Analysis of Pin Fin by Simulation Technique

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Abstract

In the development of technology, automobile field plays a vital role in terms of transporting goods, passengers etc., from one place to another by supplying and fulfilling all basic needs in the society. In automobile fields all they use is the Internal Combustion engines. In Internal combustion engines the extended surfaces called fins plays a key role in transferring the heat from source to surroundings. In fins the heat transfer occurs in two basic modes ,they are conduction and convection. Here an attempt is made to analyze the heat transfer in a fin by simulation using Ansys software. The results are obtained by varying the materials for various fins and analysis is made by simulation through Ansys software and comparison is done between fin end temperature and base temperature for different materials. Fin efficiency is calculated by general heat transfer basics. The parameters and experimental are taken from literature[9].

KEYWORDS: Aluminium, Pin Fin, Heat Transfer, Thermal Conductivity, Heat Transfer Coefficient, Internal Combustion Engines

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I. Introduction

The conduction, convection and radiation are the three modes of heat transfer occurs mainly in the universe due to temperature difference in the system. The temperature difference itself plays a key role in transferring the heat in a material from one point to another. In a solid metals the molecules are closely packed to each other where there is no air gap between them , then in this condition without changing the position of molecules the heat transfer occurs then it is termed as conduction type. But if the molecules changes its position when it transfers heat then it is called as convection type heat transfer. The third type is called radiation type which does not need any media to transfer heat.

Thermal conductivity is defined as the amount of energy conducted through the body of unit area and unit thickness in unit time. Generally the thermal conductivity of material plays a vital role in transfer of heat in a material. With the usage of fins the devices like IC engines, refrigerators etc performance can be increased by transferring much heat from the engine to surroundings. Fins are usually made of metals using Aluminium where the preferred due to light weight and noncorrosive. There are several shapes of fins used practically in reducing the heat are shown in fig 1.1 The convective heat transfer occurs between fin surface and surrounding atmosphere and plays an important role in transferring heat. Thus the convection heat transfer is calculated by following the general equation as

$$q = h(T_s - T_f)$$

where, 'h' is heat transfer coefficient, T_s is surface temperature and T_f is surrounding air film temperature.
The solid metal fins used in various fields are shown in Fig 1.1

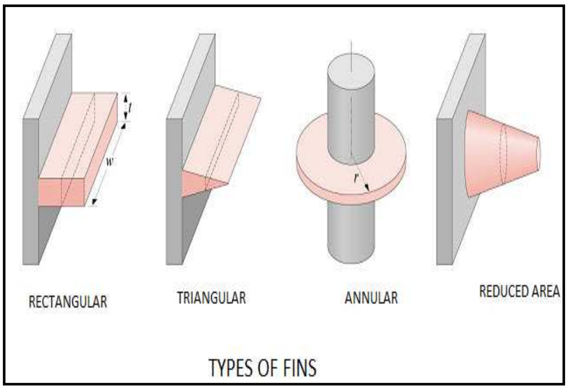


Fig:1.1 Various Shapes of Fins

These fins are generally made with aluminium material due to its less weight to strength ratio, and also the aluminium material is highly corrosion resistant. Here, in this work the general materials like Aluminium, Brass, Copper and Mild steel are considered for analysis and assumed that the heat transfer in a Fin occurs in linear direction (steady state one dimensional) along its length ie., the isotropic condition of the heat transfer in a fin is considered for analysis.

The common shape of the pin fin considered for analysis fo all the materials is shown in the below Fig 1.2.

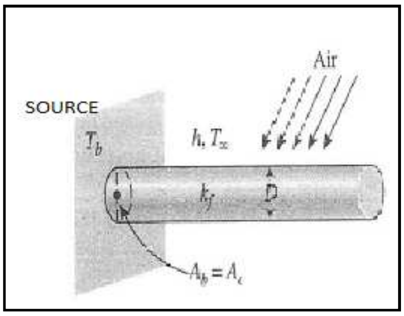


Fig: 1.2 Solid Circular Pin Fin

II. Literature Survey

Deepak Gupta et al .,[1] The main work of this project is to study and compare the fins by changing the geometry and material and thickness and a Hero Honda

Motorcycle with100 cc engine is considered for analysis. The Pro/Engineer 3D modelling software is used to make a model and the model is analyzed in ANSYS. The material used for manufacturing the models is Grey Cast Iron which has thermal conductivity of 53.3 W/m-K and Aluminium alloy 6063 which has thermal conductivity of 200W/mk.

