International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 6 (2018) pp. 354-357

Experimental Investigation of temperature in Fins

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Abstract

This experimental study is based on an investigation of temperature field inside the fin and analyzing with the use of finite element method. The whole experiment involves selection of appropriate materials and the geometries to get the best possible results. The main emphasis of the present work was to find out the best suitable geometry for the fins. Afterwards materials selected for the experiment by carefully reviewing the literature reviews. After the selection of material and geometries, fabrication is carried out. The fabricated models are mounted on a base plate and are heated by the use of heaters for a certain period of time. The temperature is then noted down at various points with the help of an infrared gun and the best geometry and the material for fins is found out. Afterwards, validate with simulated result based on extensive study of thermodynamic model and transient heat transfer analysis in an internal combustion engine. The geometry which was found out to be the most suitable was the rectangular geometry as the heat dissipation from the rectangular geometry is the most. And material which was found out to be the most suitable was copper as the heat dissipation from copper was higher than any other material. But due to various constraints with copper, aluminum can be used as a substitute material as the heat transfer rate differs only by a small amount.

Keywords: thermal analysis, fins, FEM.

Introduction

In recent years there has been great demand for high performance, lightweight, compact, and economical heat transfer components. The fins are recognized as one of the most effective means of increasing the heat dissipation. Fins can be used to achieve most effective heat transfer enhancement. Fins, as element of heat surface area extension, are extensions on exterior surfaces of objects that increase the rate of heat transfer to or from the object. This is attained by increasing the exterior surface area of the body, which in turn raises the rate of heat transfer by a sufficient degree. This is an effective way to raise the rate of heat transfer, as another way of doing so is by increasing either by the increases the heat transfer coefficient (which is constant and depends on the materials being used and the state of use) or else the temperature gradient (which depends on the surroundings of use). Clearly, changing the profile of the bodies is more suitable.

Preferably high thermal conductivity fin material should be used for particular application. In most applications the fin is surrounded by a fluid (liquid/gas) in motion, which cools or heats the fin quickly due to the large surface area, and consequently the heat gets transferred to or from the body rapidly due to the high thermal conductivity of the fin. For optimum heat transfer performance with minimal cost, the dimensions and shape of the fin have to be calculated for specific applications, and this is called design of experiment (DOE) of a fin. A conventional way of doing so is by creating a model of the fin and then simulating it under mandatory service conditions. These surfaces have been used to increase heat transfer rate by adding additional surface area and encouraging mixing. When number of fins are used to enhance heat transfer under natural convection conditions the optimum geometry of fins (corresponding to a maximum rate of heat transfer) should be used, provided this is compatible with available space and financial limitations. Fins are used to enhance convective heat transfer in a wide range of engineering applications and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface.

Literature review

In numerous designing applications huge amount of heat needed to be dissipated from small areas. The fins increase the effective surface area thereby increasing the heat transfer rate by convection and radiation. Rectangular fin and triangular fins are in the category of straight fins. Triangular fins are more suitable and attractive, since for an equal amount of heat transfer dissipation it requires much less volume than the rectangular fin.

Hence the fins have real-world importance because it provides maximum heat flow rate per unit mass with ease of manufacture. Generally in an air-cooled engine either there is forced and natural, rectangular and triangular fins are used on the periphery of engine cylinder body. Numerous efforts have been done to analyze the effect of fins and its efficiency.

