COMPARISON OF HEAT TRANSFERRING FINS OF CONVENTIONAL ALUMINIUM AND METAL MATRIX COMPOSITES

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ABSTRACT

The main objective of this study is to analyse heat transferring fins of Aluminium Silicon Carbide and 1060 Alloy of Aluminium including comparison of heat transferring capabilities and stiffness of heat transferring fins using Solidworks,[¹] modelling and Solidworks analysis software. Aluminium Silicon Carbide is a metal matrix composite (Composite material) and 1060 alloy is a conventionally used fin material. Composite material is nowadays good alternative for conventionally used Aluminium alloy and many manufacturing units are moving towards it due to high stiffness of fins as compared to conventional alloy with similar heat transfer rate and marginal change in weight of structures. Fins are compared by static analysis and thermal analysis in a particular boundary condition.

KEYWORDS

Solid Works, FEM.

INTRODUCTION

The heat transferring fins plays a vital role as heat sink in various equipment and machines. Fins increases surface area for increased heat dissipation to system or surrounding. It has a particular shape of geometry. Fins experience thermal loads from source and even some time static loads from external sources at time of cleaning or during finishing. The design and development of fins has always been a challenging task for weight, shape and design consideration. These improvements result in lighter parts with better heat transferring rate. This comparison was conducted on a rectangular pin fin with one side as a source of heat and also fixed onto that side of fin. Two different materials are analysed in same model and their results are compared. The heat transferring fins are modelled in Solidworks and analysed in Solidworks software developed by Dassault systems. This is CAD/CAM/CAE software, but we are using it for 3-D modelling and analysis with finite element analysis.[²]

1.1 Objective of Comparison

The fin producers are showing much interest in replacement of conventional Aluminium fin to Aluminium Silicon Carbide fin due to high stiffness without compromise in heat rejection capabilities and small margin in weight change. Therefore; this project aims at comparative study of thermal and static analysis of fin using Solidworks modelling and Solidworks analysis software.

II OVERVIEW OF FIN

2.1 Fin Definition

A fin,[³] is a heat sink used to transfer heat from source to surrounding.

Geometrically, it is an elongated part of any fixed geometry connected to source by one or more than one face. It transfers heat by convection process. Mainly, a fin increases surface area of heat convection causing increased rate of heat transfer.

2.2 Classification of Fin

Fins are classified on the basis of their geometry and their cross-section. It may be a pin fin, longitudinal fin or radial fin.

2.2.1 Pin Fin

Pin fins are almost in shape of pins and considered mainly as a cylindrical structure. Length to diameter ratio is mostly higher than 3:1. These pin fins are mounted perpendicular to the base and mostly used in areas of extreme cooling and rapid heat spreading. Sometimes pins are also splayed on the base.

2.2.2 Longitudinal Fins

Longitudinal fins are mainly rectangular or trapezoidal in shape extensively used in heat transferring process. Stiffness of longitudinal fins is much higher than pin fins.

2.2.3 Radial Fins

Radial fins have radius in their cross section such as flat spherical in shape with rectangular profile, trapezoidal profile or hyperbolic profile.

III BASICS OF FINITE ELEMENT ANALYSIS

3.1 Introduction to F.E.A.

The finite element analysis method is used from centuries. The principle behind this method is to simplify the problem and provide approximate solutions. A body has infinite elements, these infinite elements are made finite in a particular boundary condition. These elements are connected at nodal points which form continuous and finite formulation. The stiffness matrix of the individual element is calculated. The parameters are distributed to real structures at elements and are acted as real structure for analysis. Various stiffness matrix are assembled to provide a definite solution acting as a whole body. In this way, the finite elements are given dimensions and properties.
The Problem is Analysed in Two Ways
1. The element generation.
2. The system generation.

The first stage involves the derivation of the element stiffness matrix. The next stage is the formulation of stiffness and load of the entire structure.

Static Analysis
Static analysis includes fixed load condition eliminating inertia and damping properties likewise time varying loads. Static analysis is used to calculate the stress, strains, stiffness, deflection and reaction forces in structures caused by loads or parameters that do not cause significant inertia and damping effects. Steady loading and response conditions or loads and structures response are assumed to vary in slower rate. This includes external applied forces and pressure.

Thermal Analysis
In thermal analysis,[4] the model is provided boundary condition related to given surrounding. Certain parameters related to temperature, conduction and convection is given to the body and temperature variation with thermal stresses are obtained.

IV STATIC ANALYSIS OF FIN
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4.1 Steps Involved in Analysis with SolidWorks
1. Select new study from simulation[5] feature of Solidworks under model to be analysed.
2. Select a study from menu.
3. Provide boundary conditions such as room temperature.
4. Apply loads to the model such as temperature, loads and dynamic properties.
5. Provide element geometry as required and mesh required.