Hajare Swapnali R et al ., [2] In this work the waveform fins are used to check the enhancement of heat transfer used in electronic devices as heat sinks. The cooling performance of electronic devices has attracted increased attention owing to the demand of compact size, higher power densities and demands on system performance and re-liability. Pressure drop plays a key role across the heat sink that govern the thermal performance of the heat sink in forced convection atmosphere. The advantages of using a waveform fin heat sink are light weight, low profile and small footprint. These fins shows the increased heat transfer in heat sinks.

S. Rangadinesh et al.,[3] The experiments were done by using shoe-brush-shaped fin consisting of a single bunch of splayed metal wires of circular cross-section from copper base plate. The fin was fabricated and its heat transfer characteristics were studied through experiments and numerical simulation. Fabrication was done through sand casting and the product was machined for required dimensions and surface finish. Numerical studies were done using ANSYS Fluent 3D. Results shows that the fabricated fin maintains a lower base plate temperature than the rectangular flat fin and cylindrical pin fin for the same heat transfer rate, material and exposed area.

Sanjay Kumar Sharma et al.,[4] studied the results of computational numerical analysis of air flow and heat transfer in a light weight automobile engine, considering three different morphology pin fins. The optimum fin shape is finded out by using Ansys fluent simulation technique on minimum pressure drop and maximizing the heat transfer across the Automobile engine body. The results shows that the drop shaped pin fins show improved results on the basis of heat transfer and pressure drop by comparing other fins due to increased wetted surface area and delay in thermal flow separation from drop shape pin fin.

Yatendra Singh Tomaret al.,[4] A review was conducted on previous work done on performance of extended surfaces under free and forced convection to find the enhancement in the heat transfer rate. The effects of geometric parameters, fin height, fin diameter fin material and base-to ambient temperature difference on the heat transfer performance of fin arrays and the optimum fin separation value has been determined. From the reviews, the convection heat transfer rate from fin arrays depends on all geometric parameter, fin material and base-to-ambient temperature difference. Heat transfer increases with the increase in approach velocity, pin diameter, and number of pins.

Kaustubh Pande et al.,[5] A literature review is conducted on the performance of fins in various fields, and made a comprehensive report on the studies of fin configurations and their influences on heat transfer mechanisms, the CFD simulation methods to model the fins, experimental procedures for the fins under natural convection field, application of fins for various applications and optimizing the heat sinks. The observations from this literature review had been briefly summarized.

S.Jamala Reddy et al., [6]The workdone in this paper is to increase the heat dissipation rate by using the invisible working fluid, nothing but air. The thermal properties of fins by varying geometry, material and thickness of cylinder fins are considered for analysis. Transient thermal analysis determines temperatures and other thermal quantities that vary over time. Material used for manufacturing cylinder fin body is Aluminum Alloy A204 which has thermal conductivity of 110-150W/mk. and analyzed the cylinder fins using material and also using Aluminum alloy 6061 and Magnesium alloy which have higher thermal conductivities.

D.Merwin Rajesh et al.,[7] The work is to analyze the thermal properties such as Heat flux, Thermal gradient by varying geometry, material and thickness of cylinder fins. In this project rectangular, circular and curved fins of 3mm thickness, initially and reduce the thickness into 2.5mm and done analysis the heat transfer changes by the reducing the thickness of the fin are finded out. Pro/Engineer software is used for modelling and the simulation is done using ANSYS. Material used for manufacturing cylinder fin body is Aluminum Alloy 204 which has thermal conductivity of 110-150W/m-k .

Atul B. Zaware et al.,[8] Reduction of lead time in different software's in designing and modelling of fins is done in this project. The extended surfaces (fins) are widely used by the heat transfer equipment, for analysis of any heat transfer system and the model is prepared in Autocad. By using Unigraphics the analysis is done for different configurations of fins. The result shows that the modelling time of fins is reduced by 83%. In this way the design lead time can be minimized on large scale.

Y. Pratapa Reddy et al., [9] In the work, experiments have been conducted to find the temperature distribution within the pin fin made of bimetallic composite fin and steady state heat transfer analysis has been carried using a finite element software ANSYS to test and validate results. The temperature distribution at different regions of pin fin are evaluated by FEM and compared with the results obtained by experimental work. The results are in good agreement and thus validated.

