

Experimental Study on Heat Transfer Through Annular Composite Fins

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Abstract- The present paper focuses on the study of the radial composite fins to increase the heat transfer rate in many applications. By taking the full advantage of the convective heat transfer equation. Fins of same thickness with more than one material rather than the coatings are considered for the steady state thermal analysis is made on those fins and comparison of heat transfer rate is made between the fins of same material and fins of composite material when in bonded contact. The overall heat transfer rate will be increased in composite fins of same surface area than that of same material

Keywords- Annular Composite Fins, Same Material Fins, Composite Fins, Bonded Contact, Overall Heat Transfer Rate.

I. INTRODUCTION

A fin is an extended surface which is used to increase the heat transfer through the body which is of higher temperatures. when the surface area increase heat conduction increases, using this principle fins are used to increase the heat transfer rate from the hot body. A fin is generally made of the single material of high thermal conductivity say aluminum. There are different types of fins available based on the geometry of the fin say Straight, Annular, Longitudinal, Rectangular, Conical, Trapezoidal, Parabolic, Cylindrical (Pins, Splines), Truncated Conical Spline, Triangular Fins etc. however the basic heat transfer in the fins often follow the one basic equation but changes in the surface area and the perimeter. Many conditions can be made out depending upon the length of the fins like long, short etc. The following equation shows the basic equation of the heat transfer rate in the short fins without the tip not insulated.

$$Q = \sqrt{h \cdot P \cdot k \cdot A} \cdot (T_b - T_\infty) \cdot \frac{\left[\frac{\cosh\left[\sqrt{\frac{h \cdot P}{k \cdot A}} \cdot L\right] + \frac{h}{\sqrt{h \cdot P \cdot k \cdot A}}}{1 + \frac{h}{\sqrt{h \cdot P \cdot k \cdot A}}} \right]}{\left[\frac{\cosh\left[\sqrt{\frac{h \cdot P}{k \cdot A}} \cdot L\right]}{\sqrt{h \cdot P \cdot k \cdot A}} \right]} \quad (1)$$

The parameters which change for different materials are 'k' thermal conductivity, 'A' surface area, 'P' PERIMETER, 'L' length of the fin

II. LITERATURE REVIEW

The first approach on the composite material fin through the coating of the materials is made by the S Lalot, C Tournier, M Jensen under the title of "Fin efficiency of annular fin made of two materials" [1]. The computational method of analyzing the Evaluation of the performance of the annular composite fins using ANSYS is made by the Ashish Giri and S.A.K.Jilani which took the basis of the S Lalot methodology [2]. An numerical approach on the efficiency of the composite fins of variable thickness (taper profiles) has been made by the Cristbal Cortes and Luis I.Diez and Antonio Campo [3]. The efficiency of the extended surfaces along with the first formulations of heat transfer was made by the K.A.Gardner [4]

III. METHODOLOGY

The annular composite fins can be defined as the fins made of two different material through the bonded contact. The second material is not a coating instead the whole material is made added to the basic annular fin. The material chosen for this analysis is the high thermal conductivity material like aluminium and steel, brass, with the non metallic material porcelain. The practical way of doing this by making an external case that will form a jacket on to the base geometry

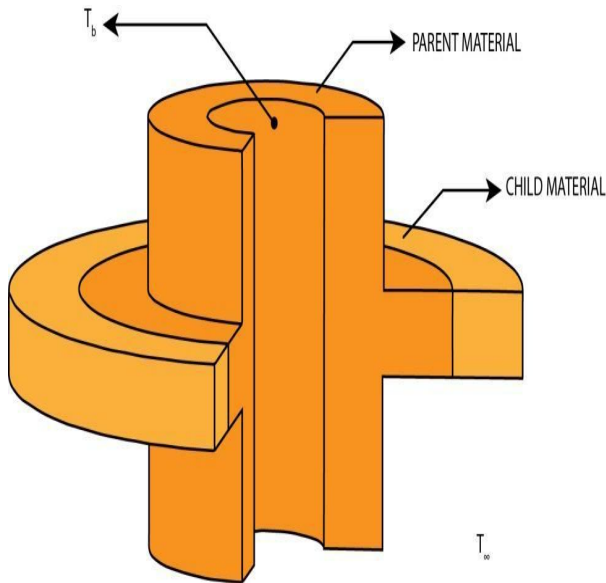


Figure 1 showing the basic geometry of the composite annular fin

The parent material is a base material which is the basic host of the fin. The second material which is called as child material of the same thickness of the base fin. The inner temperature is denoted as T_b and the outer ambient temperature is denoted as T_∞ .

