"ANALYSIS AND OPTIMIZATION OF ENGINE CYLINDER HEAT TRANSFER THROUGH FINS OF VARYING GEOMETRY AND MATERIAL"

M. Ravi Kumar[1], Dr.P.Kumar Babu[2]

[1]Asst. Professor, [2]Professor Department of Mechanical Engineering. Geethanjali College of Engineering and Technology, Hyderabad, T.S 501301-India.,, Sri Mittapalli College of Engineering, Guntur, Andhra Pradesh 522 233-India

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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. In order to cool the cylinder, fins are provided on the cylinder to increase the rate of heat transfer. By doing thermal analysis on the engine cylinder fins, it is helpful to know the heat dissipation inside the cylinder. The principle implemented in this project is to increase the heat dissipation rate by using the invisible working fluid, 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. 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 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, rectangular, circular and curved shaped fins and also by varying thickness of the fins. The 3D modeling software used is Pro/Engineer. Thermal analysis is done on the cylinder fins to determine variation temperature distribution over time. The analysis is done using ANSYS. Transient thermal analysis determine temperatures and other thermal quantities that vary over time. The variation of temperature distribution over time is of interest in many applications such as with cooling. The accurate thermal simulation could permit critical design parameters to be identified for improved life. Presently Material used for manufacturing cylinder fin body is Aluminum Alloy 204which 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: Geometry, Fins, Material, Heat transfer, Effectiveness, Pro-E, ANSYS.

1. INTRODUCTION

Internal Combustion Engine 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.

1.1NECESSITY 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 is25%, Loss to the cylinders walls 30%, Loss in exhaust gases 35%, Loss in friction 10%.

1.2 LITERATURE SURVEY Heat engines generate mechanical power by extracting energy from heat flows, much as a water wheel extracts mechanical power from a flow of mass falling through a distance. Engines are inefficient, so more heat energy enters the engine than comes out as mechanical power; the difference is waste heat which must be removed. Internal combustion engines remove waste heat through cool intake air, hot exhaust gases, and explicit engine cooling .Cooling is also needed because high temperatures damage engine materials and lubricants. Internal-combustion engines burn fuel hotter than the melting temperature of engine materials, and hot enough to set fire to lubricants. Engine cooling removes energy fast enough to keep temperatures low .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. Marine engines and some stationary engines have ready access to a large volume of water at a suitable temperature. The water may be used directly to cool the engine, but often has sediment, which can clog coolant passages, or chemicals, such as salt, that can chemically damage the engine. Thus, engine coolant may be run through a heat exchanger that is cooled by the body of water, .most of liquid-cooled engines use a mixture of water and chemicals such as antifreeze and rust inhibitors. The industry term for the antifreeze mixture is *engine coolant*. Some antifreezes use no water at all, instead using a liquid with different properties, such as propylene glycol or a combination of propylene glycol and ethylene glycol. Most "air-cooled" engines use some liquid oil cooling, to maintain acceptable temperatures for both critical engine parts and the oil itself. Most "liquid-cooled" engines use some air cooling, with the intake stroke of air cooling the combustion chamber. An exception is Wankel engines, where some parts of the combustion chamber are never cooled by intake, requiring extra effort for successful operation.

Only the fixed parts of the engine, such as the block and head, are cooled directly by the main coolant system. Moving parts such as the pistons, and to a lesser extent the crank and rods, must rely on the lubrication oil as a coolant, or to a very limited amount of conduction into the block and thence the main coolant. High performance engines frequently have additional oil, beyond the amount needed for lubrication, sprayed upwards onto the bottom of the piston just for extra cooling. Air-cooled motorcycles often rely heavily on oil-cooling in addition to air-cooling of the cylinder barrels. Liquid-cooled engines usually have a circulation pump. The first engines relied on thermo-syphon cooling alone, where hot coolant left the top of the engine block and passed to the radiator, where it was cooled before returning to the bottom of the engine. Circulation was powered by convection alone.

2. AIR COOLING SYSTEM 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:

- Surface area of metal into contact with air.
- Mass flow rate of air.
- Temperature difference between the heated surface and .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.