Allan Harry Richard. T. L et al.,[10] The present study is to improve the heat transfer characteristics and to investigate the performance of fin efficiency by using fins of different materials in pin fin apparatus. Here the system follows forced convection as the mode of heat transfer. The experiment accomplished by using blower in the riser tube, which connects to the thermocouple which flows the air to the heater. From the heater the air gets heated and the air transfer to the the pin fin in it. This procedure followed for the fin of different materials, Reynolds number, Nusselts numbers are calculated and heat transfer coefficient and fin efficiencies are analyzed.

Manir Alam et al.,[11] The principle implemented in this project is to increase the heat dissipation rate by using the invisible working fluid, nothing but air. We know that, by increasing the surface area we can increase the heat dissipation rate, so designing such a large complex engine is very difficult. Material used for manufacturing cylinder fin body is Cast Iron and materials Copper and Aluminium 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.

M. P. Shah et al., [12] In this work Thermal behaviour of cylindrical fin is numerically investigated using Ansys APDL Software for different materials like Copper, AA1100, AA2011,and AA3105. Transient and steady state analysis is carried out for the cylindrical fin under the convection and a specified base temperature condition. The length, base thickness, and end thickness of the fin is specified. Thermal conductivity of the fin material is specified. A constant temperature condition is applied at the base of the fin convective boundary conditions applied at the tip of the fin. Comparative study is being done among the fin material here used to find out the best material under the conditions. Base heat transfer rate, time to reach steady state, temperature distribution at different times, steady state temperature distribution is investigated.

III. Simulation In Ansys

Ansys software mainly works on the basis of Finite Element Analysis where the simulation is done in mainly three steps .They are

- pre-processing,
- solution and
- post processing.

In the first step the object is taken and it is divided into number of elements and the area covered by the object is meshed with fine mesh. By considering the coarse mesh the result will be nearer to the actual, but by considering the fine mesh more than five the nearest and precision result can be obtained. After meshing the loads and boundary conditions are applied and lastly in the third step the results are obtained . The results are list results and plot results type the analysis and deformed shapes are obtained. The results are always approximate but not exact. How much it is approximate can be verified by considering the fine element meshing in the object. By the increase in the meshing it consumes more time in analysing all the elements and nodes. The meshing is also done are varied by considering the elemental shape, size. by varying the shape and size of the element the results may be varied and the more precision results can be obtained.

Thermal conductivity, density and heat transfer coefficient plays a vital role in transferring heat in a pin fin where it shows different values for different materials at the end or tip of the pi fin.

IV. Methodology

In this project an attempt is made to analyze the solid pin fin temperatures and fin end temperature by experimental work [9] and by Ansys and the results are compared in terms of temperature at the end of fin and how the temperature is getting distributed in the fin material. The thermal conductivity of the material plays a vital role in transferring the heat transfer from the base of the fin to the end of the fin.

Here the conventional materials like Aluminium, copper, brass and mild steel. In general the Aluminium material is preferred to make the fins in automobile field by considering the main properties like light weight , corrosive resistance and good thermal conductivity property.

Firstly the fin is fixed in the setup and heater is made ON , after obtaining the steady state condition where negligible heat transfer is noted between surroundings temperatures and fin temperature distribution. by applying the same base temperature of the material and it is applied in simulation software like Ansys and after simulation the end temperature results are considered for different materials. the obtained are compared between experimental work and simulation work for different materials and various parameters graphs are drawn.

V. Parameters Of Fin

The various parameters for the analysis of fin are mentioned in table 5.1 , for the same parameters the materials are varied and experimentation and analysis is done. These parameters are considered [9]from the previous experimentation work done and the results are also considered from the same experimental work.

The simulation is carried out by using the Ansys simulation software(version 14.5).

Table 5.1 Parameters of various Pin Fins

Sl.no	Material	Thermal conductivity (k)	Heat transfer coefficient (h)	Outside air temperature (t_0)
Units		W/m-k	W/(m^2K)	^{0}C
1	Aluminium	237	56.78	28
2	Copper	401	57.00	28
3	Brass	125	39.70	28
4	Mild Steel	70	25.21	28

The solid pin fin is taken with a diameter of 20mm (0.02m) and the length of the fin is taken as 180mm(0.180m) and the thermocouples are placed at equidistant and experimental values are taken after fin is achieved a steady state .The other parameters are considered [9] from previous work done. The remaining parameters are shown in Table 5.2 below.

