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A numerical investigation and comparative experimental study of heat transfer analysis and optimization of solid rectangular Fin with composite material of varying different geometry and thermal properties

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Abstract - *Numerical studies have been conducted to investigate the thermal characteristics of fin. To improve the thermal properties and the Constructed optimization of the fin is performed by the finite element method. Maximum dimensionless heat transfer rate is taken used to evaluate the performance of the system. An analytical model based on the Differential Transform Method and Decomposition Method is established for predicting the performance parameters and optimum design parameters of fin by considering temperature dependent thermal conductivity of the fin material and convective heat transfer coefficient. From the optimization analysis, the temperature distribution, fin performances and optimum design parameters obtaining from the present analysis are compared with that from the published analysis and significant differences are noticed due to the superiority of the present study. The temperature distribution has been determined by solving the highly nonlinear governing equations using a semi-analytical transformation technique called Differential Transform Method. A comparison of the results with that of a numerical model shows that this transformation method is a very efficient and convenient tool for solution of non-linear problems. The effects of various geometric, thermo-physical and psychometric parameters on the temperature distribution, fin efficiency and optimum design condition have been investigated.*

Key Words -Rectangular fin, Temperature Distribution, Fin Efficiency, and Fin Effectiveness, Heat transfer Rate, Thermal Conductivity, Heat Transfer Coefficient, and Natural Convection.

1. INTRODUCTION

The aim of the present study is to improve the thermal properties and to investigate the performance of fin efficiency by using fins of different materials and composite materials in Rectangular fin apparatus. There are different shapes of fins generally used in practical applications. Aluminum is the basic metal preferred to make fins due to their light weight and cost. In general the heat transfer from fins depends upon different factors, like the material used to make the fin, thermal conductivity of the material, its shape, surface area, mode of heat transfer allowed, size / shape of fin, etc. In the present study, an attempt is made to fabricate Rectangular fin made Brass, Aluminum, Copper , Mild Steel and composite materials like Aluminum and copper or brass as composite bar and analyzed their performance in terms of temperature distribution along the fin. A constant power is supplied to the heater and the fin is placed horizontally along the axis. Now this time available on different type materials. This paper main objective compares the different type material with composite material.

Fin are the projection protruding from hot surface into ambient fluid and there meant for increasing heat transfer rate by increasing surface area of heat transfer.

Example:

1. Air cooled IC Engine.
2. Reciprocating air compressor.
3. Refrigeration condenser and air conditioning condenser.
4. Electric motor and transformer.
5. Electronic device.
6. Automobile radiation.

1.1 Rectangular Fin Geometry

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. Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it. So, as the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface as compare to fin without the extensions provided to it.

Types of extension provided on fin such as:

1. Rectangular extensions.

2. Trapezium extensions.

3. Triangular extension and.

4. Circular Segmental extension.

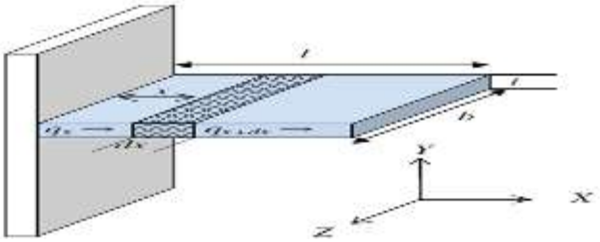


Fig: Rectangular Fin Geometry

Convection heat transfer between a hot solid surface and the surrounding colder fluid is governed by the Newton's cooling law which states that "the rate of convection heat transfer is directly proportional to the temperature difference between the hot surface and the surrounding fluid and is also directly proportional to the area of contact or exposure between them" Newton's law of cooling can be expressed as

$$Q_{conv} = h\,A\,(T_s - T_\infty)$$

Where, h = Convection heat transfer coefficient

Ts = Hot surface temperature

T∞ = Fluid temperature

A = Area of contact or exposure

The extended surfaces that enhance the heat transfer rate from the surface by exposing the larger surface area to convection. These extended surfaces are called **fins**. The term extended surface is commonly used in reference to solid that experience energy transfer by the conduction and convection between its boundary and surroundings. A temperature gradient sustains heat transfer by conduction internally, at the same time; there is energy transfer by convection into ambient from its surface. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing the temperature difference between the object and the environment, increasing the convection transfer coefficient or increasing the surface area of the object increases the heat transfer. In most cases, the area of heat transfer is increased by utilizing extended surface in the form of fins attached to walls and surfaces.

