Design & Thermal Analysis of an Extended Surface with Various Geometry by using Finite Element Method

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Abstract— A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. Increasing the temperature gradient between the object and the environment, increasing the convection heat transfer Coefficient or increasing the surface area of the object increases the heat transfer. Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it. So, as the surface area increase the more fluid contact to increase the rate of heat transfer from the base surface as compare to fin without the extensions provided to it. The heat transfer performance of fin with same geometry having various extensions and without extensions will compared and also with holes on extended surface and without holes on extended surface also compared. Fin with various extensions design with the help of software AutoCAD software and Analysis of fin performance done through the software Autodesk® Simulation and meshing using hyper meshing software and ANSYS.

Key words: Thermal Analysis, Extended Surface, Finite Element Method

I. INTRODUCTION

Fin is a solid extended surface / a combined conduction convection system. Heat is transferred by Conduction within the solid and by convection from the fin surface in a perpendicular direction to that of conduction. Finally heat is lost to the surroundings. Fins increase the rate of heat transfer by increasing the surface area without increase of primary surface area. This increased surface area reduces the convective resistance and increases the rate of heat transfer economically. The fins should have large surface area per unit volume (>700 m²/m³) with small gas flow passages with natural laminar flow for increased rate of heat transfer. It increases the heat exchange between two fluids which are separated by a sold surface as in home radiators and cooling system in cars.

A. Purpose of a Fin

To increase heat transfer by increasing the surface area without increase of primary surface area. Fin involves both (conductive + convective) heat transfer. . Finally it loses heat to the atmosphere.

B. How Fins Increase Heat Transfer

Convection equation \( q = h \Delta T \) Watts. Undoubtedly heat transfer can be increased by

1) Increasing temperature difference
2) Increasing the convection heat transfer coefficient
3) Increasing the contact surface area of the object

\( \Delta T \) can’t be increased because of fin base temperature and environment temperatures are normally fixed. Convection coefficient \( h \) can be increased by increasing the fluid flow with a fan. This also is not possible in most of the applications. Thus it is not feasible to change the first two options. Therefore, Increase of surface area \( A \), is the only choice. Use of fins does this economically.

C. Type of Fins / Shapes of Fins

Fins can be broadly classified as:
1) Longitudinal fin
2) Radial fin
3) Pin fin

![Fig. 1: Types of Fins](image)

D. Practical Applications of Fins

1) Electric motors
2) Car radiators
3) Pumps
4) Compressors
5) Internal Combustion engines
6) Transformers
7) Condensers
8) Evaporators
9) Air craft engines
10) Economizers of steam power plants
11) In nature, the ears of Jackrabbits and Fennec Foxes act as fins to release heat from within their bodies.

II. LITERATURE REVIEW

1) Enhancement of Natural Convection Heat Transfer from a Fin by Triangular Perforations of Bases Parallel and Toward its Base. Abdullah, H. Alessa et. al. [1] had studied the natural convection heat transfer enhancement from a horizontal rectangular fin embedded with equilateral triangular
perforations. The heat dissipation rate from the perforated fin is compared to that of the equivalent solid one. The effect of geometrical dimensions of the perforated fin and thermal properties of the fin was studied in detail. They concluded that, For certain values of triangular dimensions, the perforated fin can result in heat transfer enhancement. The magnitude of enhancement is proportional to the fin thickness and its thermal conductivity. The perforation of fins enhances heat dissipation rates and at the same time decreases the expenditure of the fin material.

2) A Study on the Heat Transfer Enhancement for Air Flow through a Duct with Various Ribs Inserts

B. Ramdas Pradip et. al. [2] had studied the many industries are utilizing thermal systems wherein overheating can damage the system components and lead to failure of the system. In order to overcome this problem, thermal systems with effective emitters such as ribs, fins, baffles etc. are desirable. The need to increase the thermal performance of the systems, thereby affecting energy, material and cost savings has led to development and use of many techniques termed as “Heat transfer Augmentation”. This technique is also termed as “Heat transfer Enhancement” or “Intensification”. Augmentation techniques increase convective heat transfer by reducing the thermal resistance in a heat exchanger. Many heat augmentation techniques have been reviewed, these are (a) surface roughness, (b) plate baffle and wave baffle, (c) perforated baffle, (d) inclined baffle, (e) porous baffle, (f) corrugated channel, (g) twisted tape inserts, (h) discontinuous Crossed Ribs and Grooves. Most of these enhancement techniques are based on the baffle arrangement. Use of Heat transfer enhancement techniques lead to increase in heat transfer coefficient but at the cost of increase in pressure drop.

