Design and Analysis of Cooling Fins

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Abstract - The cooling mechanism of the air cooled engine is mostly dependent on the fin design of the cylinder head and block. Cooling fins are used to increase the heat transfer rate of specified surface. Engine life and effectiveness can be improved with effective cooling. The main aim of the project is to study and comparing with100 cc Hero Honda Motorcycle fins and analyze the thermal properties by varying geometry, material and thickness. Parametric models of cylinder with fins have been developed to predict the transient thermal behavior. The models are created by varying the geometry like rectangular, circular shaped fins and also by varying thickness of the fins 3mm and 2.5mm. The 3D modeling software used is Pro/Engineer. The analysis is done using ANSYS. Presently Material used for manufacturing the models is grey cast iron which has thermal conductivity of 53.3 W/mK and aluminum alloy 6063 which has thermal conductivity of 200W/mk. We are analyzing the designed models by taking the thermal temperature of 1100^0C

Keywords: Fin, Cylinder, Engine Heat Exchanger.

I. INTRODUCTION

Most internal combustion engines are fluid cooled using either air (a gaseous fluid) or a liquid coolant run through a heat exchanger (radiator) cooled by air. In air cooling system, heat is carried away by the air flowing over and around the cylinder. Here fins are cast on the cylinder head and cylinder barrel which provide additional conductive and radiating surface. In water-cooling system of cooling engines, the cylinder walls and heads are provided with jacket Cooling fins help keep Chevrolet volt battery at ideal temperature We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same. So, this temperature must be reduced to about 150-200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling.

1.2AIR COOLING SYSTEM:

1.2.1There are mainly two types of cooling systems:

1. Air cooled system, and
2. Water cooled system.

1.2.2AIR COOLED SYSTEM

Air cooled system is generally used in small engines say up to 15-20 kW and in aero plane engines. In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. The amount of heat dissipated to air depends upon

- Amount of air flowing through the fins.
- Fin surface area.
- Thermal conductivity of metal used for fins.

ADVANTAGES OF AIR COOLED SYSTEM:

Following are the advantages of air cooled system:

- Radiator/pump is absent hence the system is light.
- In case of water cooling system there are leakages, but in this case there are no leakages.
- Coolant and antifreeze solutions are not required.
- This system can be used in cold climates, where if water is used it may freeze.

DISADVANTAGES OF AIR COOLED SYSTEM:

- Comparatively it is less efficient.
- It is used in aero planes and motorcycle engines where the engines are exposed to air directly.

Methodology

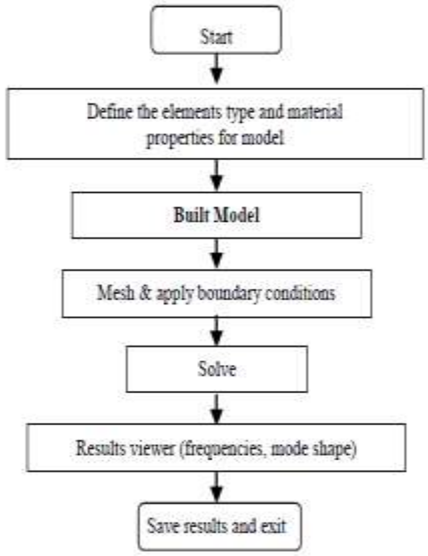
Step 1: Collecting information and data related to cooling fins of IC engines.

Step 2: A fully parametric model of the Engine block with fin is created in Pro-e software.

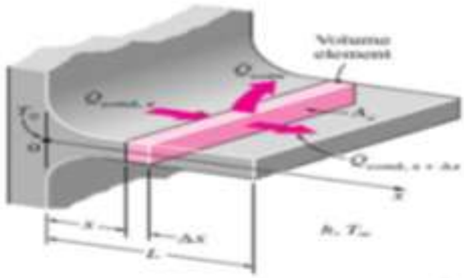
Step 3: Model obtained in Step 2 is analyzed using ANSYS 14.(APDL), to obtain the heat rate , thermal gradient and nodal temperatures.

Step 4: Manual calculations are done.

Step 5: Finally, we compare the results obtained from ANSYS and manual calculations for different material, shapes and thickness.



II. THEORETICAL CALCULATION



Volume element of a fin at location x having a length of Δx, cross-sectional area of A_c, and perimeter of p.