The detail geometric nomenclature of the composite annular material is used for the derivation of the expression is given as follows

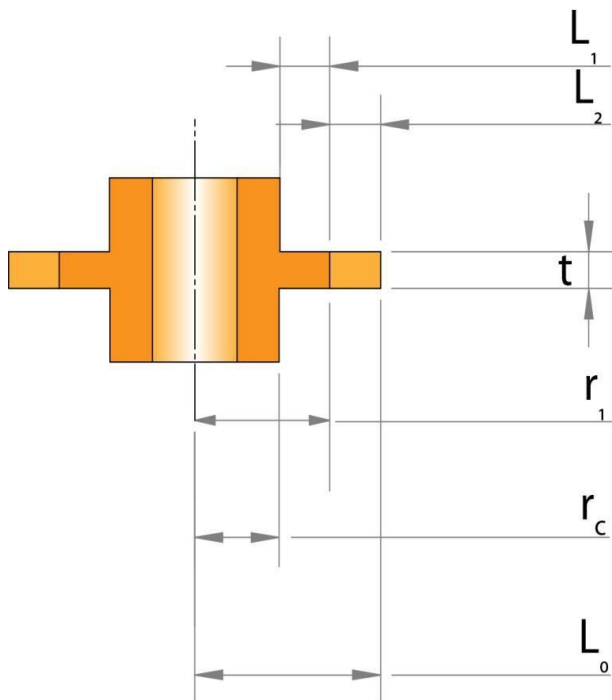


Figure 2 Nomenclature of the composite fin

Where

- L_0 is called as outer radius of the fin.
- r_c is called as the radius of the cylinder.
- t is called as thickness of the fin.
- L_1 is called as length of the parent fin.
- L_2 is called as length of child fin.
- r_1 is the radius of the parent fin.

IV. DERIVATION OF THE HEAT TRANSFER AND TEMPERATURE DISTRIBUTION OF THE COMPOSITE ANNULAR FIN

The following are the abbreviations used in the derivation of the equation.

- K_1 is coefficient of thermal conductivity of parent material
- K_2 is coefficient of thermal conductivity of child material
- P_1 is the perimeter of parent material.
- P_2 is the perimeter of child material.
- h is the convective coefficient of material.
- A_1 is the surface area of the parent fin.
- A_2 is the surface area of the child fin.

Form the equation 1 the following expression can be written as

Form the equation 1 the following expression can be written as

$$\rightarrow Q_{c,f} = Q_{PARENT} + Q_{CHILD} \quad (2)$$

As referred form the equation (1)

$$\rightarrow \left[\frac{\tanh(m_i \cdot L_i) + \frac{h_i}{m_i}}{1 + \frac{h_i}{m_i} \cdot \tanh(m_i \cdot L_i)} \right] = R_i \quad (3)$$

$$\rightarrow \sqrt{h_i \cdot P_i} \cdot k_i \cdot A_i = J_i \quad (4)$$

$$\rightarrow (T_b - T_\infty) = \Delta T \quad (5)$$

$$\rightarrow Q_{c,f} = \Delta T \cdot \sum_{i=1}^n R_i \cdot J_i \quad (6)$$

$$\rightarrow \frac{Q_{c,f}}{\Delta T} = \sum_{i=1}^n R_i \cdot J_i \quad (7)$$

Since there are two materials in this analysis the equation (7) is written as

$$\rightarrow \frac{Q_{c,f}}{\Delta T} = \sum_{i=1}^2 R_i \cdot J_i \quad (8)$$

$$\rightarrow \frac{Q_{c,f}}{\Delta T} = \sum_{i=1}^2 R_i \cdot J_i \quad (9)$$

$$\rightarrow \frac{Q_{c,f}}{\Delta T} = R_1 \cdot J_1 + R_2 \cdot J_2 \quad (10)$$

