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Full Length Research Paper

Experimental Studies on Toroidal Fins for Enhancement of Heat Transfer

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Abstract
In the present situation, there is a need for devices to carry the thermal energy generated in the system. Fins are the efficient devices which are going to carry the heat generated in the system. The experimentation with the convection phenomenon was done while taking into account natural convection. Results were observed when the fin's thickness was changed from 7mm to 3mm. We found an effectiveness of 3.37 for aluminium with a 7 mm thickness and a 3.28 for splines with a 3 mm thickness. This variance results from a reduction in thickness, which improves temperature variation. Similar phenomena were seen for gunmetal, and the results are as follows: The value obtained is 2.78 for 7mm thickness and 2.02 for 3mm thickness. A single piece of aluminium with a thickness of 3 mm will provide greater heat transfer properties when compared to other metals, according to results from both types of metal.

Keywords: *Convection, Effectiveness, Efficiency, Heat Transfer, Thickness, and Toroidal*

Introduction

In the study of heat transfer, 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. The amount of conduction, convection, or radiation of an object determines the amount of heat transfer. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to an object, however, increases the surface area and can sometimes be an economical solution to heat transfer problems [1, 2]. The reason of designing is common to analyze the effect of the heat transfer wherein the type of design is one of the factors that gave effect. The purpose of designing fin is to obtain the effectiveness of the fin. Although the fins significantly in-crease heat transfer from the cylinder, considerable improvement could still be obtained by increasing the number of fins [3]. Besides that, the thickness of fin, the gap between fins is also [4]. Besides that, the thicknesses of fin, the gap between fins are also important in the designing of the engine [5]. High capacity motors and pumps will have fins on surfaces with greater thickness, but we are unable to insert as many fins due to this thickness. We have chosen to reduce the thickness from 7mm to 3mm as a result of this practical difficulty so that we can fit more fins around the surface. In the present work Toroidal fin has been considered for the study by varying the thickness of the spline from 3 mm to 7 mm. Aluminium and gun metal have been considered for the study. Experimental analysis has been carried out to optimizer the spline thickness.

Materials and Methodology

Fig 1 shows the experimental set up, consisting of mica heater, digital temperature indicator and k type thermo couple. Figure -2 presents the toroidal fins. The toroidal fins' cylinder wall is heated using a heater to the proper temperature. By adjusting the voltage parameter, which also affects the power parameter and the emission temperature, the desired temperature is attained. To prevent electric current from travelling through the heater and into the toroidal fins, the heater is constructed of mica material.

Fig-1: Experimental Setup

Fig -2: Toroidal fins

Methodology of calculations:

1. Perimeter of Fin: $P = 2\times(x+y)$

   x= Thickness of fin= 7 mm, y= length of fin= 96 mm

   ***P*= 0.204 m**

2. Area of the Fins: $A = x \times y$

   ***A*= 0.772 ×10^{-3}m^{2}**

3. Constant m: $$m = \sqrt{\frac{hp}{kA}}$$

   h = convective heat transfer coefficient, P = perimeter of the fin, K= Thermal Conductivity of alluminium= 265 W/mk.

   m = 8.3735

4. $ml = my$

   ml=0.70785m

5. Actual heat flux Q_{act}= $\sqrt{hpkA\times\theta^{o}} \times \tanh ml$

   θ^{0}= T- T_a = 140.216 - 34 = 108.216°C

   Q_{act}= 85.9831W

6. Theoretical or Maximum heat flux $Q = V \times I$

   V= Voltage regulated for the heater= 72 v

   I= Current supplied= 0.35 A

   Q_{max} = 24.2W

7. Fin Effectiveness $$\varepsilon = \frac{Q_{act}}{Q_{max}}$$

   ε = 3.5723

   Fin efficiency $$\eta = \frac{\tanh ml}{ml}$$ where tanhml= 0.60933, ml= 0.70785

   η = 85.08 %

Calculation for Natural Convection

1. Grashoff Number: $$Gr = \frac{g\beta\Delta Tl^{3}}{\nu^{2}}$$ where ύ= kinematic viscosity of air= 1.46 × 10^{-5} m^{2}/sec,

2. T_{avg} = Average temperature of the experimental readings= 155.28 ^{0}C

   l = 0.096 m, $T_f = (T_{avg} + T_a)$ /2 T_f = 95.64°C

   $$\beta = \frac{1}{T_f + 273}$$

   β = 0.00271 K^{-1}

   Gr =18.1510×10^{6}

3. Prandtl number: $$P_r = \frac{\mu C_P}{K}$$ where μ = dynamic viscosity ofair, Cp = specific heat ofair

   And k = thermal conductivity of engine material.