3. OBJECTIVE OF THE RESEARCH : The main objective of the project is to design cylinder with fins for a 150cc engine, by changing the geometry and thickness of the fins and to analyze the transient thermal properties of the fins. Analization is also done by varying the materials of fins. Present used material for cylinder fin body is Aluminum alloy 201 which has thermal conductivity of 110 – 150 w/m^{0}k.Main aim is to change the material for fin body by analyzing the fin body with other materials and also by changing the geometry and also thickness .**Geometry of fins** – Rectangular, Circular and Curve Shaped Thickness of fins –3mm and 2.5mm**, Materials** – Aluminum Alloy A204, Aluminum Alloy 6061, Magnesium alloys.

3.1 STEPS INVOLVED IN THE PROJECT

1. MODELING
2. THEORETICAL CALCULATIONS
3. TRANSIENT THERMAL ANALYSIS

3.2 INTRODUCTION TO PRO/E: Pro/ENGINEER, PTC's parametric, integrated **3D CAD/CAM/CAE solution**, is used by discrete manufacturers for mechanical engineering, design and manufacturing. The parametric modeling approach uses parameters, dimensions, features, and relationships to capture intended product behavior and create a recipe which enables design automation and the optimization of design and product development processes. . Pro/ENGINEER provides a complete set of design, analysis and manufacturing capabilities on one, integral, scalable platform. These capabilities, include Solid Modeling, Surfacing, Rendering, Data Interoperability, Routed Systems Design, Simulation, Tolerance Analysis, and NC and Tooling Design.

3.3 MODULES IN PRO/E

- PART DESIGN, ASSEMBLY DRAWING, SHEETMETAL, MANUFACTURING.

4. HEAT TRANSFER THROUGH FINS

4.1RECTANGULAR FINALUMINUM ALLOY 204 – Thickness 3mm

Length of fin (L)=130mm=0.13m,Width of fin (b)=130mm=0.13m,Thickness y=3mm, 2y=6mm=0.006m,Perimeter of fin (P) =2(b+y) =2×0.130+2×0.003=0.266m

Cross sectional area of fin A_c=b×y=130×6=780mm^2 =0.00078m^2

K=conductivity of fin material =120w/m^{o}k

h=heat transfer coefficient =25w/m^{2o}k=0.025w/mm^{2o}k

m= $\sqrt{\frac{hp}{kA_c}}$== $\sqrt{\frac{0.266\times 25}{120\times 0.00078}}$=8.42,ϴ=T-$T_a$= 458-313= 145^{o}k

Where T=temperature of cylinder head=458^{o}k,T_a=atmospheric temperature=313^{o}k

x=distance measured from base of fin=65mm=0.065m

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

145=θ_o×$\left(\frac{120\times 8.42\times \cosh(8.42\times 0.065)+25\sin h(8.42\times 0.065)}{8.34\times 120\times \cosh(8.42\times 0.13)+25\times \sinh(8.42\times 0.13)}\right)$,145=$\theta_o$(0.697), θ_o=207.83^{o}k

Heat lost by fin Q_{fin}=KA_cmθ_o($\frac{hcosh(ml)+kmsinh(ml)}{mkcosh(ml)+hsinh(ml)}$

$=120 \times 0.00078 \times 207.83 \times 8.42 \left(\frac{25\times \cosh(8.42\times 0.13)+120\times 8.42\sin h(8.42\times 0.13)}{8.42\times 120\times \cosh(8.42\times 0.13)+25\times \sinh(8.42\times 0.13)}\right) = 132.369W$

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

$Q_{max}=h(Pl)(t_0-t_a) = h(Pl)\,\theta_o$= 120×(0.266×0.13)×207.83 = 862.711W

$\eta = (Qfin/Qmax)$ = (132.36/862.711)×100 = 15.3, Effectiveness of fin $\epsilon = \frac{\text{heat lost with fin}}{\text{heat lost without fin}}$ $\epsilon = \sqrt{(pk/hA)}$= $\sqrt{(2k/hy)}$=$\sqrt{\{(2\times 120)/(25\times 0.003)\}}$= 56.56

