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Heat Transfer Analysis of Rectangular Fins in Air Cooled Engines at Various Speeds

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Abstract* – Engine cylinder is the main component of the automobile which is subjected to high temperature variations and thermal stresses. Fins are basically mechanical structures which help to cool different parts of engine through the mode of convection process. With the mode of forced convection an air-cooled motorcycle engine dissipates huge amount of heat to the surroundings. To improve this, fins are provided on the outer surface of the cylinder. The heat transfer rate depends upon the velocity of the vehicle, geometry of fin and the ambient temperature. Many experimental methods are available in literature to analyze the effect of these factors on the rate of heat transfer. In the present paper an effort is made to study the effect of parameters on fins performance by varying its pitch, thickness and material of fin. The heat transfer surface of the engine is modeled in PROE CREO with varying thicknesses and fin spacing and simulated in ANSYS software. An expression of average fin surface heat transfer coefficient in terms of wind velocity is obtained. Heat transfer is taken as input for Thermal analysis. Finally results are obtained for temp distribution, heat flux, thermal stresses and deformation for three types of materials like alluminium, cast iron and copper.

Keywords: - Simulation, Stress, Heat transfer, fins.

I. INTRODUCTION

In Internal Combustion engines, combustion of fuel and air takes place inside the engine cylinder leads to generation of hot gases. The maximum temperature attained by the gases are 2300-2500°C .These generated high temp gases leads into burning of oil film between the moving parts and may result into seizing or welding of the same. To safe this design, this temperature must be reduced to about 150-200°C at which the engine conditions will work most effectively. Over cooling is also not suitable because it reduces its thermal efficiency. The main objective system of cooling is to maintain the engine running at its most effective operating conditions. It is observed that the engine is too difficult to operate at high temperatures. Excess heating will also damage the cylinder material.So the cooling system is designed to prevent cooling when the engine is at warming up condition. Also it will attain to maximum operating temperature, and then it starts cooling. It is also to be noted that:

(a) Total heat generated used for producing brake power (useful work) is about 20-25%.

(b) Cooling system is designed to remove heat of 30-35%.

(c) Remaining heat due to lost in friction is carried away by exhaust gases.

I.METHODS OF COOLING

There are mainly two types of cooling systems:

(a) Air cooled system, and

(b) Water cooled system.

AIR-COOLING

Air cooled system is generally used in small engines say up to 15-20 kW. In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc.

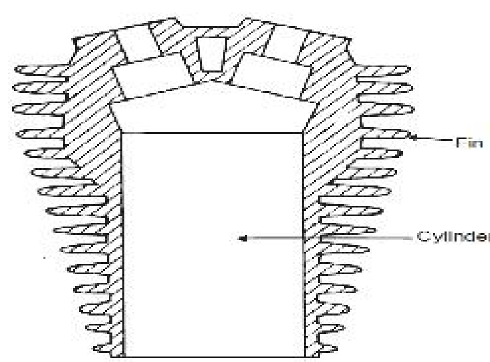


Fig 1: Air cooled engine cylinder with fins

Heat generated due to combustion in the engine cylinder will be conducted to the fins and when the air flows over the fins, heat will be dissipated to air. The amount of heat dissipated to air depends upon:

(a) Amount of air flowing through the fins.

(b) Fin surface area.

(c) Thermal conductivity of metal used for fins.

WATER COOLING SYSTEM

In this method, cooling water jackets are provided around the cylinder, cylinder head, valve seats etc. The water when circulated through the jackets, it absorbs heat of combustion. This hot water will then be cooling in the radiator partially by a fan and partially by the flow developed by the forward motion of the vehicle. The cooled water is again re circulated through the water jackets.

