Comparative Thermal Analysis by Using Simulation of Circular Fin Manufactured with Several Materials

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Abstract

Fins are mostly known as extended surfaces. Heat transfer by the convection between a surface and fluid surrounding it can be augmented by assigning to the surface thin strips of metallic elements called fins. Fins are industrialized in several structures, as per the real-world trends. However, this research work has been done on the circular fins. The concentrically annulated discs round a conduit are labeled as circumferential fins. The comparative thermal analysis applied on the different materials made up of fin, those materials were pure copper, pure aluminum, aluminum alloy 6063 and aluminum alloy 7068. The parameters considered in this analysis were temperature distribution and heat flux. Comparatively, pure copper showed optimum results such as heat flux was $1.6059 \times 10^5 \text{W/m}^2$ and minimum temperature distribution was $290.35 \degree\text{C}$.

Keywords

Fins, Extended surfaces, Heat transfer, Heat flux, Temperature distribution, ANSYS

Introduction

As technology develops, a faster rate of heat transmission is desired, making conventional techniques obsolete. As a result, the idea of making the materials in a nano size, therefore heat transfer capabilities emerged. Because it is thought to be one of the most significant issues, heat transfer has drawn a lot of attention recently. Applications for it include coil steam generators, nuclear reactors, thermosiphons, unit refrigerators, small heat exchangers, and other heat transfer devices that need a change in phase.

The heat conducted via solids, walls or borders must be incessantly debauched to the surrounding stop reserve the arrangement in a steady state. In numerous manufacturing appliances huge extents of heat must be debauched from minor zones. Transfer of heat by convection between an exterior and the fluid adjacent to it can be enlarged by assigning to the superficial tinny tiles of metals titled fins [1, 2]. The fins upsurge the active zone of the superficial there by growing the temperature transmission by convection. The fins are also mentioned as extended surfaces. The ribs fixed laterally the span of a tube are titled as longitudinal fins [3, 4]. The concentrical annulate diskettes round a conduit are labelled circumferential fins. Fin fins or spines are rods swelling from an exterior. Different types of fins are presented in figure 1.

As part of this research work, a lot more literature has been done on fins and their thermal and structural analysis. This literature also focused on the materials applied for the fins. By this literature most of the material properties were easily available. The innovative literature work is presented below.
Gupta and Wankhede. [1] created a cylinder fin body using simulation, for a 100-cc motorcycle. This research work utilized grey cast iron for the inner core and aluminum alloy fins for the fin body. For the whole body, replaced distinctly with grey cast iron and aluminum alloy 6063. The four-sided form of the fin has been substituted with a rounded one. Fins are characteristically 3 mm thick, while they are now only 2.5 mm thick. By varying the materials, geometry, and thickness of the fin body, thermal analysis has been directed. Confering to observations of investigation discoveries, utilizing rounded fins made of aluminum alloy 6063 with a thickness of 2.5 mm was superior since it enlarged heat transfer rates. Al-Abboodi et al. [2] studied a micro pin fin heat sink with 4 dissimilar fin structures circular, elliptical, square and drop forms and 2 dissimilar planning styles, i.e., inline, and staggered layout. Varma and Gautam. [3] reviewed numerous fins and optimization policies utilized by investigators for enlightening heat transmission proportion are conversed. Deprived of undertaking any anticipatory preservation, heat transmission rate might be upgraded by utilizing those several fin varieties. Singh and Sahu. [4] improved the heat transfer rates by considering several materials like graphene and aluminum foam. Extended surfaces have their chief implication in heat transfer and thermal supervision in internal combustion engines. Fins with numerous perforation contours ought to be utilized and their performance in transporting heat should be further amended. Ubed. [5] comprehended how speedily heat is transported by fins with numerous notches. To determine the heat transfer rate, CATIA was utilized to model the fins in various formations and CFD fluent was utilized for the investigation. It was evident that the fins with the quadrilateral notch had a higher heat transfer rate than the fins without holes, fins with holes, and fins with V shapes, according to the software outcomes and theoretical estimates. With the help of outcomes, the rectangular notch heat dissipation rate is high [6, 7].

