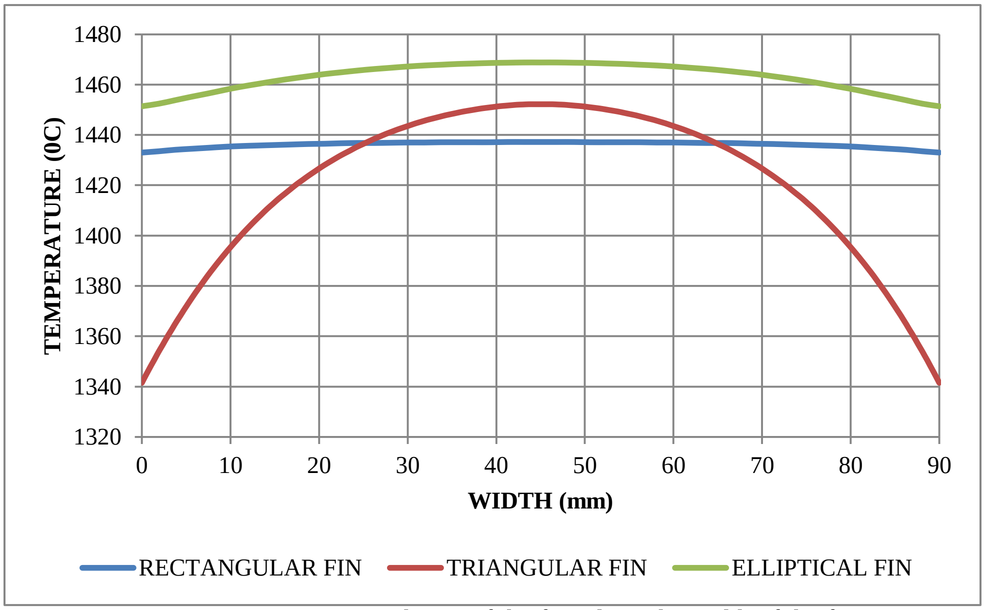

Figure 11 Temperature variations at the tip of the fins along the width of the fin

3.4Plot of heat flux at the base

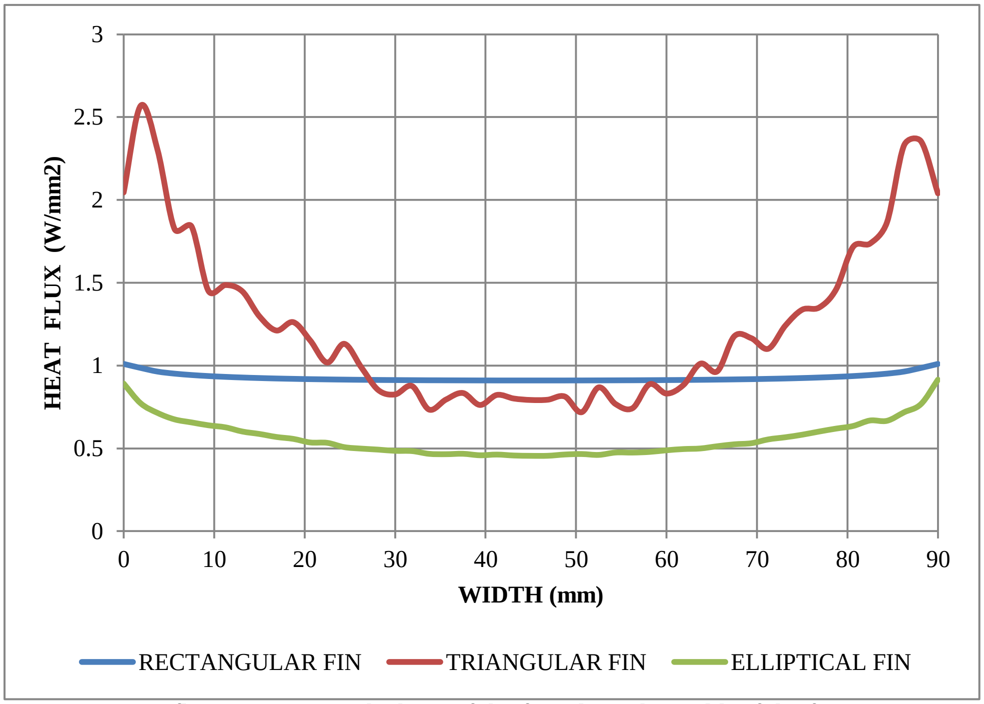

Figure 12 Heat flux variations at the base of the fins along the width of the fin

3.5Simulation values

Table 4 Values obtained as result from the simulation

S. No.	Parameters	Rectangular fin	Triangular fin	Elliptical fin
1.	Tip Temperature (^{0}C)	1433.0 to 1437.1	1341.5 to 1452.2	1451.4 to 1468.8
2.	Heat Flux at base (W/mm^2)	0.91007 to 1.01	0.718 to 2.568	0.455 to 0.915
3.	Heat Flow at base (W)	177.831	163.6164	94.484
4.	Effectiveness	16.80	15.46	8.93
5.	Efficiency (%)	86.60	81.23	46.91

4.Conclusion

For the same cross-sectional area, the rectangular fin is more efficient and effective than the triangular fin and elliptical fin, while elliptical fin has comparatively much lower effectiveness and efficiency. Also triangular and elliptical fins are quite complex in geometry as compared to the rectangular fin and therefore costly.

The lower value of effectiveness and efficiency in elliptical fin is possibly due to lower temperature gradient along the length of the fin (less difference between the base and the tip temperatures) and therefore the heat transfer due to conduction within the fin is less compared to the other two fins, resulting in decrease in the value of the heat flux that can be convected from the surface of the fin.

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