In the study [1] authors design an experimental setup and investigation of the outcomes got over arrange of, fin heights, geometry and heat dissipation rate. Endeavors are made to build up an examination between the exploratory outcomes and results acquired by utilizing CFD programming. Efforts are made to establish a comparison between the experimental results and results obtained by using CFD software. No. of test will carried out [2, 3] on mixed convection heat transfer from plate fin heat sinks subject to the influence of heat flux and its geometry. A total of 40 fins were fixed up into the upper surface of the base plate. And the area of the base plate is 120 X 120 mm^2. In the design experiment, aluminum is used to make base plate and the fins. For all tested plate fin heat sinks, however, the heat transfer performance for heat sinks with plate fins was better than that of solid pins. The main controlling variable is geometry of fin arrays, which generally designers prefer in their study. Considering all the fact which are listed above, natural convection heat transfer from vertical rectangular fin arrays with/ without notch at the center have been analyzed experimentally and theoretically. Additionally notches of different geometrical shapes have also been investigated for the motive of optimization and comparison [3]. Heat transfer investigation is carried out by placing rectangular and then triangular fins [4]. This investigation is carried out by raising temperatures on the surface of the cylinder from 200 ºC to 600ºC and increasing the length from 6 cm to 14 cm. Input parameters such as heat transfer coefficient, density, thickness and thermal conductivity of fin are taken and output parameters such as rate of heat flow, efficiency, heat flow per unit mass, and effectiveness are determined apart from this comparisons are also represented with rectangular fins. Thermal analysis is carried out using Aluminum 5052 for two stroke S.I engine [5]. from all the results obtained, authors conclude that the circular profiled fin with Al 5052 material gives the better efficiency and better life with better cooling efficiency for the single cylindrical two stroke S.I engine. A numerical modeling has been developed [6] by taking an enclosure, which is formed by two adjacent vertical fins and horizontal base. Results obtained from this enclosure are used to forecast heat transfer rate from the fin array. All the governing equations used in mathematical modeling are related to fluid in the enclosure, together with the heat conduction equation in both the fins are solved by using alternate direct implicit technique. Afterwards numerical results were obtained for temperature along the length of the fin and in the fluid in the enclosure. Similarly, in the connection of improved fin efficiency, authors [7] present a best possible Heat Sink for efficient cooling of electronic devices. The choice of an optimal heat sink depends on a number of geometric parameters such as fin height, fin length, fin thickness, number of fins, base plate thickness, space between fins, fin shape or profile, material etc. Therefore for an optimal heat sink design, fluid flow and heat transfer characteristics of standard continuous heat sinks of different designs have been carried through CFD simulations. It is noted from the results that optimum cooling is achieved by the heat sink design which contains interrupted fins with holes. These heat sink designs promises to keep electronic circuits cooler than standard heat sinks and reduction in cost due to reduction in material. An experimental study was performed to study the pressure loss characteristics and heat transfer rate in a horizontal rectangular wind tunnel having attachment of cylindrical, grooved cylindrical and perforated pin fins over a horizontal based pin fin assembly [8]. An experimental examination of pin-fin heat sinks have circular, square and diamond cross sections [9] have been done which ensemble of pin-fin heat sinks with in-line and staggered arrangements were designed and tested. The fin density effect on heat transfer and friction characteristics is examined and analyzed. With the help of the experimental setup made under different heat input conditions the temperature variations along the length of the fin is measured [10]. The methods available to analyze the heat transfer through variable cross section fin viz. analytical, numerical graphical and solutions that can be obtained with the existing packages are compared with the readings taken from the experimental setup. The main purpose of using these cooling fins is to cool the engine cylinder by air [11]. Presently Material used for manufacturing cylinder fin body is Cast Iron. In this thesis, using materials Copper and Aluminum alloy 6082 are also analyzed. Thermal analysis is done using all the three materials by changing geometries, distance between the fins and thickness of the fins for the actual model of the cylinder fin body. Authors [12, 19] investigated the problem of cross-flow forced convection heat transfer from a horizontal cylinder with multiple, equally spaced, high conductivity permeable fins on its outer surface numerically. In the same way, the heat transfer from cylinder to air of a two-stroke internal combustion finned engine was simulated [13]. The cylinder body, cylinder head (both provided with fins), and piston have been numerically analyzed and optimized in order to minimize engine dimensions. The computational fluid dynamic simulations were carried out [14] on a 2-dimensional computational domain bounded by planes of symmetry parallel to the flow. The air approach velocity was in the range of 0.5m/s to 5m/s. the staggered plate fin geometry showed the highest heat transfer for a given combination of pressure gradient and flow rate. Geometric parameters of fin affects on the performance of fins, so proper selection of geometric parameter such as height of fin, length of fin, spacing between the fins and depth of notch is needed [15].

The finite difference method in conjunction with the least-squares scheme and experimental temperature data is used to predict the average heat transfer coefficient and fin efficiency on the fin of annular-finned tube heat exchangers in natural convection for various fin spacing [16]. Heat transfer rate and efficiency were investigated for circular and elliptical annular fins for different environmental conditions [17]. After investigation it was found that elliptical fin efficiency is more than circular fin. Computational fluid dynamic analysis and experimental analysis were conducted on elliptical fins for heat transfer parameters such as heat transfer coefficient and tube efficiency by forced convection [18, 19]. The experiment is conducted for different air flow rate with varying heat input. After a brief review of the basic methods used to enhance the heat transfer surface area as well as the heat transfer coefficient, a simple experimental method is used to assess the heat transfer phenomena in the fins of different geometries. The method is demonstrated on plate fins as elements for the heat transfer enhancement, but it can in principle be applied also to other fin forms. That is varying various parameters (height, spacing).

