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RESEARCH ARTICLE

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ANALYSIS OF HEAT TRANSFER RATE BY VARYING COOLING FLUID FOR ENGINE CYLINDER FINS

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ABSTRACT

The main aim of the project is to analyze the thermal properties by varying cooling fluid, material and thickness of cylinder fins. Parametric models of cylinder with fins have been developed to predict the thermal behavior. The models are created by the geometry, rectangular and also by varying thickness of the fins for both geometries. Cooling fluids used in this thesis is air, oil. The 3D modeling software used is Pro/Engineer. Thermal analysis is done on the cylinder fins to determine variation in temperature distribution. The analysis is done using ANSYS. Transient thermal analysis determines temperatures and other thermal quantities that vary over time.

For manufacturing cylinder fin body Aluminum Alloy 204 is used today which has thermal conductivity of 110-150W/mk. We are analyzing the cylinder fins using this material and also using Aluminum alloy 6061 and Magnesium alloy which have higher thermal conductivities.

Key words: Cooling Fluid, Cylinder fins, Aluminum Alloy 204, Aluminum Alloy 6061, Magnesium

I. INTRODUCTION

The internal combustion engine is an engine in which the combustion of a fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine, the expansion of the high-temperature and -pressure gases produced by combustion applies direct force to some component of the engine, such as pistons, turbine blades, or a nozzle. This force moves the component over a distance, generating useful mechanical energy.

NECESSITY OF COOLING SYSTEM IN IC ENGINES

All the heat produced by the combustion of fuel in the engine cylinders is not converted into useful power at the crankshaft. A typical distribution for the fuel energy is given below: [3]

Useful work at the crank shaft = 25 percent
Loss to the cylinders walls = 30 percent
Loss in exhaust gases = 35 percent
Loss in friction = 10 percent

It is seen that the quantity of heat given to the cylinder walls is considerable and if this heat is not removed from the cylinders it would result in the pre ignition of the charge. In addition, the lubricant would also burn away, thereby causing the seizing of the piston. Excess heating will also damage the cylinder material.

Keeping the above factors in view, it is observed that suitable means must be provided to dissipate the excess heat from the cylinder walls, so as to maintain the temperature below certain limits.

However, cooling beyond optimum limits is not desirable, because it decreases the overall efficiency due to the following reasons:

1. Thermal efficiency is decreased due to more loss of heat to the cylinder walls.
2. The vaporization of fuel is less; this results in fall of combustion efficiency.
3. Low temperatures increase the viscosity of lubrication and hence more piston friction is encountered, thus decreasing the mechanical efficiency.

The basic principle involved in this method is to have current of air flowing continuously over the heated metal surface from where the heat is to be removed. The heat dissipated depends upon following factors: [4]

a) Surface area of metal into contact with air.
b) Mass flow rate of air.
c) Temperature difference between the heated surface and air.
d) Conductivity of metal.

Thus for an effective cooling the surface area of the metal which is in contact with the air should be increased. This is done by using fins over the cylinder barrels. These fins are either cast as an integral part of the cylinder or separate finned barrels are inserted over the cylinder barrels. These fins are either cast as an integral part of the cylinder or separate finned barrels are inserted over the cylinder barrel. Sometimes, particularly in the case of aero engines, the fins are machined from the forged cylinder blanks.

Our aim is to change the material for fin body by analyzing the fin body with other materials and also by changing the thickness.

Geometry of fins – Rectangular

Thickness of fins – 3mm and 2.5mm

Materials – Aluminum Alloy A204, Aluminum Alloy 6061, Magnesium alloys.

Cooling Fluid – Air, Oil

STEPS INVOLVED IN THE PROJECT

1. MODELING OF ENGINE BODY
2. THEORETICAL CALCULATIONS
3. THERMAL ANALYSIS

For modeling of the fin body, we have used **Pro-Engineer** which is parametric 3D modeling software. For analysis we have used ANSYS, which is FEA software.