In a conventional heat exchanger heat is transferred from one fluid to another through a metallic wall and other things being equal, the rate of heat flow is directly proportional to the extent of the wall surface and to the temperature difference between one fluid and the adjacent surface. If thin strips of metal are attached to the basic surface, extending into one of the fluids, the total surface is thereby increased which results in an enhanced rate of heat flow. These attached heat conducting strips constitute what are generally termed "extended surfaces" or "fins". Fins are of various types, the most common among them being (a) Rectangular (b) Annular (c) Spines.

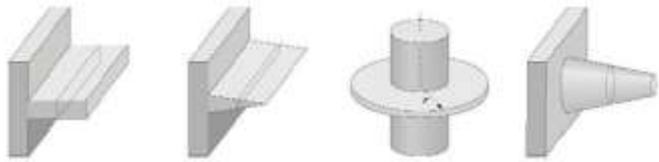


Fig: Different type Shape of Fin.

Thermal analysis is the process of finding the values of temperature at different points when the material is in steady state condition. A steady state is the material condition where there is input heat energy equal to output heat energy. The important factors which mainly affect the heat transfer rate are the thermal conductivity of material, size of material etc. Different materials have different thermal conductivity and it affects the rate of heat transfer. By increasing the length and diameter of the pin fin, the heat transfer rate can be improved but the fin faces the difficulty of increased self-weight and size.

Extended surfaces have fins attached to the primary surface on one side of a two-fluid or a multiplied heat exchanger. Fins can be of a variety of geometry—plain, wavy or interrupted—and can be attached to the inside, outside or to both sides of circular, flat or oval tubes, or parting sheets. Pins are primarily used to increase the surface area (when the heat transfer coefficient on that fluid side is relatively low) and consequently to increase the total rate of heat transfer. In addition, enhanced fin geometries also increase the heat transfer coefficient compared to that for a plain fin. Fins may also be used on the high heat transfer coefficient fluid side in a heat exchanger primarily for structural strength (for example, for high pressure water flow through a flat tube) or to provide a thorough mixing of a highly-viscous liquid (such as for laminar oil flow in a flat or a round tube). Fins are attached to the primary surface by brazing, soldering, welding, adhesive bonding or mechanical expansion, or extruded or integrally connected to tubes.

Fins are used in a large number of applications to increase the heat transfer from surfaces. Typically, the fin material has a high thermal conductivity. The fin is exposed to a flowing fluid, which cools or heats it, with the high thermal conductivity allowing increased heat being conducted from the wall through the fin. The design of cooling fins is encountered in many situations and we thus examine heat transfer in a fin as a way of defining some criteria for design.

Fins are always used only when the heat transfer coefficient or relatively lesser, that is with air or gas. The heat transfer performance of fin with same geometry having various extensions and without extensions is compared. Near about ranging 5% to 13% more heat transfer can be achieved with these various extensions on fin as compare to same geometry of fin without these extensions. Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it. So, as the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface as compare to fin without the extensions provided to it. As a common heat transfer enhancement device, pin-fin are widely used in the heat dissipation of electronic components, and its heat transfer performance is essential for the life and reliability of electronic components. Convection condition, and the results showed that there exists an optimal density of pin-fins which makes the heat transfer rate (HTR) be maximization.