Fin Equation

Consider a volume element of a fin at location x having a length of x, cross-sectional area of Ac, and a perimeter of p, as shown in Fig. Under steady conditions, the energy balance on this volume element can be expressed as

$$\begin{pmatrix}\text{Rate of heat}\\ \text{conduction into}\\ \text{the element x}\end{pmatrix} = \begin{pmatrix}\text{Rate of heat}\\ \text{conduction fron}\\ \text{the element x} + \Delta x\end{pmatrix} + \begin{pmatrix}\text{Rate of heat}\\ \text{convection into}\\ \text{the element}\end{pmatrix}$$

where

$Q_{convection} = h(p\Delta x)(T - Ta)$

$$\frac{d^2\theta}{dx^2} = m^2\theta \text{ , where, } m^2 = \frac{hp}{KA_c}$$

$$\theta(x) = C_1e^{mx} + C_2e^{-mx}$$

fin with finite length and tip un-insulated.

$$Q_{fin} = \sqrt{hpKAc}\,(T_S - T_a)\left(\frac{\tan h(ml) + \frac{h}{Km}}{1 + \frac{h}{Km}\tan h(ml)}\right)$$

$$\frac{\theta}{\theta_0} = \frac{T - Ta}{Ts - Ta} = \frac{\cos h\{m(l-x)\} + \frac{h}{Km}[\sin h\{m(l-x)\}]}{\cos h(ml) + \frac{h}{Km}[\sin h(ml)]}$$

Efficiency of fin (η_{fin}) = $\frac{\text{Actual heat transfer by the fin}}{\text{maximum heat that would be transferred if whole surface of the fin is maintained at the base temperature}}$.

RECTANGULAR FIN

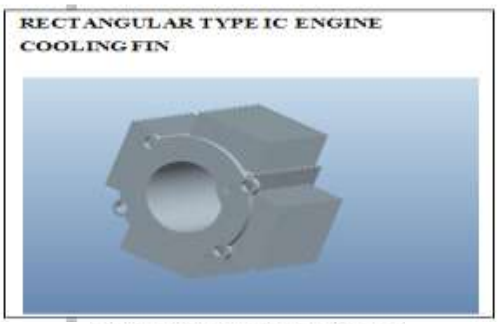
Material	Al -6063		GCI	
Thermal conductivity (K)	200 w/mk	200 w/mk	53.3 w/mk	53.3 w/mk
Heat transfer coefficient (h)	30 w/m²k	30 w/m²k	30 w/m²k	30 w/m²k
Thickness (t)	3 mm	2.5 mm	3 mm	2.5 mm
Length (L)	100mm	100 mm	100 mm	100 mm
Cross –section area(A_C)	600 mm²	500 mm²	600 mm²	500 mm²
Perimeter (P) in meter	0.406 m	0.405 m	0.406 m	0.405 m
Surface temperature (T_S)	1000⁰C	1000⁰C	1000⁰C	1000⁰C
Ambient temperature (T_a)	30⁰C	30⁰C	30⁰C	30⁰C
M	10.074	11.0227	19.5157	21.352
Ml	1.0074	1.10227	1.95157	2.1352
Cosh(ml)	1.5518	1.6715	3.5908	4.2884
Cosh(0.5ml)	1.12956	1.1557	1.5150	1.6261
Sinh(ml)	1.1866	1.3394	3.4488	4.17025
Sinh(0.5ml)	0.5252	0.5794	1.1381	1.2822
tanh(ml)	0.7646	0.8013	0.9604	0.9724
h/Km	0.0148	0.0138	0.0288	0.0263
$T_{x=L/2} = T_a + (T_S - T_a)\frac{\cosh[m(l-x)] + \frac{h}{Km}[\sinh(m(l-x))]}{\cosh(ml) + \frac{h}{Km}[\sinh(ml)]}$	648.08	848.31	292.86	250.55
$T_{x=L} = T_a + (T_S - T_a)\frac{\cosh[m(l-x)] + \frac{h}{Km}[\sinh(m(l-x))]}{\cosh(ml) + \frac{h}{Km}[\sinh(ml)]}$	732.96	982.17	436.85	396.07
$Q_{fin} = \sqrt{hpKAc}\,(T_S - T_a)\left(\frac{\tanh(ml) + \frac{h}{Km}}{1 + \frac{h}{Km}\tanh(ml)}\right)$	903.77	861.9	582.73	537.49