   Pr =0.843

4. Nusselt Number: $$Nu = \frac{hl}{k} = .59 \times (Gr \times \Pr)^{0.25}$$

Where, Nu = Nusselt's number, Gr = Greshoff's number, Pr = Prandlt number, h = convective heat transfer coefficient, L = length of fin and k = thermal conductivity of air.

Nu= 34.25

h = 8.68W/m^{2}K

Results & Discussion

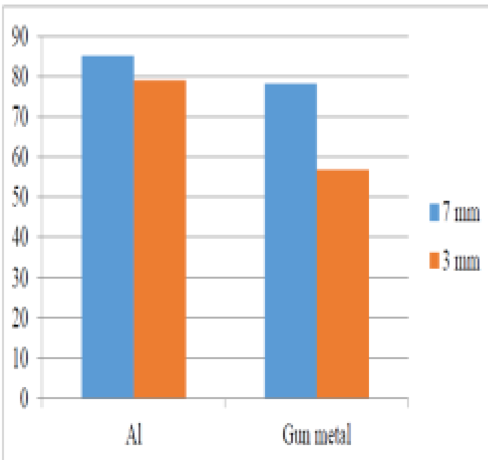

Fig. 3 Bar chart for Actual heat transfer Q_{act}

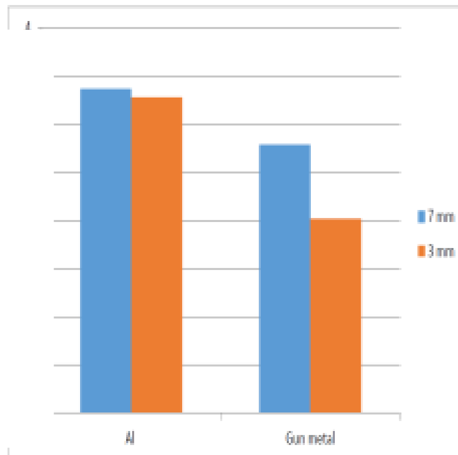

Fig.4 Bar chart for effectiveness

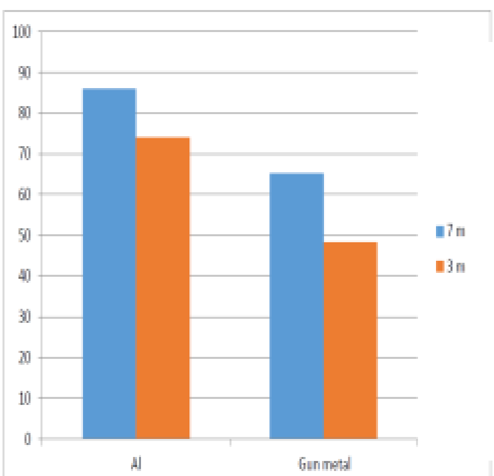

Fig.5 Bar chart for efficiency

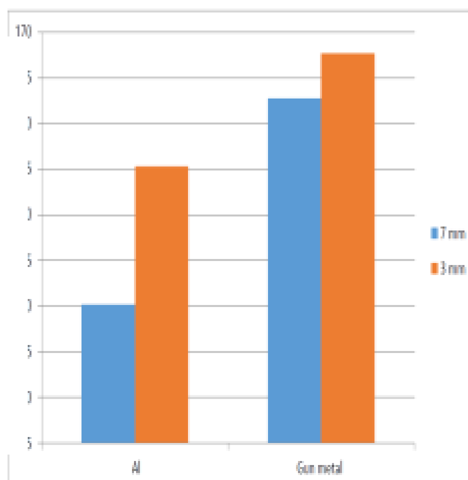

Fig.6 Bar chart for temperature difference $\theta°$

According to the aforementioned experimental findings, fins made of two distinct materials would have varied cross-sectional areas (change in thickness), which will result in the following effects. Al is a great material that, as we all know, offers superior thermal qualities to the other materials. As Al has a conductivity of 265 W/mK, it will transmit heat quickly, which is why an average temperature of about 1400 C has been noted in the observation table. This is brought on by the observation of greater conductivity levels [6]. Additionally since the fins' spline part is one of their unique designs, on which we have experimented. The same toroidal shape of the fin has been taken into consideration in this work while reducing its thickness from 7mm to 3mm. We have found that the typical temperature during experimentation is roughly 155.280C. This rise in average temperature is the result of the 4mm reduction in thickness. We lowered the thickness from 7mm to 3mm based on literature research and expert advice, which has improved heat transfer[7].

We arrived to the conclusion that fins with spline thickness in the range of 3mm to 7mm will provide us with the maximum efficiency by comparing the data such as maximal heat transmission, effectiveness, and efficiency. According to our findings, a fin with a 3mm spline thickness has an effectiveness of 3.28, which is closer to the 7mm thickness of this spline and has an efficiency of 86%. Temperature variations between these two are almost identical, but a fin with a 3mm thickness will carry the most heat at its tip surface [8]. We can increase the number of splines and achieve improved heat transfer qualities by reducing the thickness of the fins on the toroidal shape.

All researchers have conducted studies on Al and Cu kinds, according to a review of the literature. As a result, we have taken into consideration a special substance called gunmetal, which is composed of Cu and Zn and has a lower thermal conductivity and a greater specific heat rate [9]. Similar to the previous trials, we have heated the gunmetal to a temperature of 78 W. The effectiveness of 2.78 resulted in a 66% efficiency, with the average temperature detected being around 162°C. These observations are caused by the zinc presence in gunmetal, a substance that acts as an insulator and provides resistance to the flow of heat [10].