Where

$$\rightarrow m_i = \sqrt{\frac{h_i \cdot P_i}{k_i \cdot A_i}} \quad (11)$$

$$A_i = 2 \cdot \pi \cdot (r_i \cdot t + r_i^2 - r_0^2) \quad (12)$$

$$A_i = 2 \cdot \pi \cdot (r_i \cdot t + L_i^2 - r_0^2) \quad (13)$$

$$P_i = 2 \cdot \pi \cdot r_i \quad (14)$$

$$P_2 = 2 \cdot \pi \cdot L_0 \quad (15)$$

A. TEMPERATURE DISTRIBUTION EQUATION OF THE COMPOSITE FIN

$$\frac{\cosh(m_i(L_i - X)) + C_i \cdot \sinh(m_i(L_i - X))}{\cosh(m_i \cdot L_i) + C_i \cdot \sinh(m_i \cdot L_i)} = U_i \quad (16)$$

From the equation 16 the temperature distribution can be written as

$$\frac{T - T_\infty}{T - T_\infty} = \sum U_i \quad (17)$$

b. EFFICIENCY OF THE COMPOSITE ANNULAR FIN

$$\rightarrow \eta_{c,f} = \frac{Q_{c,f}}{Q} \quad (19)$$

$$\rightarrow \eta_{c,f} = \frac{Q_{c,f}}{\Delta T \cdot h \cdot (P_1 \cdot l_1 + P_2 \cdot l_2)} \quad (20)$$

By substiting the equation (6) in equation (20) we can write as

$$\rightarrow P_i \cdot l_i = G_i \quad (21)$$

$$\rightarrow \eta_{c,f} = \frac{1}{h_{i+1}} \left[\frac{R_i \cdot J_i}{G_i} \right] \quad (22)$$

$$\rightarrow \eta_{c,f} = \frac{1}{h_{i+1}} \left[\frac{R_i \cdot J_i}{G_i} \right] \quad (23)$$

For stagnant air of simplified case h is 5W/m⁰C then

$$\rightarrow \eta_{c,f} = \frac{1}{5_{i+1}} \left[\frac{R_i \cdot J_i}{G_i} \right] \quad (24)$$

V. FEA OF THE ANNULAR COMPOSITE FIN'S

The finite element analysis is carried for the validation of the composite fins and the procedure is carried in ANSYS 12.1 student's version and the steady state thermal module is used.

The following is the CAD model of the annular composite fins

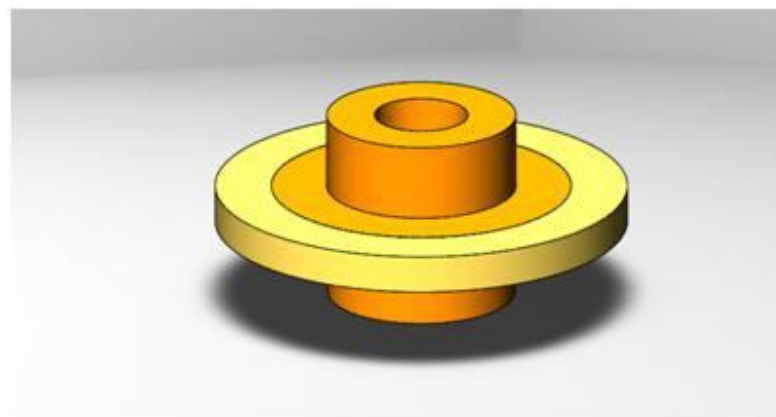


Figure 3 3D CAD model of the annular composite fin

The materials are applied to the CAD model in two ways with same material is applied to whole geometry first

and then the following material pairing are applied and the analysis is conducted.

The dimensions used to model the composite annular fins is as follows

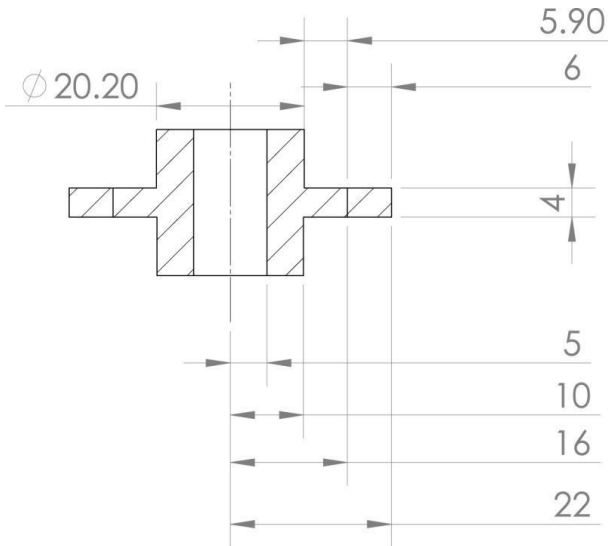


Figure 4 The dimensions of the composite annular fin

Meshing is made by the refinement of 2 in order to capture the high curvatures around the fin geometry and the triangular method is used to patch up the body. The total number of the nodes are 23816 and total number of the elements are 11806