Circular fin

Material	Al -6063		GCI	
Thermal conductivity (K)	200 w/mk	200 w/mk	53.3 w/mk	53.3 w/mk
Heat transfer coefficient (h)	30 w/m²k	30 w/m²k	30 w/m²k	30 w/m²k
Thickness (t)	3 mm	2.5 mm	3 mm	2.5 mm
Length (L)	85mm	85 mm	85 mm	85 mm
Cross –section area(A_C)	1012.47 mm²	843.73 mm²	1012.47 mm²	843.73 mm²
Perimeter (P) in meter	680.98 mm	679.98 mm	680.98 mm	679.98 mm
Surface temperature (T_S)	1000⁰C	1000⁰C	1000⁰C	1000⁰C
Ambient temperature (T_a)	30⁰C	30⁰C	30⁰C	30⁰C
m	10.0443	10.9949	19.4568	21.2982
ml	0.8537	0.9345	1.6538	1.8103
Cosh(ml)	1.3870	1.4693	2.7090	3.1379
Cosh(0.5ml)	1.0924	1.111	1.3618	1.4383
Sinh(ml)	0.9612	1.0765	2.5177	2.974
Sinh(0.5ml)	0.4399	0.4844	0.9244	1.0339
tanh(ml)	0.6929	0.7326	0.9293	0.9478
h/Km	0.0149	0.0136	0.02892	0.02642
$T_{x=L/2} = T_a + (T_S - T_a)\frac{\cosh[m(l-x)] + \frac{h}{Km}[\sinh(m(l-x))]}{\cosh(ml) + \frac{h}{Km}[\sinh(ml)]}$	683.66⁰C	722.20 ⁰C	293.06⁰ C	250.57⁰C
$T_{x=L} = T_a + (T_S - T_a)\frac{\cosh[m(l-x)] + \frac{h}{Km}[\sinh(m(l-x))]}{\cosh(ml) + \frac{h}{Km}[\sinh(ml)]}$	760.52⁰C	790.70⁰ C	437.05⁰ C	395.69⁰C
$Q_{fin} = \sqrt{hpKAc}\,(T_S - T_a)\left(\frac{\tanh(ml) + \frac{h}{Km}}{1 + \frac{h}{Km}\tanh(ml)}\right)$	1329.67 w	1382.15 w	582.67 w	537.28 w

III. FINITE ELEMENT FORMULATIONS

Pro-E Model of Cooling Fins



MODAL ANALYSIS

ANSYS Structural software addresses the unique concerns of pure structural simulations without the need for extra tools. The product offers all the power of nonlinear structural capabilities - as well as all linear capabilities - in order to deliver the highest-quality, most reliable structural simulation results available. ANSYS Structural easily simulates even the largest and most intricate structures.

ANSYS Design Space software is an easy-to-use simulation software package that provides tools to conceptualize design and validate ideas on the desktop. A subset of the ANSYS Professional product, ANSYS design space allows users to easily perform real-world, static structural and thermal, dynamic, weight optimization, vibration mode, and safety factor simulations on all designs without the need for advanced analysis knowledge.

Dynamics software provides incredibly short solution times for even the most complex multi-part assemblies undergoing dramatic translations and rotations. It is an ANSYS Workbench add-on module that works directly with ANSYS Structural, ANSYS Mechanical, and ANSYS Metaphysics.

The following are the material properties

Aluminum alloy 6063

Thermal conductivity K = 200 W/m-K=0.2 W/mm-K

Specific heat Cp = 0.9 J/g0C = 900 J/Kg-K

Density = 2.7 g/cc = 2700 kg/m^3= 0.0000027 kg/mm^3

Grey Cast Iron

Thermal conductivity K=53.3 W/m-K= 0.0533W/mm-K

Specific heat Cp= 490 J/Kg-K

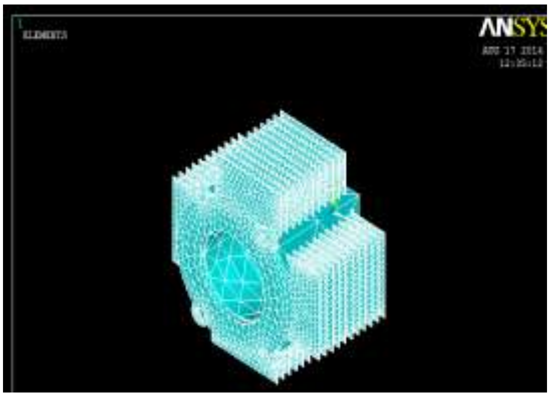
Density=7.1 g/cc = 7100 kg/m^3=0.0000071 kg/mm^3

Boundary conditions:

Thermal Temperature taken in analysis =1100 deg = 1373K

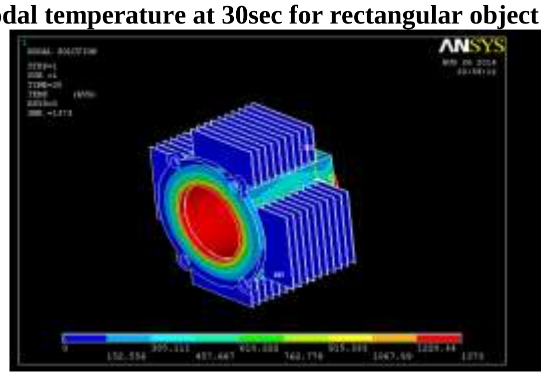
GREY CAST IRON AT CORE AND FIN WITH ALUMINUM ALLOY 6063 –3 Mm THICKNESS (Rectangular)

MESHING MODELS OF RECTANGULAR COOLING FIN



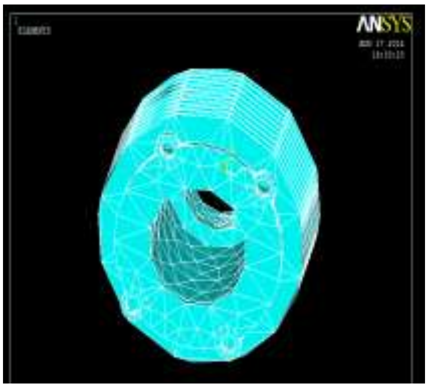
COOLING FINS NODAL TEMPERATURE

Nodal temperature at 30sec for rectangular object

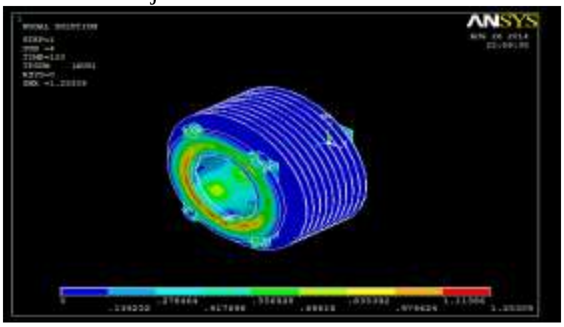


MAXIMUM ABSOLUTE VALUES
NODE 83460
VALUE 1373.0

MESHING MODELS OF CIRCULAR COOLING FIN



for circular object



Analysis Results Table

Rectangular Fin

	3mmthickness		3mmthickness				2.5mmthickness			
	Fin with Aluminum alloy 6063 and core with Grey Cast Iron		Aluminum alloy 6063		Grey Cast Iron		Aluminum alloy 6063		Grey Cast Iron	
	30sec	120sec	30sec	120sec	30sec	120sec	30sec	120sec	30sec	120sec
Nodal Temperature(K)	1373	1415	1465	1374	1685	1410	1373	1374	1483	1375
Thermal Gradient(K/mm)	68.64	23.65	29.33	2.03	70.01	25.83	32.07	3.108	100.3	74.35
Thermal Flux(W/mm^2)	3.66	1.26	5.87	0.46	3.73	1.33	6.42	0.62	5.34	3.96

Circular Fin

	3mmthickness				2.5mmthickness			
	Aluminum alloy 6063		Grey Cast Iron		Aluminum alloy 6063		Grey Cast Iron	
	30sec	120sec	30sec	120sec	30sec	120sec	30sec	120sec
Nodal Temperature(K)	1464	1374	1373	1405	1373	1373	1694	1416
Thermal Gradient(K/mm)	29.81	2.98	69.96	25.29	30.53	3.43	68.87	20.51
Thermal Flux(W/mm^2)	5.96	0.60	3.73	1.35	6.10	0.68	3.67	1.25

IV. CONCLUSIONS

In this paper we have designed a cylinder fin body used in a 100cc Hero Honda Motorcycle and modeled in parametric 3D modeling software Pro/Engineer. Present used material for fin body is aluminum alloy fins and internal core with grey cast iron. We are replacing with Aluminum alloy 6063 and Grey cast iron separately for entire body. The shape of the fin is rectangular; we have changed the shape with circular shaped. The default thickness of fin is 3mm; we are reducing it to 2.5mm.

We have done thermal analysis on the fin body by varying materials, geometry and thickness. By observing the analysis results, using circular fin, material Aluminum alloy 6063 and thickness of 2.5mm is better since heat transfer rate is more. But by using circular fins the weight of the fin body increases. So if we consider weight, using circular fins is better than other geometries. So we can conclude that using material Aluminum alloy 6063 is better, reducing thickness to 2.5mm is better and using fin shape circular by analysis and fin shape curved by weight is better. By observing the results, using circular fins the heat lost is more, efficiency and effectiveness is also more.

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