Table 5.2 Parameters of solid pin fins

Sl.no	Material	Diameter	Length	Base temperature
Units		Meters	Meters	^{0}C
1	Aluminium	0.02	0.180	91.6
2	Copper	0.02	0.180	79.6
3	Brass	0.02	0.180	78.2
4	Mild Steel	0.02	0.180	65.3

VI. Results

VI.I Experimental Results:

These are taken from[9] and the simulation is done for the same materials and the results are compared.

Table 6.1 Experimental values of various solid pin fins

Thermocouple distances (mm)	At X=0	X=35	X=70	X=105	X=140	X=175
Material	T_1	T_2	T_3	T_4	T_5	T_6
Aluminium	91.6	79.78	71.2	65.57	62.28	58.5
Copper	79.6	73.05	68.19	64.85	62.89	60.2
Brass	78.9	71.5	68.1	60.2	49.5	39.7
Mild steel	65.5	58.1	49.2	43.1	35.8	28.1

VI.II ANSYS Results:

After simulation the obtained results are shown below as results in below figures listed as 6.2(a),6.2(b),6.2(c)&6.2(d). .The materials shown are Aluminium, copper, brass and mild steel. The input parameters given for Ansys analysis are thermal conductivity of the material, density of the material, convective heat transfer cofficient and the surrounding temperature.

The below figure 6.2(a) shows the temperature distribution of Mild Steel pin fin where the base temperature is given as 65.3 ^{0}C and end temperature is obtained as 46.97 ^{0} C.

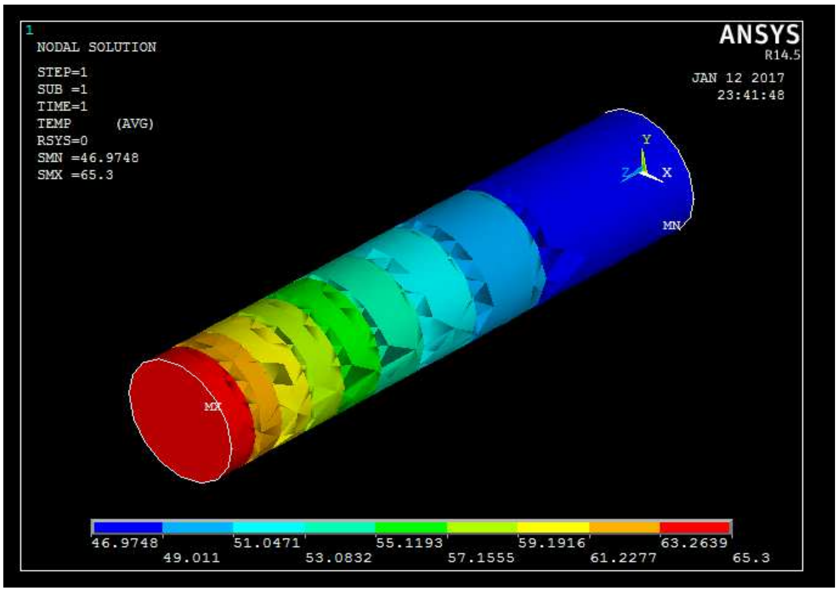


Fig 6.2(a) Temperature Distribution of Mild Steel Fin

The below figure 6.2(b) shows the temperature distribution of Aluminium pin fin where the base temperature is given as 91.6 ^{0}C and end temperature is obtained as 71.44 ^{0} C.