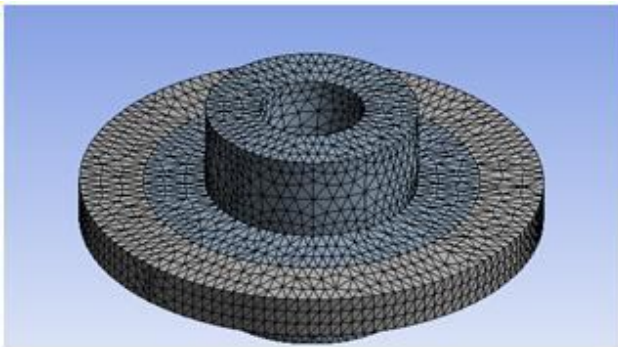


Figure 5 The mesh model of the composite annular fin

VII. BOUNDARY CONDITIONS

The boundary conditions are applied for the analysis with Temperatures of 50° is applied on the inner surface of the cylinder and rest of the body is made to expose to environment so convective heat transfer take place so stagnate air of simplified case is applied on the all other surfaces. The ambient temperatures are 25°C is applied

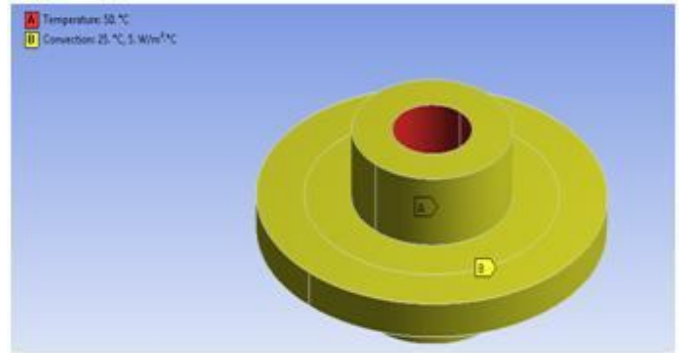


Figure 6 The boundary conditions of the Analysis

VII. REULTS AND DISCUSSIONS

The analysis is made to run for 1s and the following results are obtained. The following are the result’s obtained and the following table brief up the analysis with respect to attribute.