II. DESIGN AND THEORETICAL CALCULATIONS

DESIGN OF CYLINDER FIN BODY

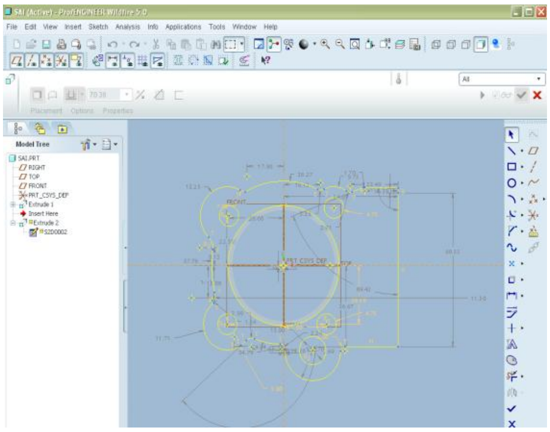


Fig 2.1 2D Model of Engine Cylinder

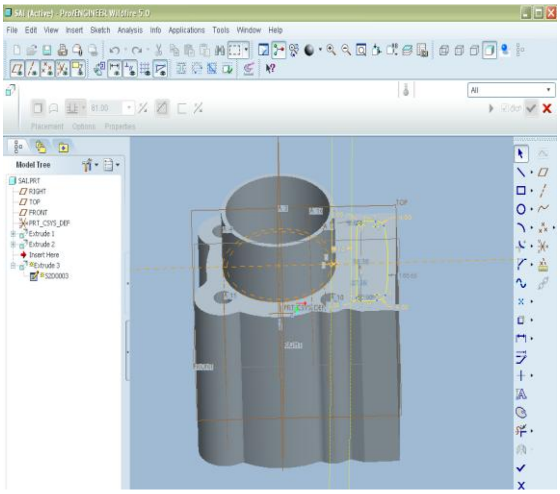
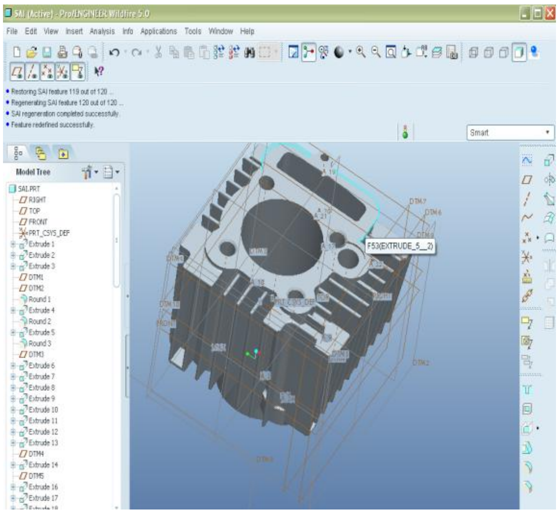


Fig 2.2 Extruding of 2D Model



- Restoring SAI feature 119 out of 120 ...
- Regenerating SAI feature 120 out of 120 ...
- SAI regeneration completed successfully.
- Feature redefined successfully.

Fig2.3 cylinder with rectangular fins

HEAT TRANSFER THROUGH FINS:

COOLING FLUID - AIR

ALUMINUM ALLOY 204 – Thickness 3mm

Length of fin (L), Width of fin (b), Thickness (y)

Perimeter of fin (P) =2b+2y

Cross sectional area of fin $A_c=b\times y$

K=conductivity of fin material

h=heat transfer coefficient

m= Parameter

$m=\sqrt{\frac{hp}{kA_c}}$

$\Theta=T-T_a$

Θ = Excess Temperature

Where T=temperature of cylinder head

T_a=atmospheric temperature

x=distance measured from base of fin

$$\Theta=\Theta_o\times\left(\frac{\text{kmcosh}[m(l-x)]+h[\sin h\{m(l-x)\}]}{kmcos\,h(ml)+h[sin\,h(ml)]}\right)$$

Heat lost by fin

$$Q_{fin}=KA_cm\Theta_o\left(\frac{hcos\,h(ml)+kmsin\,h(ml)}{mkcos\,h(ml)+hsin\,h(ml)}\right)$$

Maximum heat transferable by fin when if entire fin at base temperature

$Q_{max}=h(Pl)(t_0-t_a) = h(Pl)\,\Theta_o$

Efficiency (η) = (Qfin/Qmax)

