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Optimization of Engine Cylinder Fins for Varying Geometry and Material

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Abstract: *The Engine cylinder is one of the major automobile components, which is subjected to high temperature variations and thermal stresses. Fins are provided on the cylinder to increase the rate of heat transfer to cool the cylinder. It is helpful to know the heat dissipation inside the cylinder by doing thermal analysis on the engine cylinder fins,*
The principle implemented in this project is to increase the heat dissipation rate by using the invisible working fluid, nothing but air. It is known that by increasing the surface area the heat dissipation rate can be increased. Designing of such a large complex engine is very difficult. The main purpose of using these cooling fins is to cool the engine cylinder by air.
The main aim of the project is to analyze the thermal properties by varying geometry, material, distance between the fins and thickness of cylinder fins. Parametric models of cylinder with fins have been developed to predict the transient thermal behavior. The models are created by varying the geometry circular and also by varying thickness of the fins for both geometries. The 3D modeling software used is Pro/Engineer.
Thermal analysis is done on the cylinder fins to determine variation of temperature distribution over time. The analysis is done using ANSYS. Thermal analysis determines temperatures and other thermal quantities. The accurate thermal simulation could help critical design parameters to be identified for improved life.
Presently the Material used for manufacturing cylinder fin body is Cast Iron. In this thesis, usage of materials like Cast Copper and Aluminum alloy 6082 is 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.

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 a 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:

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

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 preignition 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:
Thermal efficiency is decreased due to more loss of heat to the cylinder walls.
The evaporation of fuel is less; this results in fall of combustion efficiency.
Low temperatures increase the viscosity of lubrication and hence more piston friction is encountered, thus decreasing the mechanical efficiency. Though more cooling improves the volumetric efficiency, yet the factors

mentioned above result in the decrease of overall efficiency. Thus it may be observed that only sufficient cooling is desirable and any deviation from the optimum limits will result in the deterioration of the engine performance.

Experimental Procedure

The main aim of this is to design cylinder with fins for Passion Plus 100cc engine, by changing the geometry, distance between the fins and thickness of the fins and to analyze the thermal properties of the fins. Analysis is also done by varying the materials of fins. Presently used material for cylinder fin body is Cast Iron.
The 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.
Geometry of fins – Original model and Modified Model
For Original Model - Thickness of fins – 2mm and Distance between the fins – 7.5mm
For Modified model - Thickness of fins – 1.5mm and Distance between the fins for combustion side 9.8mm and for opp side 4.25 mm
Materials – Cast Iron, Cast Copper and Aluminum alloy 6082

Steps Involved In This Are

1. Modeling
2. 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.

Mathematical Calculations
1. Original Model
Heat Transfer Through Fins
Fin Thickness - 2mm and Fin Distance - 7.5mm

Length of fin (L)=65.3mm=0.06538m
Width of fin (W)=53.71mm=0.05371m
Thickness δ=2mm
2δ=4mm=0.004m
Perimeter of fin (P) =$2W+4\delta$
$=2\times53.71+4\times2=115.42$mm=0.11542m
Cross sectional area of fin $A_c=L\times W=65.38\times53.71=3511.5598mm^2$
$=0.0035115m^2$
K=conductivity of fin material =50w/mk
=0.05w/mmk
h=heat transfer coefficient =39.9w/m^2k=0.0399 w/mm^2k

$m=\sqrt{\frac{hp}{kA_c}}==\sqrt{\frac{0.11542\times39.9}{50\times0.003511}}=5.12184$ 1/m

$\Theta=T-T_a=237K$
Where T=temperature of cylinder head=550K
T_a=atmospheric temperature=313K
x=distance measured from base of fin=70.38mm=0.07038m

$$\Theta=\Theta_o\times\left(\frac{hcoshml+kmsinhml}{mkcoshml+hsinhml}\right)\times sinhmx$$

$$237=\Theta_o\times\left(\frac{39.9\times\cos(39.9\times5.12184\times0.06538)+50\times5.12184\sin(39.9\times5.12184\times0.0653)}{5.1218\times50\times\cos(39.9\times5.1218\times0.0653)+39.9\times\sin(39.9\times5.1218\times0.06538)}\right)\times\sin(39.9\times5.12184\times0.0703)$$