MESH STATICS
Mesh Quality: Fine.
Mesh Tool: Solid works meshing tool.
Type of Element: Tetrahedrons.
Number of Nodes: 23450.
Number of Elements: 13870.

BOUNDARY CONDITIONS:
Load: 100Newton.
Ambient Temperature: 298 Kelvin.
Material-1: 1060 Alloy.
Material-2: AlSiC.

Type of Analysis: Static.
Fig. 4.1.1: Loads and fixtures shows the fixture at inside face and load applied to upper face.
Fig. 4.1.2: Mesh details shows mesh geometry (tetrahedral) and their layout in model.

Fig. 4.1.1: Loads and Fixtures.
Fig. 4.1.2: Mesh Details.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young's Modulus (E)</td>
<td>6.9E+010 N/M^2</td>
</tr>
<tr>
<td>Shear Modulus (G)</td>
<td>2.7E+010 N/M^2</td>
</tr>
<tr>
<td>Poisson's Ratio (μ)</td>
<td>0.33</td>
</tr>
<tr>
<td>Density (ILLISECONDS)</td>
<td>27 00 KG/M^3</td>
</tr>
</tbody>
</table>

Table 4.2 Material-1 Details (Static)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young's Modulus (E)</td>
<td>1.92e+011 N/m^2</td>
</tr>
<tr>
<td>Shear Modulus (G)</td>
<td>7.7e+010 N/m^2</td>
</tr>
<tr>
<td>Poisson's Ratio (μ)</td>
<td>0.242</td>
</tr>
<tr>
<td>Density (.MILLISECONDS)</td>
<td>30 10 kg/m^3</td>
</tr>
</tbody>
</table>

Table 4.3: Material-2 Details (Static)

4.4 Results of Structural Analysis of both Materials
Fig. 5.4.1: Stress plot for material-1 and Fig.5.4.3: Stress plot for material-2 represents stress plot of respected materials in different colour shades as provided in index.

Fig. 5.4.2: Displacement plot for material-1 and Fig.5.4.4: Displacement plot for material-2 represents deflection of respected fins in different colour shades as provided in index.
V THERMAL ANALYSIS OF FIN

5.1 Boundary Conditions:
Convective coefficient of air- 200 w/m²K
Ambient temperature- 300 kelvin.
Source temperature- 373 kelvin.
Material-1: 1060 Alloy.
Material-2: AlSiC.
Type of thermal analysis: Steady state.

Fig. 5.1.1: Thermal loads represents green coloured areas as for convection[7] in all faces and blue fixtures in inner side for temperature source.

Table 5.2: Material-1 Details (Thermal)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Conductivity</td>
<td>200 W/(m²K)</td>
</tr>
<tr>
<td>Specific Heat</td>
<td>900 J/(kgK)</td>
</tr>
<tr>
<td>Mass Density</td>
<td>2700 kg/m³</td>
</tr>
</tbody>
</table>

Table 5.3: Material-2 Details (Thermal)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Conductivity</td>
<td>170 W/(m²K)</td>
</tr>
<tr>
<td>Specific Heat</td>
<td>714 J/(kgK)</td>
</tr>
<tr>
<td>Mass Density</td>
<td>3010 kg/m³</td>
</tr>
</tbody>
</table>
5.4 Results of Thermal Analysis of both Materials

Fig.5.4.1: Temperature distribution for material-1 and Fig.5.4.2: Temperature distribution for material-2 represents temperature distribution (10) form source of temperature to end of fin in different colour shades provided as in index.

<table>
<thead>
<tr>
<th>Material</th>
<th>Maximum Temperature</th>
<th>Minimum Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 1060 alloy</td>
<td>373 kelvin</td>
<td>333.498 kelvin</td>
</tr>
<tr>
<td>(2) AlSiC</td>
<td>373 kelvin</td>
<td>330.021 kelvin (Uncertain value due to lesser number of nodes analysed)</td>
</tr>
</tbody>
</table>

Table 5.4: Results of Thermal Analysis of both Materials

VI RESULTS AND CONCLUSION

6.1 RESULTS

Heat transferring fin composed of composite material i.e. Aluminium Silicon Carbide (AlSiC) is approximately 3 times stiffer than conventionally used Aluminium alloy (1060 Alloy), although heat rejection rate is approximately same for both conventional alloy and composite material fin. Weight difference between both materials is very small.

6.2 CONCLUSION

From this comparison and analysis, we come to the conclusion that metal matrix composite Aluminium Silicon Carbide (AlSiC) is approximately 3 times much stiffer than conventionally used Aluminium alloy (1060 Alloy), no considerable change in heat rejection capability for both materials is found. There is a marginal weight increase in AlSiC as compared to 1060 alloy. For higher stiffness of fin with lighter weight is certainly an advantage for material optimisation in industries and organisations. Thus, metal matrix composite is a better alternative for conventional Aluminium alloy fin with good bending stiffness.

VII REFERENCES