Effectiveness of fin

є=Heat lost with fin / Heat lost without fin

Effectiveness should be more than 1

THERMAL FLUX CALCULATIONS

T_i Inside temperature

T_o Outside temperature

Heat flow

Heat Flux h = q/a

III. THERMAL ANALYSIS OF FIN BODY

COOLING FLUID – AIR

ALUMINUM ALLOY 204 –3mm THICKNESS

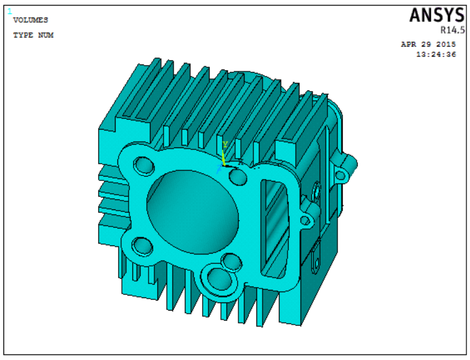


Fig3.1 Imported Model

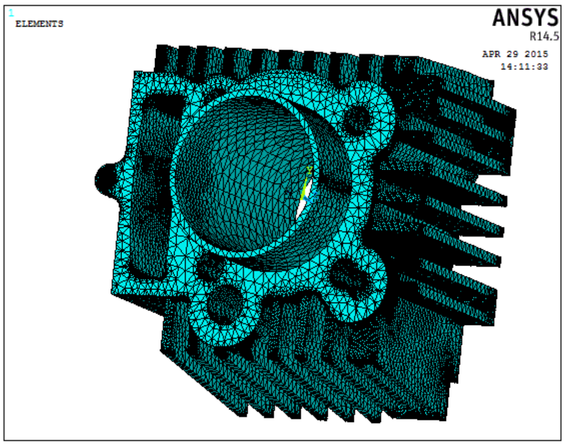


Fig 3.2 Meshed model

Define Loads -Apply Thermal-Temperature- on Area-Select inside area=5585K

Convections – on Areas (select Remaining areas-Film Co-efficient – 25 W/mmK

Bulk Temperature – 313 K

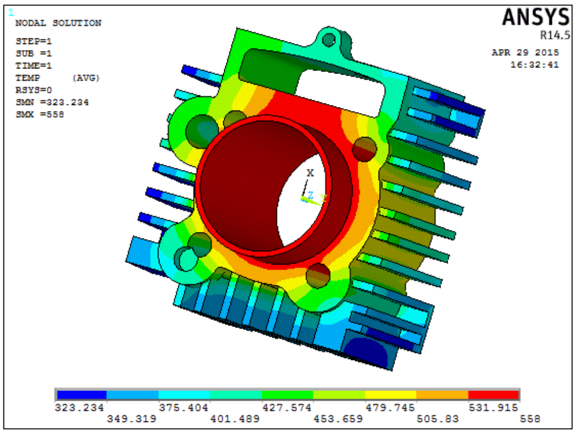


Fig3.3 Nodal Temperature

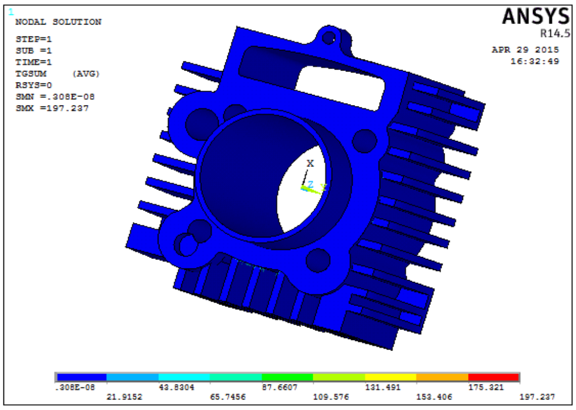


Fig3.4 Thermal Gradient Vector Sum

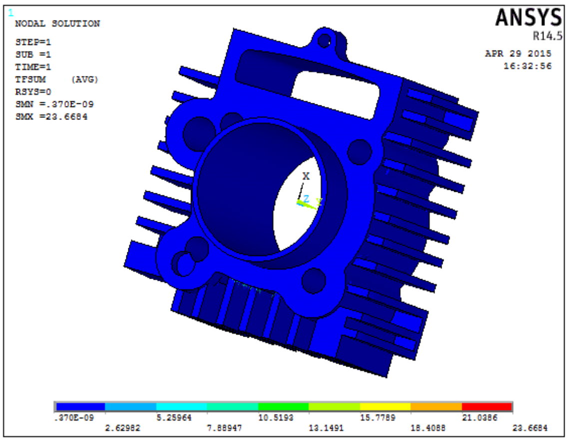


Fig 3.5 Thermal Flux Vector Sum

RESULTS

COOLING FLUID – AIR

	3 mm Thickness			2.5mm Thickness		
	Aluminum Alloy 204	Aluminum Alloy 6061	Magnesium	Aluminum Alloy 204	Aluminum Alloy 6061	Magnesium
Nodal Temperature (K)	558	558	558	558	558	558
Thermal Gradient (K/mm)	197.237	179.695	185.362	68.6534	59.564	62.2775
Thermal Flux (w/mm^2)	23.6684	32.3451	29.4726	8.2384	10.7215	9.90213

MASS OF CYLINDER FINS

3 mm FINS

	Al 204	Al 6061	Mg
Rectangular	1.0100279 Kg	9.7395552 e^{-1} Kg	8.9459618 e^{-1} Kg

2.5 mm FINS

	Al 204	Al 6061	Mg
Rectangular	9.7228382 e^{-1} Kg	9.3755940 e^{-1} Kg	8.6116567 e^{-1} Kg

Theoretical results table

		THICKNESS (mm)	HEAT LOST (W)	EFFECTIVENESS	EFFICIENCY (%)
RECTANGULAR	**Al 204**	**3**	132.507	56.56	15.36
		2.5	140.64	61.96	11.49
	Al 6061	**3**	128.64	69.28	11.01
		2.5	135.09	75.89	8.83
	Mg	**3**	131.21	65.11	12.41
		2.5	132.27	71.33	11.85

COOLING FLUID – OIL

		THICKNESS (mm)	HEAT LOST (W)	EFFECTIVENESS	EFFICIENCY (%)
RECTANGULAR	**Al 204**	**3**	279.65	40	24.62
		2.5	315.13	43.81	17.11
	Al 6061	**3**	272.19	48.98	18.87
		2.5	238.57	53.66	16.12
	Mg	**3**	274.24	46.04	20.54
		2.5	276.03	50.43	19.32

Thermal analysis results table