3) Natural Convective Heat Transfer from Interrupted Rectangular Fins

Golnoosh Mostafavi [3] had investigated the steady-state external natural convection heat transfer from vertically mounted rectangular interrupted finned heat sinks. After regenerating and validating the existing analytical results for continuous fins, a systematic numerical, experimental, and analytical study is conducted on the effect of the fin array and single wall interruption. FLUENT and COMSOL Multiphysics software are used in order to develop a two-dimensional numerical model for investigation of fin interruption effects. Results show that adding interruptions to vertical rectangular fins enhances the thermal performance of fins and reduces the weight of the fin arrays, which in turn, can lead to lower manufacturing costs.

4) Enhancement of Natural Convection Heat Transfer on Vertical Heated Plate by Multiple V-fin arrays

Sable, M.J. et. al. [4] had investigated for natural convection adjacent to a vertical heated plate with a multiple v-type partition plates (fins) in ambient air surrounding. As compared to conventional vertical fins, this v-type partition plate’s works not only as extended surface but also as flow tabulator. In order to enhance the heat transfer, V-shaped partition plates (fins) with edges faced upstream were attached to the two identical vertical plates. They observed that among the three different fin array configurations on vertical heated plate, V-type fin array design performs better than rectangular vertical fin array and V-fin array with bottom spacing design. The performance was observed to improve further, with increase in the height of the V-plates (fin height).

5) Experimental and Parametric Study of Extended Fins in The Optimization of Internal Combustion Engine Cooling Using CFD

J. Ajay Paul, Sagar Chavan Vijay [5] had investigated Extended Fins in the Optimization of Internal Combustion Engine they found for high speed vehicles thicker fins provide better efficiency. When fin thickness was increased, the reduced gap between the fins resulted in swirls being created which helped in increasing the heat transfer. Large number of fins with less thickness can be preferred in high speed vehicles than thick fins with less numbers as it helps inducing greater turbulence.

6) Finite Element Analysis and Experimental Study of Convective Heat Transfer Augmentation from Horizontal Rectangular Fin by Triangular Perforations

Kumbhar D.G, Dr. N.K. Sane, Chavan S. T., et al (2009) [6]. In this paper, the effect of triangular perforations on rectangular fin is investigates the comparison of perforated fin with solid fin for temperature distribution along the fin and heat transfer rate. The analysis is done using software ANSYS and also by experimentation. The investigation observed that heat transfer rate increases as well as the same time reduce the cost of fin with perforations as compared to fins of similar dimensions without perforations. It concluded that heat transfer rate is different for different materials or heat transfer rate changes with change in thermal conductivity of the material.

7) Design and Analysis of Extended Surfaces with Different Thermal Conductivity Using ANSYS 12

Ankit Mayank[10] “Design and Analysis of Extended Surfaces with Different Thermal Conductivity Using ANSYS 12 It is concluded that when we change the material and heat flux, then heat transfer rate is increased. If we increase the thermal conductivity of material then cooling rate of fin will be increased, which can be seen in nodal temp. As thermal conductivity increases the nodal temperature reduces. Fourier’s law states as the conductivity increases, heat transfer rate also increases which can be seen with our analysis (Copper with highest conductivity gives better heat transfer).
III. DESIGNING OF EXTENDED SURFACE WITH AUTO CAD

![Projected Fin Section Types](image)

Fig. 1: Projected Fin Section Types

IV. DESIGN MODELS OF EXTENDED SURFACE (FINS) USING SOLID WORKS

![Design Models of Extended Surface](image)

Fig. 2: Fin with Rectangular projection.

Fig. 3: Fin with Triangular projection.

Fig. 4: Fin with Circular projection

Fig. 5: Fin with Trapezium Projection

Fig. 6: Mesh Diagram

V. RESULTS & DISCUSSION

Discussed earlier from the previous papers only concentrated on the parameter changes. But we analyze the various types of extension on the extended surface. & gives the result for various extension with holes and without holes on extended surface.