Attribute	Image
A	
B	
C	

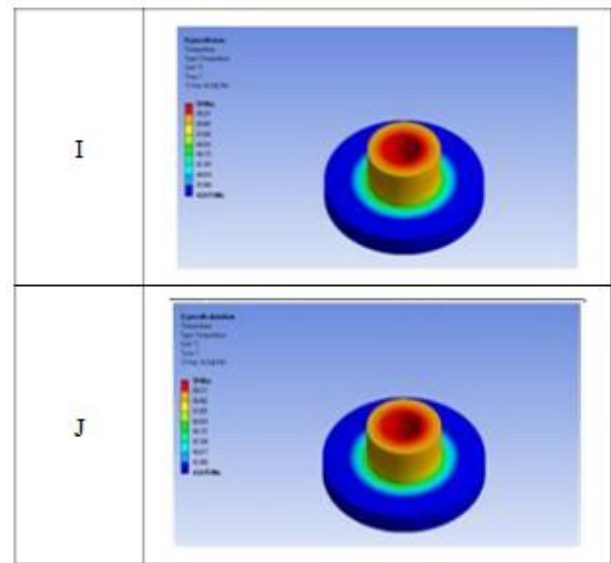
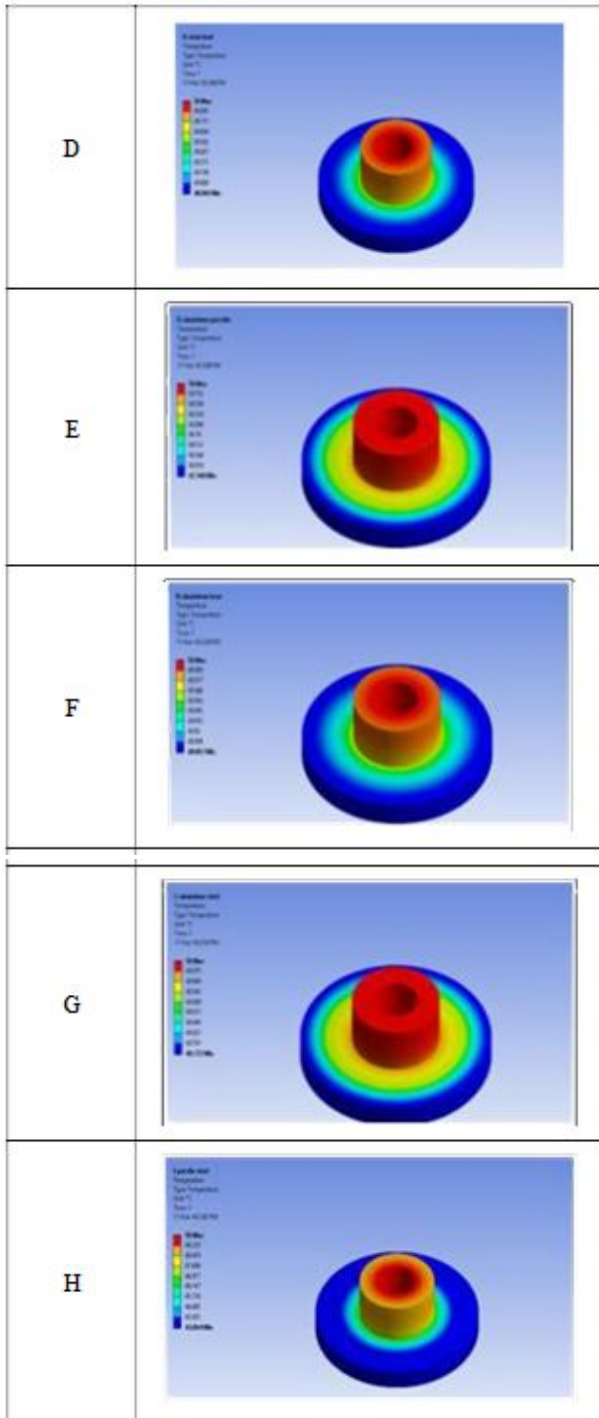


Table 1 Temperature distribution of the composite annular fin at different attribute

Parent material	Child material	Attribute
Aluminum	Aluminum	A
Brass	Brass	B
Porcelain	porcelain	C
Steel	Steel	D
Aluminum	Porcelain	E
Aluminum	Brass	F
Aluminum	Steel	G
Porcelain	Steel	H
Porcelain	Brass	I
Porcelain	Aluminum	J

The following plot gives the minimum and temperatures with respect to the attribute.

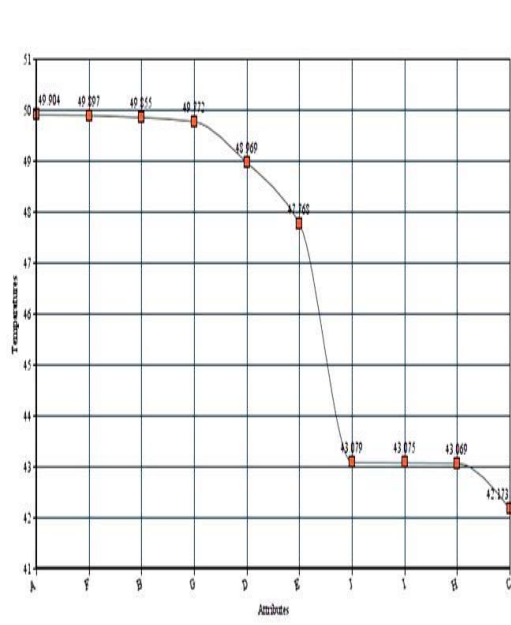


Figure 7 the minimum temperatures of the sorted attributes

VIII. CONCLUSION

The above study infer that the usage of the metallic annular fins has shown no significant change in the heat transfer. But the implementation of the non-metallic materials with the metallic has given the significant results in the heat transfer and another improvement in the heat transfer is made by using the total nonmetallic materials in the fins has given a profound and large change in the heat transfer, though the manufacturing of this kind of fins is easy with the castings and the composite material based fins can also be made with the slurry based casting technique and by making a jacket

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