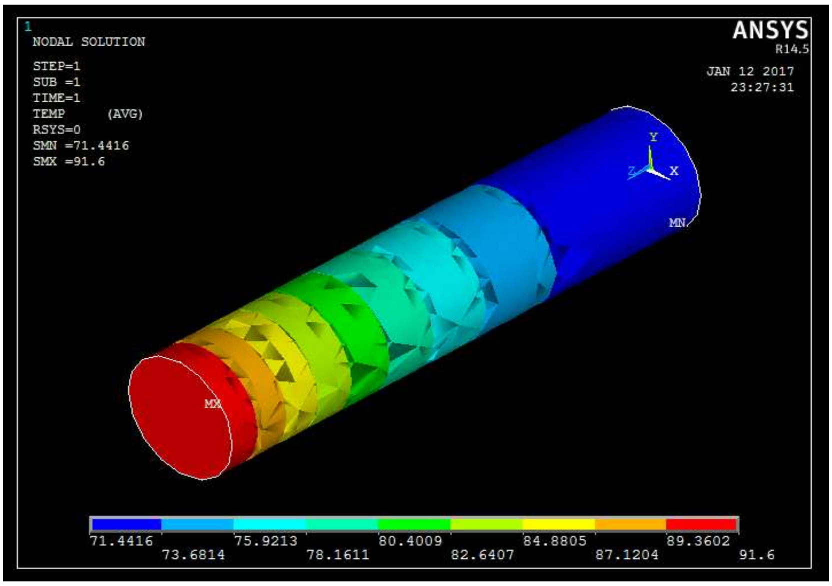


Fig 6.2(b) Temperature Distribution of Aluminium Fin

The below figure 6.2(c) shows the temperature distribution of Brass pin fin where the base temperature is given as 78^0 C and end temperature is obtained as $58.6\ ^0$ C.

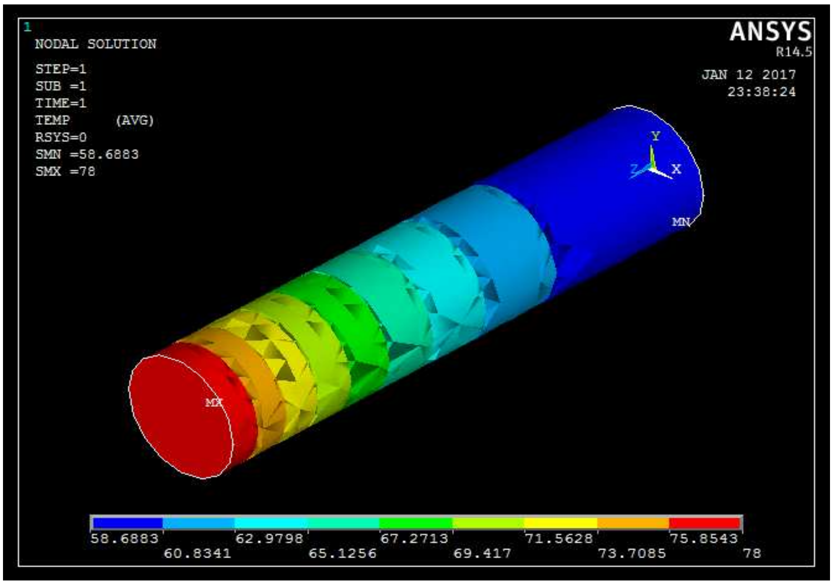


Fig 6.2(c) Temperature Distribution of Brass Fin

The below figure 6.2(d) shows the temperature distribution of copper pin fin where the base temperature is given as 79.6 ^{0}C and end temperature is obtained as 68.7^0 C.

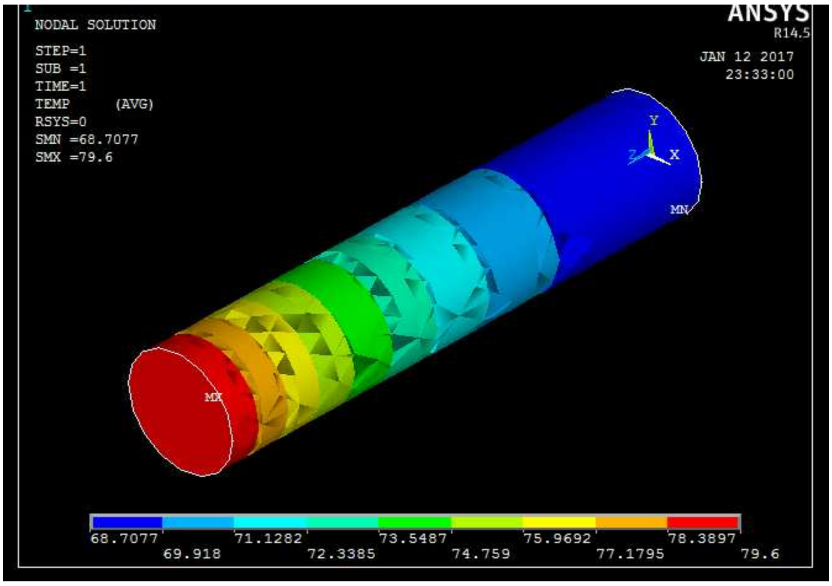


Fig 6.2(d) Temperature Distribution of Copper Fin

VI.III Comparison of Results by Tabular Form:

The find end or tip temperature is compared in the tabular form shown in Table 6.3(a). The various conclusions are as follows based on results.