Methodology

The first objective of the work was to find out the best suitable geometry for the fins. There were three main geometries that were chosen after reading various research papers and these geometries are rectangular, triangular and trapezoidal. Now, after the selection of suitable geometries their fabrication had to be done so before that perform calculations for the dimensions of fins. The calculations could have been done by making fins of constant surface are through which the heat gets dissipated from the fin. After finding out the fins, the fabrication of fins is done. The materials selected for the experiment by carefully reviewing the literature reviews are - mild steel, copper, brass and

aluminum. The fabrication of the selected geometries is done on these selected materials according to the calculations.
The fabricated materials are then mounted on a mild steel plate with the help of welding. The welding procedure used is MIG (Metal Inert Gas Welding). The mild steel plate containing the fins is then mounted on a heater and allowed to heat for a period of 10 to 15 minutes so that a stale temperature can be recorded on the base plate i.e. mild steel plate everywhere. The temperature of the base plate is then measure with the help of an infrared gun. Then, the temperature of the fins is measured. Three marks are made on the fins at a distance of 3 cm each. The infrared gun is then pointed on the marks and it shows the temperature (T_1, T_2 and T_3 respectively on the marking point) of the fins which is recorded. This procedure is done for all the fin geometries. After noting down the temperature of each mark on the fin the best suitable geometry is found out.

Figure 1: Shapes of fabricated fins

Afterwards another experiment had to be done to find out the best suitable material for the fins.
There were four main materials that were chosen after reading various research papers and these materials are- Aluminum, Brass, Copper and Mild Steel. After the selection of suitable materials their fabrication had to be done. The fins were fabricated using the same dimensions that were used in geometry related study.

Table 1: General properties of used fin materials

Materials	Thermal Conductivity (W/m °C)		
	At 25°C	At 125 °C	At 225 °C
Copper	401	400	398
Aluminium	250	255	250
Brass	111	115	128
Mild Steel	54	51	47

Results
The geometry that came out to be the best from experiment was triangular. Thus, all the materials are fabricated in triangular shape to find out the maximum possible heat dissipation form the various materials. Table 2 containing the various temperatures found during the experiment.

Table 2: Temperature at different heights for different geometries

Temp. (°C)	Geometries		
	Rectangular	Trapezoidal	Triangular
T_1	165	165	177
T_2	90	120	135
T_3	45	80	35

The best material that was found out was Copper as temperature indicated in Table 3. However, this result was known to us from the research paper. Since the cost of copper is high it is not used as a material in fins and thus we had to find out the second best material for the fins. The second best material that was found for the fin was aluminum. Aluminum as low density and thus has a low mass and thus the weight and cost of aluminum is quite less on comparison with copper and thus aluminum is the most preferred material for the manufacturing of fins. Copper is also used as a material for fins where weight and cost is not an issue.

Table 3: Temperature at the source, middle and the tip of the fins

Temp. (°C)	Materials			
	Aluminium	Brass	Copper	Mild Steel
T_1	270	240	275	210
T_2	170	135	175	125
T_3	50	35	60	40

Conclusion

Most Suitable Geometry:
The geometry which was found out to be the most suitable was the triangular geometry as the heat dissipation from the triangular geometry is the most which is also verified by the calculations and the literature review done on the basis of the experiment. Thus, triangular geometry should be used for the manufacturing of fins.

Most Suitable Material:
The material which was found out to be the most suitable was copper as the heat dissipation from copper was higher than any other material. The result is also verified by the calculations done on the basis of experiment and the literature review done. Thus, Copper should be chosen as the material for fins. Now, during the manufacturing there are a lot of scenarios that are to be considered which are cost of material, manufacturability of material, weldability of material etc. The density of copper is much more than that of aluminum this means that the weight of aluminium is less than copper so the

cost of copper is much more in comparison when the material is of the same dimensions. Thus, Copper costs more. Moreover, copper has to be welded using soldering and the strength of soldering isn't as much as that of welding thus at higher temperature there is a possibility of the soldering getting burned down and also copper is of more weight than aluminium. Thus, Aluminum can be used as a substitute material instead of copper as the heat transfer rate differs only by a small amount. Thus if cost is a constraint then aluminum fins should be used.

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