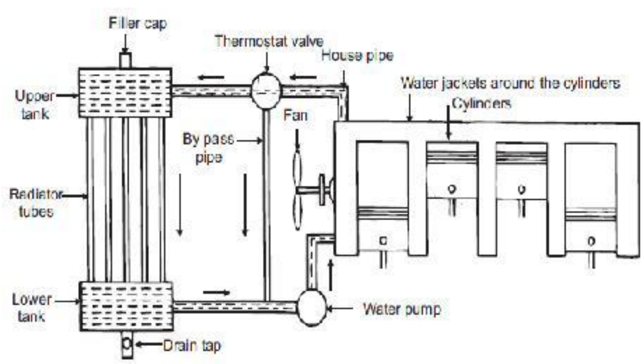


Fig- 2: Water Cooled Engine with Radiator

II. SYSTEM MODEL

Fins: 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. The amount of conduction, convection, radiation of an object determines the amount of heat it transfers. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to the object, however, increases the surface area and can sometimes be economical solution to heat transfer problems. Circumferential fins around the cylinder of a motor cycle engine and fins attached to condenser tubes of a refrigerator are a few familiar examples

Fig-3 Automobile Fin

III. PREVIOUS WORK

Fernando simulated the heat transfer from cylinder for two-stroke internal combustion finned engine. The cylinder body, cylinder head (both provided with fins), and piston have been numerically analyzed and optimized in order to minimize engine dimensions. The maximum temperature admissible at the hottest point of the engine has been adopted as the limiting condition. Starting from a zero-dimensional combustion model developed in previous works, the cooling system geometry of a two-stroke air cooled internal combustion engine has been optimized in this paper by reducing the total heat dissipated by the engine. A total reduction of 20.15% has been achieved by reducing the total engine fin thickness from 2 mm to 2.5. mm and by changing the material of aluminium,cast iron aspect ratio varies from 1.39 to 1.95. In parallel with the total volume reduction, a slight increase in engine efficiency has been achieved.

S Chandra sekhar & S.D.V.V.S.Bhimeshwar Reddy analyzed the thermal properties by changing the geometry, material and thickness of cylinder fins. The models were created by catia varying the geometry, rectangular, circular and curved shaped fins. Material used for manufacturing cylinder fin body was Aluminum Alloy 204 which has thermal conductivity of 110-150W/mk and also using Alluminium alloy 6061 and Magnesium alloy which have higher thermal conductivities. They concluded that by reducing the thickness and also by changing the shape of the fin to curve shaped, the weight of the fin body reduces thereby increasing the efficiency. The weight of the fin body is reduced when Magnesium alloy is used and using rectangular fin, material Aluminum alloy 6061 and thickness of 2mm is better since heat transfer rate is more and using rectangular fins the heat lost is more, efficiency and effectiveness is also more.

J. Ajay Paul et.al. Carried out some Numerical Simulations to determine characteristics of heat transfer of different parameters of fin namely, air velocities number of fins, fin thickness at varying. Experimentally A cylinder with a single fin mounted on it was tested. Using CFD The numerical simulation of the setup was done. Cylinders with fins of 2 mm and 3 mm thickness were simulated for 2, 3, 4 & 6 fin configurations. They concluded that.

1When fin thickness was increased, the reduced gap between the fins resulted in swirls are created which helps in increasing the rate of heat transfer.
2. Large number of fins with minimum thickness can be preferred in high speed vehicles than thick fins with less numbers as it helps inducing greater turbulence and hence higher heat transfer.

IV. PROPOSED METHODOLOGY

DESIGN PARAMETERS FOR ORGINAL MODEL

Engine cylinder with fins is a complicated shape which was developed in professional software PROE which is integrated 3D CAD/CAM/CAE solution, is used

by discrete manufacturers for mechanical engineering, design and manufacturing. Successful parametric, 3D CAD modeling system.

Table 1 Material properties taken into consideration

Parameters	Aluminum alloy 6082	CI	CU
E (GPa)	71	110	110
Poisson ratio	0.33	0.28	0.34
K(w/m ^{0} c)	160	52	401
α(/^{0}c)	2.30E-05	1.10E-05	1.80E-05
CP (J/Kg ^{0}C)	875	447	385
ρ(kg/m^3)	2770	7200	8300

SPECIFICATION OF THE PROBLEM

Objective of the project is to design cylinder with fins for SUZUKI FIERO 147cc engine, by Changing the fin thickness and distance between the fins to analyze the thermal properties of the fins. Analyzation is also done by varying the materials of fins. Present used material for cylinder fin body is Cast Iron. Our aim is to change the material for fin body by analyzing the fin body with other materials and also by changing the geometry distance between the fins and thickness of the fins. Thickness of fins are 2, 2.5, 3 and 3.5mm Distance between the fins – 8, 9, 10 and 11mm. Materials are considered for analysis Cast Iron, Copper and Aluminum alloy 6082.