- In all the results the Ansys results shows the increased values than experimental results[9]

Table 6.3(a) Fin end temperature of various fins

Slno	Material	Experimental value	Ansys value
1	Aluminium	58.5	71.44
2	Copper	60.2	68.7
3	Brass	39.7	58.6
4	Mild Steel	28.1	46.97

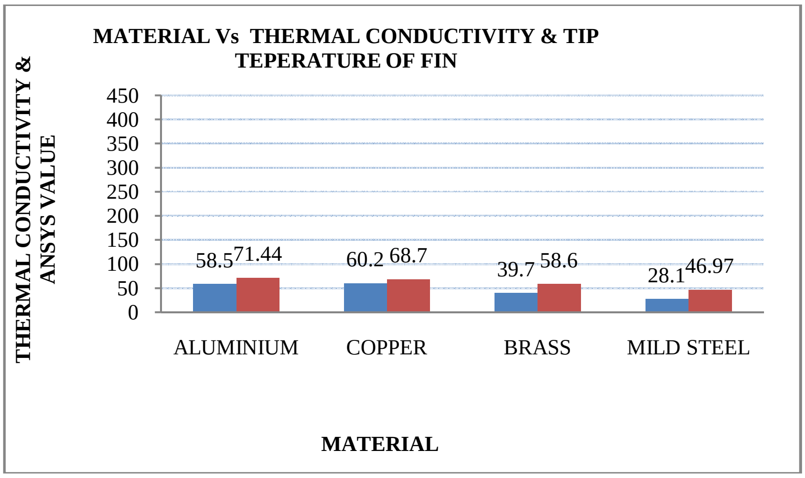
Depending on the thermal conductivity the heat transfer rate is varied in different temperatures and the variation is shown in below tabular form of table 6.3(b)

Table 6.3(b) Thermal conductivity and temperature variation of various fins at the end of fin

Slno	Material	Thermal conductivity (k)	Ansys value
1	Aluminium	237	71.44
2	Copper	401	68.7
3	Brass	125	58.6
4	Mild Steel	70	46.97

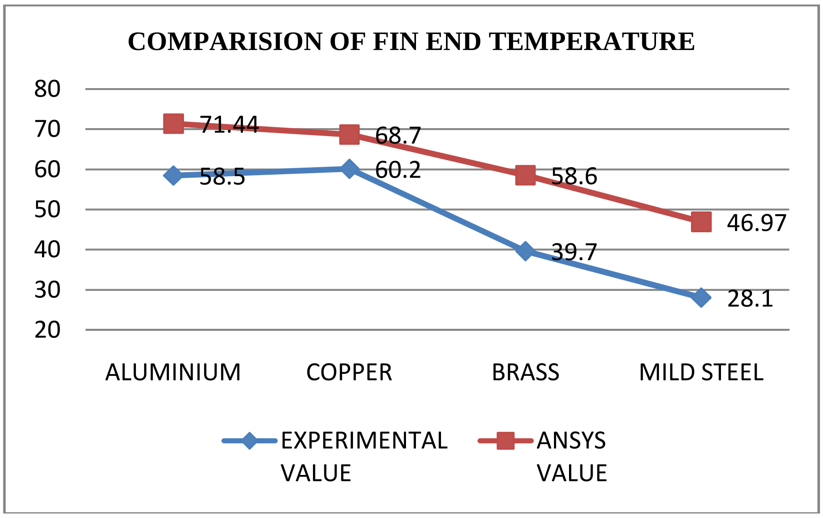
VI.IV Comparison of Results by Graphs :

The variation in thermal conductivity and end tip temperature value by ansys simulation is compared and shown in below graph 6.4(a).



6.4.(a) Comparion Graph of material thermal conductivity and tip end temperature value by Ansys

The comparison is done by graph between experimental value and simulation value for various fins and shown in below graph 6.4(b)



VI.V CONCLUSIONS:

- The aluminum material shows the end temperature greater than copper due to thermal conductivity variation and weight ratio.
- The least value at the tip of fin shown by mild steel is due to less thermal conductivity and it is not preferred in practical due to high corrosion effect.
- Brass also shows the less value compared to aluminum and copper due to an alloy properties and variation thermal conductivity.

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