In this experiment, we've reduced the spline's thickness from 7 mm to 3 mm. We noticed the effectiveness of 2.02 with 50% efficiency at an average temperature of 50C in comparison to a 7 mm thickness. Given that gunmetal has a density of 8.72*103 kg/m3, decreasing its cross-sectional area will result in less actual heat transfer and a higher temperature [11]. Through experimentation, we have shown that the efficacy of 2.02 is lower than the effectiveness of 2.78 for splines with a 7 mm thickness. This finding results from the reduced cross-sectional area.

We got to the conclusion that aluminium has a better thermal conductivity value, less specific heat, and a lower density when we compared the two metals. When compared to gunmetal, we can see that it requires more heat to raise the temperature, while aluminium fins transfer heat more quickly because to their greater thermal conductivity value. When compared to aluminium, gunmetal requires more specific heat to raise its temperature and transfer heat energy as a result. In this experimental study, we changed the spline's thickness for both metals from 7mm to 3mm [12].

Observations have shown that the observed temperature differential is most likely caused by the exchange of heat with the atmosphere when the spline's thickness is reduced. This value suggests that the measured temperature difference will rise if the thickness is decreased [13]. Gunmetal has produced similar results, but the temperature difference is just about 80 to 100 degrees Celsius. This is because gunmetal's conductivity has decreased as a result of higher specific heat.

Conclusion

The experimentation with the convection phenomenon was done while taking into account natural convection. Results were seen when the fin's thickness was changed from 7mm to 3mm. We found an efficacy of 3.37 for aluminium with a 7 mm thickness, and a 3.28 for splines with a 3 mm thickness. This variance results from a reduction in thickness, which improves temperature variation. Similar phenomena were seen for gunmetal, and the results are as follows: The value obtained is 2.78 for 7mm thickness and 2.02 for 3mm thickness. In comparison to other metals, aluminium with a 3 mm thickness will have greater heat transfer properties when findings from both the metal and optimisation are observed. These findings are a result of the altered metallic characteristics of aluminium and gunmetal.

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