Length of fin (L)=48.35mm

T_i = Inside temperature = 300 ^{0}C

T_o = Outside temperature =35^{0}C
Film coefficients have taken into analysis with respectof time like at 10sec-30 w/m2c.
LC=L+T=48.35+2=50.35
R1=29.15(radius of bore)
R2C=R1+LC=79.5 ή X=0.77Q max =2π(R2C2-R12)h(T0-T∞)=273.2 WFilm coefficient have taken into analysis with respect of time like at 10sec-30 w/m2c.

At 20sec-40 w/m0c and 30sec-50 w/m0c while vehicle is getting different speed

R2C/R1=2.27

AM=T(R2C-R1)=100.7

(LC)3/2(h/KAM)1/2=0.4875

Q actual=273.2 X 0.77=210 W (on both sides of fin)

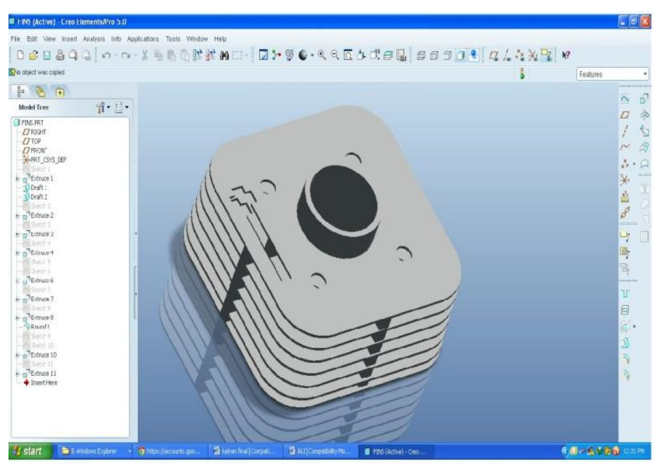


Fig: 4 SUZUKI FIERO Cylinder is modeled in PROE CREO

V. SIMULATION/EXPERIMENTAL RESULTS

CASE-I: Aluminum 3 mm thick, 10 mm spacing

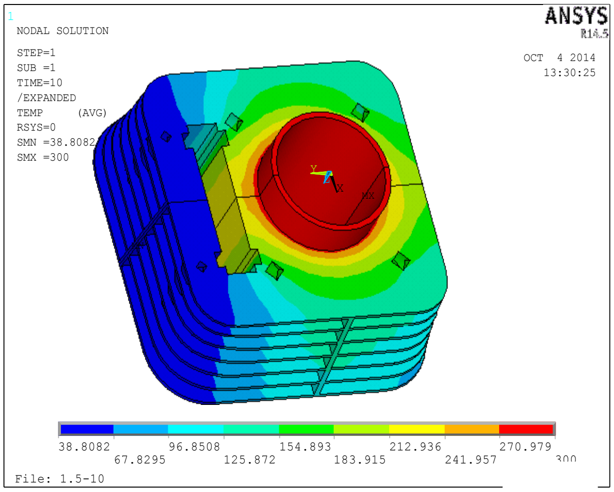


Fig: 5 Temp distributions in cylinder at 10 sec for AL

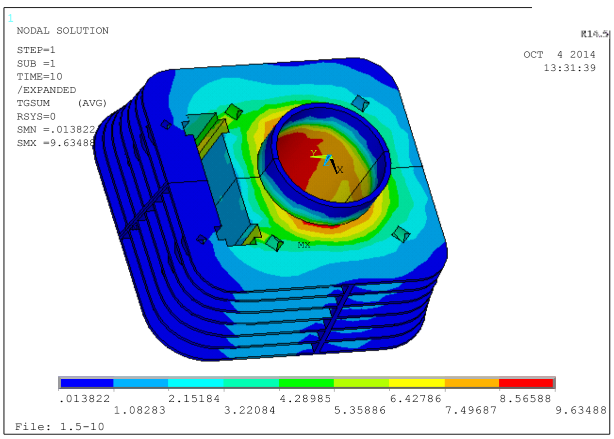


Fig: 6 Thermal gradients in cylinder at 10 sec for AL

CASE-II: CI 3 mm thick, 10 mm spacing

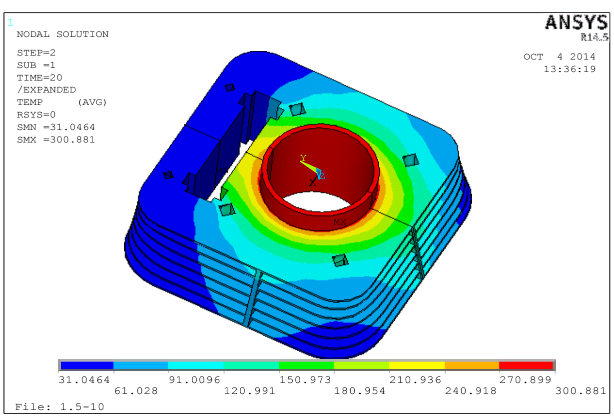


Fig: 7 Temp distributions in cylinder at 10 sec for CI

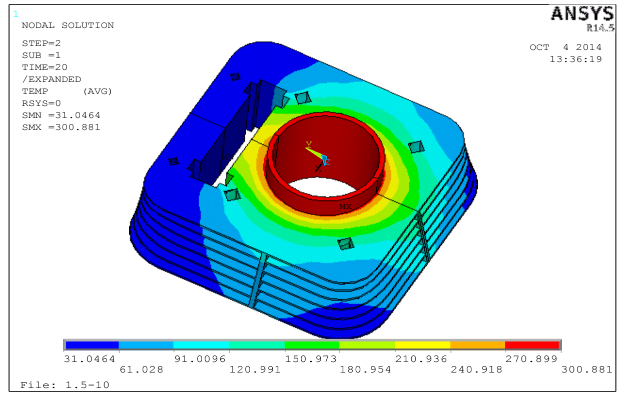


Fig: 8 Temp distributions in cylinder at 20 sec for CI

CASE-III: Copper 3 mm thick, 10 mm spacing

Table At 10 sec fin thickness 3 mm ,spacing 10 mm

Material	Heat Flux	Deformation	Stresses	Gradient
AL	1.071	0.697	205	6.69
CU	1.645	0.693	171.7	5.597
CI	0.498	0.283	241	9.586

