Design of Fin for Various Variables

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ABSTRACT

In this paper, the heat transfer of fin without and with various extensions such as rectangular extensions, triangular extensions and trapezium extension is analyzed by changing its material (such as Aluminium alloy, Copper alloy and Structural steel), and then a comparison is made between them. After comparison near about 12% more heat transfer is observed in the fin with various extensions in compare to fin without extensions for all the material. Here maximum heat transfer is obtained for the fin with rectangular extension for each material and the material for which heat transfer is maximum is copper. So after overall comparison it is found that that Copper alloy with rectangular extension gives the maximum heat transfer.

I. INTRODUCTION

A fin is an extruded surface that are basically used to increase the surface area of an object so that the rate of heat transfer is increased. Here fins are taken with different extensions which are made up of different material. Types of extensions provided on these fins are as (a) Rectangular extensions, (b) Trapezium extensions, (c) Triangular extensions. And the material of fin are as (a) Aluminium alloy (b) Copper alloy (c) Structural steel.

Fig. 1: Fin with (a) Rectangular extensions, (b) Trapezium extensions, (c) Triangular extensions
II. LITERATURE REVIEW
Baljit Singh Ubhi et.al. [1] has studied the heat transfer through fin by giving different extensions on the base fin (which has rectangular geometry) for structural steel material. After studying he compared the heat transfer through fin with extensions and without extension, then he found that fin with extension gives higher heat transfer compare to fin without any extension.

Dr. I. Satyanarayana et.al [2] has studied the natural convective heat transfer from inclined narrow plate in which he investigated the steady state natural convection from heat sink from narrow plate-fins having parallel arrangement mounted on inclined base. The dimensions of model are L=200mm, W=140mm & height=20mm and he concluded that temperature and heat flux is varying while changing the fins height and also which material is most suitable for the thermal boundary conditions.

Mayank Jain et.al [3] has studied the heat transfer analysis and optimization fins by variation in geometry in which he analyzed the thermal heat dissipation of fins by varying its geometry such as rectangular, circular, triangular, and fins with extension. After modeling and analysis, he found that triangular fin with material Aluminium alloy 6061 is better since temperature drop and heat transfer in a triangular fin is much more compared to others.

Mulukuntla Vidya Sagar et.al.[4] has studied the heat transfer through fin provided on engine cylinder by varying the geometry of fin. In this study he has taken two geometry which was analyzed for two different material by varying the thickness of fin. In this analysis he found that circular fin of aluminium alloy gives maximum heat transfer compare to others.

III. DESIGN AND ANALYSIS OF FIN WITH AND WITHOUT EXTENSIONS FOR DIFFERENT MATERIALS
A. Designing of fins
Here fins without and with various extensions are designed with the help of design software Solidworks 2018.

The specification of the fin without any extensions i.e. main fin is as:
Length = 40mm, width = 240mm and thickness = 15mm
And specification of various extensions provided on the base fin is shown below and number of extensions used on main fin is 10 nos.

![Fig. 2: (1) Rectangular extension, (2) Triangular extension, (3) Trapezium extension](image)

B. Analysis of fin for Heat Transfer with Simulation Software
After the designing process the analysis of fin for heat transfer is performed by using software ANSYS Workbench 19.2 (ANSYS Academic Teaching Mechanical & CFD). Here in this software firstly we imported the design model SLDPRT file in ANSYS Workbench 19.2 and then it makes the result as ANSYS FEA model wbpj file format. After this select the analysis as thermal analysis for steady state heat transfer process. After assigning the unit system select the material of fin. Now from the 3D mesh setting set the fine mesh and generate the mesh of design. Here the mesh type is rectangular for fin with trapezium and triangular extensions and triangular mesh type for fin with rectangular extensions and without extension.

