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Heat Transfer Analysis by CFD on Different Shapes of Fins and Experimental Validation

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***Abstract*: The main aim of the project is to analyze the thermal heat dissipation of fins by varying its geometry. Parametric models of fins have been developed to predict the transient thermal behavior. There after models are created by varying the geometry such as square, pin fin(circular), pentagon, hexagon, octagon, decagon, dodecagon and fins with extension. The modeling software used is ANSYS design modeler. The analysis is done using ANSYS fluent18.0. Presently Material used for manufacturing fin body is generally Aluminium Alloy 6063 which has thermal conductivity of 201.218W/Mk. We are analyzing the fins using material Aluminium Alloy 6063 which has higher thermal conductivity of about 201.218W/Mk. After determining the material, the third step is to increase the heat transfer rate of the system by varying geometrical parameters with constant surface area.**

***Keywords*: Mechanical device, parameters and geometry**

1. Introduction

A fin is a type of heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature at optimal levels. The problem arises when the heat transferred by these fins are not sufficient enough to cool the heat generating devices and causes damage to the components of the device. The basic solution available is that the shape of fins can be optimized such that the heat transfer density is maximum when the space and the materials used for the finned surfaces are constraints.

Aim & Objective: The main aim of the project is to analyse heat transfer analysis and optimization of fins by variation in geometry. The main objective of the project is to increase the heat transfer rate of fin which could be achieved by modifying certain parameters and geometry of the same.

2. Literature review

S. H. Barhatte, 2011, in this paper natural convection heat transfer from vertical rectangular fin arrays with and without notch and fins with triangular notch have been investigated experimentally and theoretically. It was observed that heat transfer coefficient and in turn the rate of heat transfer can further be increased by increasing the surrounding fluid velocity i.e. by forced convection. It is also observed that heat transfer coefficient is highest for the set of fins with triangular notch. Results has been shown by the CFD as well as experimental analysis in table 1 and table 2.

G. Raju, 2012, in this paper maximization of heat transfer thorough fins arrays of an internal combustion engine cylinder have been investigated, under one dimensional, steady state conduction and free convection modes. In this study, binary coded generic algorithm technique is used to obtain maximum heat transfer and corresponding optimum dimensions of rectangular and triangular profile fin array. This study also includes the effect of spacing between fins on various parameters like total surface area, heat transfer coefficient and total heat transfer.

Heat transfer through triangular fin array per unit mass is more than that of heat transfer through rectangular fin array. Therefore, the triangular fins are preferred for automobiles, central processing units, aero-planes, space vehicles etc. where,

Table 1
HTC for different notches at base temp of 60^0C

S. No	W/O Notch	Rectangular	Circular	Triangular	Trapezoidal
1.	6.235	6.039	6.114	6.29	6.0983
2.	6.1788	6.0707	6.1893	6.291	6.112
3.	6.2152	6.0482	6.2281	6.2785	6.1065
4.	6.2306	6.0762	6.2152	6.3057	6.1038
5.	6.2958	6.1524	6.1971	6.2934	6.0818
Avg.	6.23122	6.07746	6.18882	6.29172	6.1004

Table 2
Comparison of HTC by CFD and HTC by experiment

Base temperature (At 60^0C)	W/O Notch	Rectangular	Circular	Triangular	Trapezoidal
CFD	5.3434	6.039	5.31779	7.03509	7.0260
Experimental	6.231	6.07	6.18882	6.29172	6.1001

weight is the main criteria. At wider spacing, shorter fins are more preferred than longer fins. The aspect ratio for an optimized fin array is more than that of a single fin for both rectangular and triangular profiles

3. Material selection

We began our project by taking a reference fin. The fin is taken from an Amplifier used in sound instruments. The analysis is done by ansys CFD. The test results were compared with the standard values of the properties of Aluminium Alloy tables. The tested composition revelled the fin material to be aluminium alloy 6063.