According to the literature most of the research has been focused on thermal and structural analysis of rectangular fins made of aluminum alloys. Only a few of them concentrated on the circular fins. So, the present work has been done on the circular fin and compared the thermal analysis among the fins made of aluminum and its alloys and pure copper.

**Circular fins**

Circular fins are probably known as annular fins and technically mentioned as circumferential fins. In engineering, an annular fin is a precise kind of fin applied in heat transmission that diverges, radially, in cross-sectional area [8-10]. Attaching an annular fin to an object upsurges the quantity of superficial zone in interaction with the adjacent fluid, which growths the convective heat transmission between the entity and adjacent fluid. Because surface is a growth as span from the entity growths, an annular fin transfers more heat than a similar pin fin at any specified span. Annular fins as shown in figure 2 are often used to increments the heat exchange in liquid-gas heat exchanger arrangements.

**In line arrangement of circular fins**

Initially, the fin diameter is fundamentally measured by a proposal constraint for the complete heat sink measurement, transverse pitch P, longitudinal pitch P, and the diagonal pitch P. Amid tube centers as shown in figure 3. The following form represents the dimensions of P:

\[
P_D = \left(\sqrt{P^2} + \left(P_T/2\right)^2\right)_L
\]

**Materials and Method**

For analyzing the fin, which is simulated in ANSYS software. This ANSYS software is one of the promising software for engineering applications. In ANSYS workbench steady state thermal module has been selected for the thermal analysis of fins made up of current research materials.

**Research materials**

This research has been done on the several materials those are pure copper, pure aluminum, aluminum alloy 6063, which has the chief alloying elements are zinc (0 to 0.10%), magnesium (0.45 to 0.90%), copper (0 to 0.10%), aluminum (97.5 to 99.35%), and others. Aluminum alloy 7068, which has the chief alloying elements are zinc (7.3 to 8.3%), magnesium (2.2 to 3.0%), copper (1.6 to 2.4%) and zirconium (0.05 to 0.15%) and aluminum 85.43% and others. Previously, most...
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Table 1: Material properties.

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Density (g/cm³)</td>
<td>8.96</td>
<td>2.70</td>
<td>2.69</td>
<td>2.85</td>
</tr>
<tr>
<td>2</td>
<td>Thermal conductivity (W/(m.K))</td>
<td>401</td>
<td>237</td>
<td>209.5</td>
<td>190</td>
</tr>
<tr>
<td>3</td>
<td>Young’s modulus (GPa)</td>
<td>119</td>
<td>70</td>
<td>68.3</td>
<td>73</td>
</tr>
<tr>
<td>4</td>
<td>Specific heat (J/kg.K)</td>
<td>392</td>
<td>903</td>
<td>900</td>
<td>1050</td>
</tr>
<tr>
<td>5</td>
<td>Poisson’s ratio</td>
<td>0.34</td>
<td>0.35</td>
<td>0.3</td>
<td>0.31</td>
</tr>
</tbody>
</table>

of this research work has been done on the aluminum and its alloys, but these materials may have a chance of rust or corroding but copper will not ever rust as well as never corrode because it contains very small amount of iron. All the material properties are considered from the auspicious journals. The important material properties are tabulated in table 1.

Simulation

First of all, in steady state thermal module, rectangular base has drawn with the dimension of 200 x 100 mm in geometry in ANSYS workbench. In addition to extruding this base with a depth of 15 mm. Furthermore, fins with 10 mm diameter have drawn and extrude it with depth of 50 mm. After completion of the design process and apply the fine mesh for the accurate results as shown in figure 4 and figure 5.

Thermal parameters

For analyzing the fins, it is important to give the inputs. Firstly, apply the engineering materials and their properties then give the inputs as temperature was 300 °C and film co-efficient as 25 W/m²°C. After application of inputs, click on to solution from the outline then select temperature and total heat flux finally select the option solve.