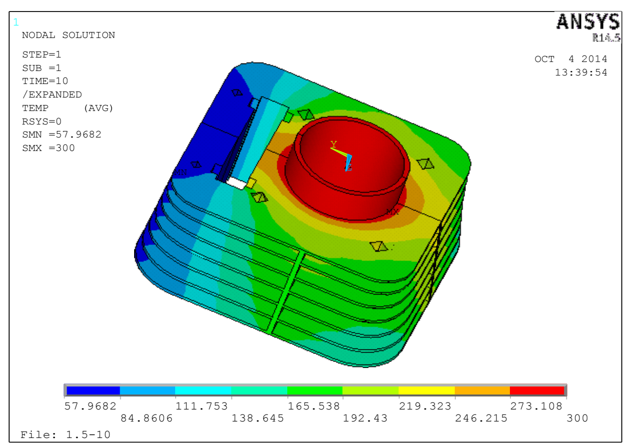


Fig: 9 Temp distributions at 10 sec for copper cylinder

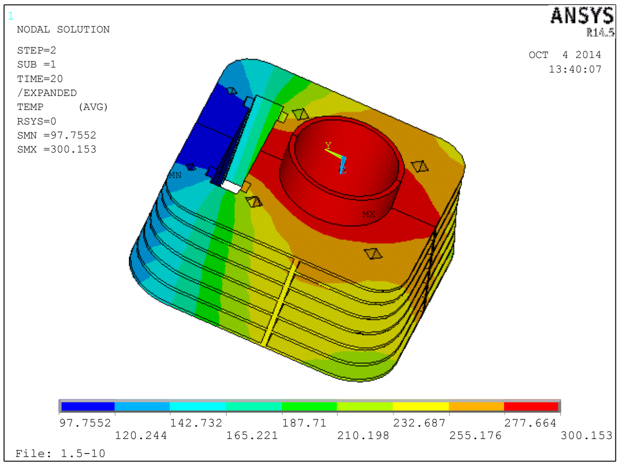


Fig: 10 Temp distributions at 20 sec for copper cylinder

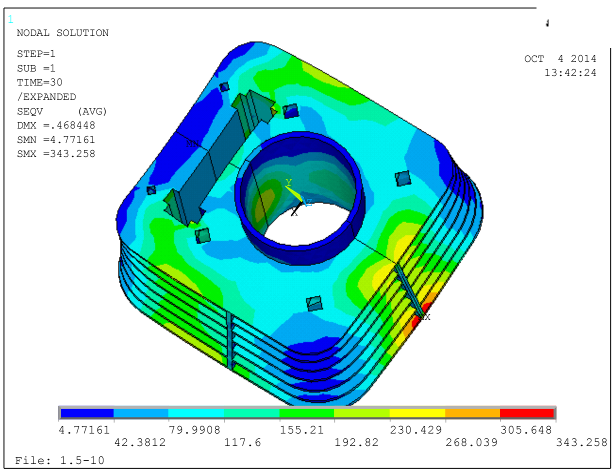


Fig: 11 Thermal stresses at 30 sec for copper cylinder

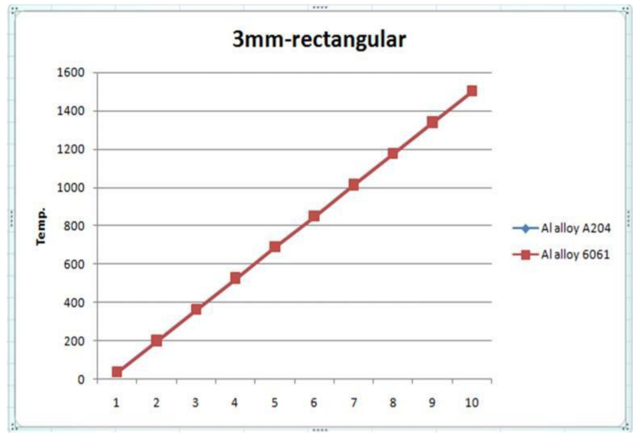
Table 2 At 10 sec fin thickness 3 mm, spacing 10 mm

Heat flux, deformation, stresses and heat gradient values for different materials at 2 mm thick for 10sec from the above table heat flux value for copper material having higher value as compared to remaining material, stresses and heat gradient values of cast-iron are higher and deformation is lowest as compared to remaining material.

Table 3 At 20 sec fin thickness 3 mm, spacing 10 mm

Table At 20 sec fin thickness 3 mm ,spacing 8 mm				
Material	**Heat Flux**	**Deformation**	**Stresses**	**Gradient**
AL	1.104	0.748	211	7.97
CU	1.67	0.781	168.05	5.679
CI	0.493	0.249	231.5	8.48

Heat flux, deformation, stresses and heat gradient values for different materials at 8 mm spacing from the above table heat flux value for copper material having higher value as compared to remaining material, stresses and heat gradient values of cast-iron are higher and deformation is lowest as compared to remaining material.



Graph Temperature variation along time

Above graph shows the temperature variations in the rectangular and circular fins. But in the rectangular cross section fins the temperature variation in the materials Aluminium alloy 6061 are on the same line i.e. the two lines are coincide each other. So that in rectangular cross sectioned fins the temperature is not distributed over the entire area of the engine cylinder fin. The above graph shows if aluminum fin thickness increases thermal stresses value and same

Things are repeated for remaining materials.

VI. CONCLUSION

- Engine cylinder is modeled by changing the thickness of fin and spacing between the fins in PROE CREO software.
- Transient Thermal analyses are performed for three different types of materials like cast iron, copper and aluminum.
- Initially different thickness of different materials are considered for analysis and results have found in that aluminum 3 mm thickness fins are optimum model according to heat transfer value to Varying speed conditions and deformation, thermal stresses and weight of cylinder.

- Secondary 3 mm thickness of different material with different spacing between fins are considered in that if we reduce the spacing between fins we can increases the number of fins alternately heat flux value is increases and deformation and thermal stresses are in allowable limit.
- Finally optimum model have found as aluminum 3mm thickness and 8 mm spacing, with 8 number of Fins.
- The results shows, by using rectangular fin with material Aluminum Alloy 6061 is better since heat transfer rate of the fin is more at different speeds.

VII. FUTURE SCOPES

1. Thermal Analysis of engine cylinder with alloy materials.

2. Design and vibration analysis of engine cylinder.

3. Analysis of cylinder and piston by varying different compression ratios

4. Thermal Analysis of engine cylinder at various climatic conditions.

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