2. Experimental Setup

The experimental apparatus consists of a simple or circular cross section pin fin which is fitted in a rectangular duct. The other end of the duct is attached to suction end of a blower and the air flows past the fin perpendicular to the axis. One end of the fin projects outside the duct and is heated by an electrical heater. Temperature at five points along the length of the fin. The air flow rate is measured by an orifice meter fitted on the delivery side of the blower. The apparatus consists of a pin fin placed inside an open duct the other end of the duct to connected to suction side of blower the delivery side of a blower is taken on through on orifice meter to atmosphere, the air flow rate can be varied by the blower speed regular and can be measured on the U-tube manometer connected to one end of the pin fin. The panel of the apparatus consists of voltmeter, ammeter and digital temperature indicator, heat regulator in it. Thermocouples are mounted along the length of fin and a thermocouple notes the duct fluid temperature. When top cover the fin is opened and heating started, performance of fin with natural convection can be evaluated and with top cover closed and blower started, fin can be tested in forced convection.

The Experimental set-up consisting of the following parts

1. Main Duct (Rectangular)
2. Heater Unit
3. Middle Portion
4. Data unit

1. Main Duct Rectangular):A rectangular channel constructed by using galvanizing steel of 1mm thickness and 150 X100mm cross section, 1000mm long connected to suction side of blower.

2. Heater Unit: Heater unit (test section) has a diameter of 160mm and with of 20mm which is wound on the cylindrical fin portion the heating unit mainly considered of an electrical heater. The heater input 0 to 230 volt and 2 amps.

3. Middle Portion: On the middle portion of the rectangular duct there is pin fin attach and to heat that pin fin on the middle portion of rectangular duct band heater is wound to heat the pin fin.

4. Data Unit: It consists of various indicating devices which indicate the reading taken by various components like thermocouples, voltmeter, ammeter, and manometer. There is multichannel digital temperature indicator which shows reading taken by the five thermocouples.

Experimental Setup ***Aluminum rectangular fin***

Copper rectangular fin, copper and aluminum composite

Table -1: Property of Material

Column1	Column2
FINE MATERIALS	THERMAL CONDUCTIVITY W/MK
mild steel	46
brass	110
aluminium	232
copper	398
Brass + aluminium	372
Copper + aluminium	835

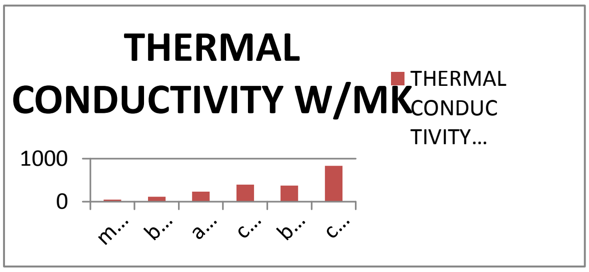
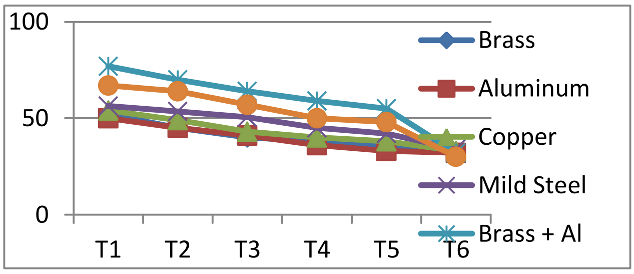


Table-2: Comparison of Temperature Distribution With constant

Materials	T1	T2	T3	T4	T5	T6
Brass	52	45	40	38	35	32
Aluminum	50	45	41	36	33	32
Copper	54	49	43	40	38	33
Mild Steel	56.3	53.5	50.5	45	42	34
Brass + Al	77	70	64	59	55	32
Copper + Al	67	64	57	50	48	30



3. CONCLUSION

Now this review paper main objective is compare the thermal conductivity of different materials and temperature distribution along the fin temperature dependence of thermal conductivity. Aluminum, Iron and Copper being widely used fin materials; the study of variable thermal conductivity with its resultant impact on the performance of fins becomes imperative. Both increase and decrease of thermal conductivity of metals with temperature occur in practice depending upon the material and the range of temperature involved. Future Experimental investigation and thermal analysis on Nano-particle copper coating over aluminum cylindrical pin fin.

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