Θ_o=246.9800K

HEAT LOST BY FIN

$$Q=KA_cm\Theta_o\left(\frac{hcoshml+kmsinhml}{mkcoshml+hsinhml}\right)$$

Q =50
$\times 0.003511 \times 5.12184 \times 246.98 \times (0.9595) = 213.0755w$

Effectiveness OF FIN

$\epsilon = \frac{\text{heat lost with fin}}{\text{heat lost without fin}}$

$\epsilon = \frac{1}{\sqrt{B_i}}\left(\frac{\sqrt{B_i}+\tanh\left(\sqrt{B_i}\times l\right)}{1+\sqrt{B_i}+\tanh\left(\sqrt{B_i}\times l\right)}\right)$

Where B_i=biot number

$B_i = \frac{h\times\delta}{k} = \frac{39.9\times 0.002}{50} = 1.596\times 10^{-3}$

$\epsilon = \frac{1}{\sqrt{1.596\times 10^{-3}}}\left(\frac{\sqrt{1.596\times 10^{-3}}+\tan 39.9\left(\sqrt{1.596\times 10^{-3}}\times 0.06538\right)}{1+\sqrt{1.596\times 10^{-3}}+\tan 39.9\left(\sqrt{1.596\times 10^{-3}}\times 0.06538\right)}\right) = 3.16121$

Effectiveness should be more than 1

Thermal Flux Calculations

Contact area A = 4019 mm^2
Fin area = 3109.38mm^2
Cylinder out side area =15026.4 mm^2
Over all surface area = 4436+15026.4
= 19462.4mm^2
T_i = Inside temperature = 550K
T_o = Outside temperature =313K
ΔT = 237K
d = 50.2 mm

1.1 CAST IRON

Film coefficient = U = 39.9w/m^2K = 0.0000399W/mm^2K

Heat flux

Heat flow q = UAΔT
= 0.0399×4019×237
= 38004.8697w
Heat Flux h = q/a =38004.8697/19462.4= 1.9527 w/mm^2

1.2 ALUMINUM ALLOY 6082

Film coefficient = U = 0.0399 w/ mm^2k

Heat flux

Heat flow $q = UA\Delta T$
=38004.8697w
Heat Flux h = q/a =38004.8697/19462.4= 1.9527 w/mm^2

1.3 CAST COPPER

Film coefficient = U = 0.0399 w/ mm^2k

Heat flux

Heat flow $q = UA\Delta T$
=38004.8697w
Heat Flux h = q/a =38004.8697/19462.4= 1.9527 w/mm^2

II. Modified Model

Fin Thickness 1.5 mm, Fin Distance 9.8 mm for combustion side and 4.25 for opp side

Length of fin (L)=61.8638mm =0.06186m
Width of fin (W)=61.4588mm=0.0614588m
Thickness δ=1.5mm
2δ=3mm=0.003m
Perimeter of fin (P) =2W+4δ
=2×61.45+4×1.5=128.9mm=0.1289m
Cross sectional area of fin A_c=L×W=61.8638×61.4588=3802.074911mm^2
=0.003802m

K=conductivity of fin material =50w/mk
=0.05w/mmk
h=heat transfer coefficient =39.9w/m^{2}k=0.0399 w/mm^{2}k

m= $\sqrt{\frac{hp}{kA_c}}$== $\sqrt{\frac{0.1289\times39.9}{50\times0.003802}}$ =5.20141 1/m^2

ϴ=T-T$_a$=237k
Where T=temperature of cylinder head=550k
T$_a$=atmospheric temperature=313k
x=distance measured from base of fin=61.4558mm=0.0614558 m

ϴ=ϴ$_o$ × $\left(\frac{hcoshml+kmsinh\,ml}{mkcoshml+hsinhml}\right)$ ×sinhmx

237= ϴ$_o$ ×
$\left(\frac{39.9\times\cos(39.9\times5.20141\times0.06186)+50\times5.20141\,\sin(39.9\times5.20141\times0.06186)}{5.2041\times50\times\cos(39.9\times5.20141\times0.06186)+39.9\times\sin(39.9\times5.20141\times0.06186)}\right)$ ×
$\sin(39.9\times5.20141\times0.0614558)$