	3 mm Thickness			2.5mm Thickness		
	Aluminum Alloy 204	Aluminum Alloy 6061	Magnesium	Aluminum Alloy 204	Aluminum Alloy 6061	Magnesium
Nodal Temperature (K)	558	558	558	558	558	558
Thermal Gradient (K/mm)	87.6949	75.5283	79.0025	85.7383	75.4867	78.5508
Thermal Flux (w/mm^2)	10.5234	13.5951	12.5614	10.2886	13.5876	12.4896

Theoretical thermal flux (W/mm^2) results table

	3mm	2.5mm
AIR	0.00095	0.00129
OIL	0.0019	0.00257

IV. CONCLUSION

In this thesis, a cylinder fin body for a 150cc motorcycle is modeled using parametric software Pro/Engineer. The original model is changed by changing the thickness of the fins. The thickness of the original model is 3mm it has been reduced to 2.5mm. By reducing the thickness of the fins, the overall weight is reduced.

Present used material for fin body is Aluminum Alloy 204. In this thesis, two other materials are considered which have more thermal conductivities than Aluminum Alloy 204. The materials are Aluminum alloy 6061 and Magnesium Alloy. Thermal analysis is done for all the three materials. The material for the original model is changed by taking the consideration of their densities and thermal conductivity.

By observing the thermal analysis results, thermal flux is more for Aluminum alloy 6061 than other two materials and also by reducing the thickness of the fin, the heat transfer rate is increased.

Thermal flux is also calculated theoretically. By observing the results, heat transfer rate is more when the thickness of the fin is 2.5mm.

So we can conclude that using Aluminum alloy 6061 and taking thickness of 2.5mm is better.

FUTURE SCOPE

The shape of the fin can be modified to improve the heat transfer rate and can be analyzed. The use of Aluminum alloy 6061 as per the manufacturing aspect is to be considered. By changing the thickness of the fin, the total manufacturing cost is extra to prepare the new component.

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