![Results & Discussion](image)

Fig. 7: Circular Extensions

Fig. 8: without Extensions

A. Analysis of Aluminium Material with Various Extensions
Fig. 9: Rectangular Extensions

Fig. 10: Trapezium Extensions

Fig. 11: Triangular Extensions

B. Analysis of Castiron Material With Various Extensions

Fig. 12: Circular Extensions

Fig. 13: Without Extensions

Fig. 14: Rectangular Extensions

Fig. 15: Trapezium Extensions

Fig. 16: Triangular Extensions
C. Analysis of Copper Material with Various Extensions

Fig. 17: Circular Extensions

Fig. 18: Without Extensions

Fig. 19: Rectangular Extensions

Fig. 20: Trapezium Extensions

D. Analysis of Aluminium Material with Holes Various Extensions

Fig. 21: Triangular Extension

Fig. 22: Circular Extensions

Fig. 23: Without Extensions

Fig. 24: Rectangular Extensions
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Fig. 25: Trapezium Extensions

Fig. 26: Triangular Extensions

E. Analysis of Cast Iron Material with Holes Various Extensions

Fig. 27: Circular Extensions

Fig. 28: Without Extensions

F. Analysis of Copper Material with Holes Various Extensions

Fig. 29: Rectangular Extensions

Fig. 30: Trapezium Extensions

Fig. 31: Triangular Extensions

Fig. 32: Circular Extensions
Now, the different material like aluminum, copper and cast iron values analysis will be displayed in table as given below. The cast iron will be the best one when comparing to the both aluminum and copper.

Table 1: Analysis for Various Extensions without Holes

<table>
<thead>
<tr>
<th>TYPE OF EXTENSION</th>
<th>AL °C</th>
<th>CI °C</th>
<th>CU °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECTANGULAR EXTENSION</td>
<td>77.414</td>
<td>74.157</td>
<td>77.086</td>
</tr>
<tr>
<td>CIRCULAR EXTENSION</td>
<td>77.491</td>
<td>74.323</td>
<td>77.173</td>
</tr>
<tr>
<td>TRIANGULAR EXTENSION</td>
<td>77.399</td>
<td>74.124</td>
<td>77.069</td>
</tr>
<tr>
<td>TRAPEZOIDAL EXTENSION</td>
<td>77.511</td>
<td>74.366</td>
<td>77.196</td>
</tr>
<tr>
<td>NORMAL FIN</td>
<td>77.063</td>
<td>73.407</td>
<td>76.693</td>
</tr>
</tbody>
</table>

Table 2: Analysis for Various Extensions with Holes

<table>
<thead>
<tr>
<th>TYPE OF EXTENSION</th>
<th>WITHOUT HOLE °C</th>
<th>WITH HOLE °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECTANGULAR EXTENSION</td>
<td>76.166</td>
<td>71.538</td>
</tr>
<tr>
<td>CIRCULAR EXTENSION</td>
<td>76.158</td>
<td>71.523</td>
</tr>
<tr>
<td>TRIANGULAR EXTENSION</td>
<td>76.096</td>
<td>71.396</td>
</tr>
<tr>
<td>TRAPEZOIDAL EXTENSION</td>
<td>76.156</td>
<td>71.519</td>
</tr>
<tr>
<td>NORMAL FIN</td>
<td>76.077</td>
<td>71.353</td>
</tr>
</tbody>
</table>

Table 3: Analysis for Temperature Distribution of Various Extensions

This is the comparative table for all three type of material such as, aluminium, cast iron and copper. Comparing on the basis of with holes of extended surface as well as without holes of extended surface. Cast iron material is better than that of the other two materials.
VI. CONCLUSION & FUTURE SCOPE

The analysis is done in SOLID WORKS and ANSYS version. the following conclusions were made from the ANSYS simulation it is observed that the various extensions of extended surface with different materials such as aluminium, castiron and copper with the thermal conductivity and film coefficient .cast-iron material is better heat transfer with other materials. And also with holes on extended surface and without holes on extended surface also compared.

VII. FUTURE SCOPE

The following are the suggestions for future work, the work can be carried with different base material as well as different fin materials. It can be useful for future applications in several fields. And also changing with composite materials also adopted in future work.

REFERENCES