Results and Discussion

After completion of meshing, the inputs are applied on the designed circular fin modal. The temperature 300 °C is applied at the base plate area and convective heat transfer coefficient 22 W/m²°C is applied at the fins surface. After applying these boundary conditions on the designed circular fin modal, the parameters such as the temperature distribution and heat flux at the different materials were examined.

Temperature distribution and heat flux for copper material

By applying the above boundary conditions on a copper material, the temperature distribution in circular fins as shown in figure 6 and distribution of heat flux as shown in figure 7. The maximum temperature occurred at base plate and minimum temperature was 290.35 °C occurred at the tip of the fin. And maximum heat flux showed 1.6059 x 10⁵ W/m² and minimum heat flux presented 1231.3 W/m².

Temperature distribution and heat flux for aluminum

By applying the above boundary conditions on an
aluminum material, the temperature distribution in circular fins as shown in figure 8 and distribution of heat flux as shown in figure 9. The maximum temperature occurred at base plate and minimum temperature presented that 283.99 °C occurred at the tip of the fin. And maximum heat flux gave $1.5796 \times 10^5$ W/m² and minimum heat flux showed 1198.4 W/m².

**Temperature distribution and heat flux for aluminum alloy 6063**

By applying the above boundary conditions on a 6063-aluminum material, the temperature distribution in circular fins as shown in figure 10 and distribution of heat flux as shown in figure 11. The maximum temperature was at base plate and minimum temperature was 282.04 °C at the tip of the fin. And maximum heat flux presented that $1.5715 \times 10^5$ W/m² and minimum heat flux obtained that 1190.2 W/m².

**Temperature distribution and heat flux for aluminum alloy 7068**

By applying the above boundary conditions on a 7068-aluminum material, the temperature distribution in circular fins as shown in figure 12 and distribution of heat flux as shown in figure 13. The maximum temperature occurred at base plate and minimum temperature 280.26 °C occurred at the tip of the fin. And maximum heat flux showed $1.5641 \times 10^5$ w/m² and minimum heat flux as 1183.4 w/m². The results were tabulated in table 2.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Material</th>
<th>Temperature (°C)</th>
<th>Heat flux (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td>1</td>
<td>Copper</td>
<td>300</td>
<td>290.35</td>
</tr>
<tr>
<td>2</td>
<td>Aluminum</td>
<td>300</td>
<td>283.99</td>
</tr>
<tr>
<td>3</td>
<td>Aluminum alloy 6063</td>
<td>300</td>
<td>282.04</td>
</tr>
<tr>
<td>4</td>
<td>Aluminum alloy 7068</td>
<td>300</td>
<td>280.26</td>
</tr>
</tbody>
</table>
Conclusions

By the impartial results, it is concluded that copper showed favorable results. Usually, fins are manufactured with aluminum and its alloys from an economical point of view. But now a day’s copper is also abundantly available. This research work has been done on the analysis of heat flux and temperature distribution. Heat flux, nothing but thermal flux, is a movement of energy per unit area per unit period. Temperature distribution designates sequences of temperature extents at diverse pack positions interior of a system, to measure the temperature homogeneity and constancy over the system and categorize the cold spot. From the analysis the fair conclusions have been mentioned below.

- Copper has better material properties as compared with aluminum.
- However, the analysis concluded that copper is suitable for the fins because of its extreme outcome of temperature distribution and heat flux.
- By using the copper material, the maximum temperature occurred at base plate.
- The minimum temperature exposed that 290.35 °C occurred at the tip of the fin for copper.
- From the analysis of copper, maximum heat flux offered that 1.6059 x 10^5 W/m^2.
- The minimum heat flux obtained that 1231.3 W/m^2.

With the help of the above outcomes, compared with the other materials, copper gave the best outputs in heat flux and temperature distribution point of view. Hence this research strongly suggests that fins will be manufactured with copper materials.

Acknowledgements

None.

Conflict of Interest

None.

References