C. Input to the Meshed Model
this the load and constraints assigned to the meshed

In model is as:
Thermal conductivity of Aluminium alloy, \( K_a = 156 \text{ W/m }^\circ\text{C} \)
Thermal conductivity of Copper alloy, \( K_c = 401 \text{ W/m }^\circ\text{C} \)
Thermal conductivity of structural steel, \( K_s = 60.5 \text{ W/m }^\circ\text{C} \)
Convection coefficient of heat transfer, \( h = 40 \text{ W/m}^2\circ\text{C} \)
Temperature of wall surface at which fin attached, \( t_o = 55 \circ\text{C} \)
Ambient temperature, \( t_s = 30 \circ\text{C} \)
D. Results from the analysis

After generation of mesh and giving the input parameters, run the simulation for the models. Hence, the temperature contour will obtained. The temperature contour for fin made up of different material without and with various extensions is as:-

**Fig. 3:** Temperature contour of fin without extension for Structural steel

**Fig. 4:** Temperature contour of fin with rectangular extension for Structural steel

**Fig. 5:** Temperature contour of fin with triangular extension for Structural steel

**Fig. 6:** Temperature contour of fin with trapezium extension for Structural steel

After this, the comparison is made for these geometry of fin as:

| Length of fin (mm) | Present work | Previous work [1] |
|-------------------|--------------|-------------------|
|                   |              | Fin with different type of extensions (Temp. in °C) |              |              |
|                   |              | Rectangular | Trapezium | Triangular | Without extension | Rectangular | Trapezium | Triangular | Without extension |
| 5                 | 54.281       | 54.323      | 54.364    | 54.559    | 53.903            | 53.944      | 53.938    | 53.914    |
| 10                | 53.912       | 53.921      | 53.973    | 54.206    | 53.538            | 53.592      | 53.584    | 53.552    |
| 15                | 53.584       | 53.598      | 53.743    | 53.884    | 53.173            | 53.241      | 53.231    | 53.190    |
| 20                | 53.293       | 53.322      | 53.414    | 53.574    | 52.807            | 52.889      | 52.877    | 52.828    |
| 25                | 52.049       | 53.088      | 53.199    | 53.342    | 52.442            | 52.537      | 52.523    | 52.466    |
| 30                | 52.852       | 52.886      | 52.984    | 53.111    | 52.077            | 52.185      | 52.169    | 52.105    |
| 35                | 52.726       | 52.741      | 52.861    | 52.881    | 51.711            | 51.833      | 51.816    | 51.743    |
| 40                | 52.607       | 52.644      | 52.738    | 52.800    | 51.346            | 51.482      | 51.462    | 51.381    |

**TABLE-1** Temperature distribution along the length of fins for Structural steel
Fig. 7: Plot showing the temperature variation along length of fin with different extensions and fin without extension for Structural steel

Fig. 8: Temperature contour of fin without extension for Aluminium alloy

Fig. 9: Temperature contour of fin with rectangular extension for Aluminium alloy

Fig. 10: Temperature contour of fin with trapezium extension for Aluminium alloy

Fig. 11: Temperature contour of fin with triangular extension for Aluminium alloy
After this, the comparison is made for these geometry of fin as:

| Length of fin (mm) | Fin with different type of extensions (Temp. in °C) |
|-------------------|------------------------------------------------------|
|                   | Rectangular | Trapezium | Triangular | Without extension |
| 5                 | 54.503      | 54.724    | 54.741     | 54.820            |
| 10                | 54.281      | 54.556    | 54.622     | 54.676            |
| 15                | 54.079      | 54.427    | 54.487     | 54.532            |
| 20                | 53.902      | 54.314    | 54.352     | 54.418            |
| 25                | 53.753      | 54.214    | 54.264     | 54.323            |
| 30                | 53.634      | 54.134    | 54.175     | 54.227            |
| 35                | 53.544      | 54.074    | 54.125     | 54.129            |
| 40                | 53.484      | 54.034    | 54.050     | 54.074            |

**TABLE-3** Temperature distribution along the length of fins for Aluminium alloy

**Fig. 12:** Plot showing the temperature variation along length of fin with different extensions and fin without extension for Aluminium alloy

**Fig. 13:** Temperature contour of fin without extension for Copper alloy

**Fig. 14:** Temperature contour of fin with rectangular extension for Copper alloy

**Fig. 15:** Temperature contour of fin with trapezium extension for Copper alloy
After this, the comparison is made for these geometry of fin as:

**TABLE-4** Temperature distribution along the length of fins for Copper alloy

| Length of fin (mm) | Rectangular | Trapezium | Triangular | Without extension |
|--------------------|-------------|-----------|------------|-------------------|
| 5                  | 54.803      | 54.891    | 54.898     | 54.929            |
| 10                 | 54.715      | 54.825    | 54.851     | 54.872            |
| 15                 | 54.635      | 54.774    | 54.797     | 54.815            |
| 20                 | 54.565      | 54.729    | 54.744     | 54.770            |
| 25                 | 54.506      | 54.689    | 54.709     | 54.732            |
| 30                 | 54.450      | 54.657    | 54.674     | 54.694            |
| 35                 | 54.423      | 54.634    | 54.654     | 54.655            |
| 40                 | 54.399      | 54.618    | 54.634     | 54.648            |

IV. RESULTS AND DISCUSSION

Here heat transfer for fin having convected tip is calculated by following formula:

\[
Q_{\text{fin}} = \sqrt{hPka_{\text{cs}}(t_{\text{o}} - t_{\text{a}})} \left[ \frac{\tanh \left( \frac{ml}{k} \right) + \frac{k}{km}}{1 + \frac{k}{km} \tanh \left( \frac{ml}{k} \right)} \right]
\]

for which length of fin = 0.04 m, cross section area \( (A_{\text{cs}}) \) and perimeter \( (P) \) of fin with rectangular extensions is 4200 \( \times 10^{-6} \) m\(^2 \) and 0.57 m respectively, cross section area \( (A_{\text{cs}}) \) and perimeter \( (P) \) of fin with triangular extensions is 3900 \( \times 10^{-6} \) m\(^2 \) and 0.518 m respectively and cross section area \( (A_{\text{cs}}) \) and perimeter \( (P) \) of fin with trapezium extensions is 4050 \( \times 10^{-6} \) m\(^2 \) and 0.526 m respectively. The fin without extension have 21.766 W heat transfer value.

**TABLE-5** Heat transfer comparison for Structural steel
### Type of extensions

| Type of extensions       | Heat transfer (in W) | Increase in heat transfer (in W) | Percentage increase in heat transfer (in %) |
|-------------------------|---------------------|---------------------------------|--------------------------------------------|
| Fin with rectangular extension | 26.30               | 2.93                            | 12.54                                      |
| Fin with trapezium extension     | 24.47               | 1.10                            | 4.71                                       |
| Fin with triangular extension        | 24.03               | 0.66                            | 2.83                                       |

**TABLE-6** Heat transfer comparison for **Aluminium alloy**

| Type of extensions       | Heat transfer (in W) | Increase in heat transfer (in W) | Percentage increase in heat transfer (in %) |
|-------------------------|---------------------|---------------------------------|--------------------------------------------|
| Fin with rectangular extension | 26.72               | 3.05                            | 12.91                                      |
| Fin with trapezium extension     | 24.83               | 1.16                            | 4.92                                       |
| Fin with triangular extension        | 24.39               | 0.72                            | 3.06                                       |

**TABLE-7** Heat transfer comparison for **Copper alloy**

The effectiveness of extension on fin made up of different material is calculated by formula below:

\[
\varepsilon = \frac{q_{\text{fin with extension}}}{q_{\text{fin without extension}}}
\]

| Material/Geometry | Fin with rectangular extension | Fin with trapezium extension | Fin with triangular extension |
|-------------------|-------------------------------|-----------------------------|-----------------------------|
| Structural steel  | 1.1268                        | 1.0489                      | 1.0290                      |
| Aluminium alloy   | 1.1258                        | 1.0470                      | 1.0280                      |
| Copper alloy      | 1.1294                        | 1.0490                      | 1.0300                      |

**TABLE-8** Comparison of effectiveness of extensions on fin

V. CONCLUSIONS

The overall conclusion of the whole analysis:

- Extensions provided on fin gives 12% more heat transfer compare to fin without any other extensions.
- Compare to all other extensions rectangular extension provides maximum heat transfer.
- Heat transfer through fin made up of Copper alloy is higher as compare to Aluminium alloy and Structural steel.
- Compare to all other extensions rectangular extension gives minimum temperature at the end of fin.
- Temperature at the end of fin made up of Copper alloy is maximum compare to fin made up of other materials.
- Compare to all other extensions effectiveness of rectangular extension is maximum.
- The effectiveness of fin made up of Copper alloy is greater than other two materials.

REFERENCES

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