ϴ$_o$=2913.623958

Heat lost by fin

Q=KA$_c$mϴ$_o$$\left(\frac{hcoshml+kmsinh\,ml}{mkcoshml+hsinhml}\right)$

=50 $\times 0.003802\times5.20141\times2913.62395\times(0.6384)=1839.2026w$

Effectiveness of fin

$\epsilon=\frac{\text{heat lost with fin}}{\text{heat lost without fin}}$

$\epsilon=\frac{1}{\sqrt{B_i}}\left(\frac{\sqrt{B_i}+\tanh(\sqrt{B_i}\times l)}{1+\sqrt{B_i}+\tanh(\sqrt{B_i}\times l)}\right)$

Where B$_i$=biot number

B$_i$=$\frac{\square\times\delta}{k}$=$\frac{39.9\times0.0015}{50}$=1.197×10^{-3}

$\epsilon=\frac{1}{\sqrt{1.197\times10-3}}\left(\frac{\sqrt{1.197\times10-3}+\tan39.9(\sqrt{1.197\times10-3}\times0.06186)}{1+\sqrt{1.197\times10-3}+\tan39.9(\sqrt{1.197\times10-3}\times0.06186)}\right)=1.8105$

Effectiveness should be more than 1

FIN THICKNESS 4mm

Contact area A = 2492.8847 mm
Fin area = 2382.987mm
Cylinder outside area =15092mm
Over all surface area = 19207mm
T$_i$ Inside temperature = 550K
T$_o$ Outside temperature =313K
Δ□ = 237K
d = 50.2 mm

2.1 CAST IRON:

Film coefficient = U = 0.0399w/ mm^{2}K

Heat flux

Heat flow q = UAΔ□
= 0.0399×2492.8847×237
= 23573.4655w
Heat Flux h = q/a =23573.4655/19207= 1.22733w/mm^2

2.2 ALUMINUM ALLOY 6082

Film coefficient = U = 0.0399 w/ mm^{2}k

Heat flux

Heat flow q = UAΔ

= 0.0399×2492.8847×237

= 23573.4655w

Heat Flux h = q/a =23573.4655/19207= 1.22733w/mm^2

2.3 CAST COPPER

Film coefficient = U = 0.0399 w/ mm^{2}k

Heat flux

Heat flow q = UAΔ

= 0.0399×2492.8847×237

= 23573.4655w

Heat Flux h = q/a =23573.4655/19207= 1.22733w/mm^2

III. Results And Discussion

Original Model

	CAST IRON	CAST COPPER	ALUMINUM ALLOY 6082
WEIGHT (KG)	2.35	2.48	0.8936
NODAL TEMPERATURE (K)	550	550	550
THERMAL GRADIENT (K/MM)	208.137	187.34	103.537
THERMAL FLUX (W/MM^2)	10.407	11.802	18.637

Modified Model

	CAST IRON	CAST COPPER	ALUMINUM ALLOY 6082
WEIGHT (KG)	2.126	2.24	0.808
NODAL TEMPERATURE (K)	550	550	550
THERMAL GRADIENT (K/MM)	213.632	188.74	104.635
THERMAL FLUX (W/MM^2)	10.682	11.891	18.834

IV. Conclusion

- In this paper, a cylinder fin body for Passion Plus 100cc motorcycle is modeled using parametric software Pro/Engineer. The original model is changed by changing the geometry of the fin body, distance between the fins and thickness of the fins.
- Present used material for fin body is Cast Iron. In this thesis, thermal analysis is done for all the three materials Cast Iron, Cast Copper and Aluminum alloy 6082. The material for the original model is changed by taking the consideration of their densities and thermal conductivity. Density is less for Aluminum alloy 6082 compared with other two materials so weight of fin body is less using Aluminum alloy 6082. Thermal conductivity is more for Al alloy than other two materials.
- By observing the thermal analysis results, thermal flux is more for Aluminum alloy than other two materials and also by using Aluminum alloy, its weight is less, so using Aluminum alloy 6082 is better.

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