Mechanical Properties: The standard values mechanical and thermal properties of Aluminium Alloy 6063 are taken from International Alloy Designations and Chemical Composition Limits for Wrought Aluminium and Wrought Aluminium Alloys. The values of various properties are found to be

- Tensile strength: 145-186MPa (21.0-27.0ksi)
- Specific heat capacity: 900 J/kg*K
- Density: 2.69 g/cm^3
- Melting temperature: 615^{0}C
- Thermal conductivity: 201-218 W/m*K
- Linear thermal expansion coefficient: 2.34*10^{-5}K^{-1}
- Young's modulus: 68.3 GPa (9,910 ksi)

4. Calculations

A. Grashoff Number (Gr)

$Gr = g\beta(Ts-T\infty)\ L^3/\ v^2$

We have,

g = 9.81 m/s^2

L = 0.02 m

TS - T∞ = 10.34 ^{0}C

TS = 30^{0}C

T∞ = 37^{0}C

C = 1.601*10-5 m^2/s

Substituting all the above values in the above formula We get,

Gr =307268.002

B. Prandtl Number (Pr)

$Pr = c_p\mu/k$

We have, Properties of dry air at atmospheric pressure and temperature as:

ρ = 1.1644 kg/m

μ = 18.65*10 $^{-6}$ kg/m-s

k = 26.38*10^{-6} W/m ^{0}C

c p =1.0064 kJ/kg ^{0}C

Substituting all the above values in the above formula we get,

Pr = 0.932

C. Rayleigh Number (Ra)

Ra = Gr∗Pr,

We have,

Gr = 307268.002

Pr = 0.932

Substituting all the above values in the above formula We get,

Ra = 2.86*10^5

D. Nusselt Number (Nu)

Nu = 0.59 * (Ra)0.25

The above formula for 'Nu' is applicable for 'Ra' lying in between 10.4to 10.9

We have,

Ra = 2.38*10^5

Substituting the value of Ra in the above formula We get,

Nu = 13.644

E. Convective heat transfer coefficient (h)

h = k∗Nu/L

We have,

Nu = 13.644

k = 26.38*10^{-3} W/m-ºC

L = 0.02 m

Substituting the above values, we get,

h = 17.996 W/ºC-m^2

A. Heat dissipated (Q_{fin})

Qin=√hPkAc∗(Ts−T∞)∗tanh(ml) +h/km+1+h/km tanh(ml)

The above formula is applicable for a fin of finite length and uninsulated tip.

5. Analysis

After creating the 3D model in solid works, we imported the part file in ANSYS for the CFD analysis. We began our analysis by defining the material from material library and its properties and the various constant such as convective heat transfer coefficient of the system. Next step was to define the base temperature of the fin and the ambient temperature. The solution then generated by the ANSYS gave the total temperature drop and the temperature gradient over the fins by CFD. The various solutions generated for the various shape fins are

A. Circular fin at 36ºC

In the very first analysis, the base of the reference fin is kept at 36ºC and the ambient temperature is taken as 27ºC. The solution generated by the ANSYS fluent for the above boundary conditions is depicted below. The overall temperature drop between the fin base and tip is found to be.

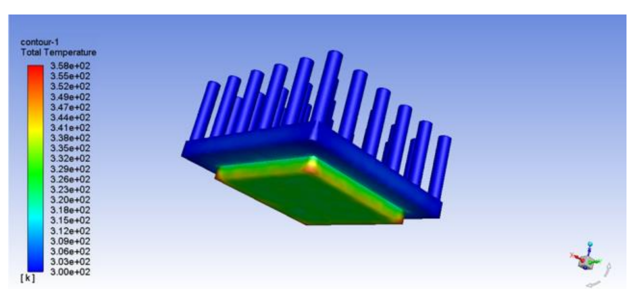

Fig. 1. Circular fin at 36ºC

B. Future scope

- The purpose of this project is to take a step towards a complete analysis of the heat dissipation through fins. Ideally it should prevent overheating for all its applications.

- A gap is seen in the present scenario of fins heat dissipation. The gap is seen for more cases; such as fins with extension during the run of the project.
- Currently the complete analysis of fins is based on a micro level. The fin being analyzed here are of an Amplifier of a sound system.
- The results obtained after the completion of this project, can be generalized and can be applied for various large-scale applications such as fins for IC Engines, which can help in considerable increase in the its efficiency and life.

6. Conclusion

This paper presented the implementation of heat transfer analysis by CFD on different shapes of fins and experimental validation.

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