4.2ALUMINUM ALLOY 6061 – Thickness 3mm

Length of fin (L)=130mm=0.13m,Width of fin (b)=130mm=0.13m,Thickness y=3mm

2y=6mm=0.0006mPerimeter of fin (P) =2(b+y) =2×0.130+2×0.003=0.266m

Cross sectional area of fin A_c=b×y=130×6=780mm^2 =0.00078m^2

K=conductivity of fin material =180w/m^{o}k,h=heat transfer coefficient =25W/m^{2}K

m= $\sqrt{\frac{hp}{kA_c}}$= $\sqrt{\frac{0.266\times 25}{180\times 0.00078}}$ =6.8, ϴ=T-T_a=145k

Where T=temperature of cylinder head=458^{o}k,T_a=atmospheric temperature=313^{o}k

X=distance measured from base of fin=65mm=0.065m

$\Theta=\Theta_o\times(\frac{km\cosh[m(l-x)]+h[\sinh\{m(l-x)\}]}{km\cosh(ml)+h[\sinh(ml)]}$

145= $\Theta_o\times(\frac{180\times6.8\times\cosh(6.8\times0.065)+25\sinh(6.8\times0.065)}{6.8\times180\times\cosh(6.8\times0.13)+25\times\sinh(6.8\times0.13)}$, 145=$\Theta_o\times$(0.77), Θ_o=187.57°k

Heat lost by fin Q=$KA_cm\Theta_o$ $(\frac{h\cosh ml+km\sinh ml}{mk\cosh ml+h\sinh ml})$

=180×0.00078×6.8×187.57$(\frac{25\times\cosh(6.8\times0.13)+180\times6.8\sinh(6.8\times0.13)}{6.8\times180\times\cosh(6.8\times0.13)+25\times\sinh(6.8\times0.13)})$=128.640$W$

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

Q_{max}=h (Pl) (t_0-t_a) = h (Pl)Θ_o= 180×(0.266×0.13)×187.57 = 1167.5W

η = (Qfin/Qmax) = (128.640/1167.5) ×100 = 11

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

$\epsilon=\sqrt{(pk/hA)}=\sqrt{(2k/hy)}=\sqrt{\{(2\times180)/(25\times0.003)\}}$= 69.28

4.3MAGNESIUM – Thickness 3mm

Length of fin (L)=130mm=0.13m,Width of fin (b) =130mm=0.13mThickness y=3mm 2y=6mm=0.006m,Perimeter of fin (P) =2(b+y) =2×0.130+2×0.003=0.266m

Cross sectional area of fin A_c=b×y=130×6=780mm^2 =0.00078m^2

K=conductivity of fin material =159w/m°k,h=heat transfer coefficient =25W/m^{2}K

m= $\sqrt{\frac{hp}{kA_c}}=\sqrt{\frac{0.266\times25}{159\times0.00078}}$ =7.32,Θ=T-T_a=145°k

Where T=temperature of cylinder head=458°k,T_a=atmospheric temperature=313°k

X=distance measured from base of fin=65mm=0.065m

$\Theta=\Theta_o\times(\frac{km\cosh[m(l-x)]+h[\sinh\{m(l-x)\}]}{km\cosh(ml)+h[\sinh(ml)]})$

145= $\Theta_o\times(\frac{159\times7.32\times\cosh(7.32\times0.065)+25\sinh(7.32\times0.065)}{7.32\times159\times\cosh(7.32\times0.13)+25\times\sinh(7.32\times0.13)})$, 145=$\Theta_o\times$0.751, Θ_o=192.92°k

Heat lost by fin Q=$KA_cm\Theta_o$ $(\frac{h\cosh ml+km\sinh ml}{mk\cosh ml+h\sinh ml})$

=159×0.00078×7.3×192.92$(\frac{25\times\cosh(7.32\times0.13)+159\times7.32\sinh(7.32\times0.13)}{7.32\times159\times\cosh(7.32\times0.13)+25\times\sinh(7.32\times0.13)})$=131.21$W$

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

Q_{max}=h (Pl) (t_0-t_a) = h (Pl)Θ_o= 159×(0.265×0.13)×192.92 = 1056.7

η = (Qfin/Qmax) = (131.21/1056.7) ×100 = 12.4

Effectiveness of fin$\in = \frac{\text{heat lost with fin}}{\text{heat lost without fin}}$

$\epsilon = \sqrt{(pk/hA)} = \sqrt{(2k/hy)} = \sqrt{\{(2 \times 159)/(25 \times 0.003)\}} = 65.11$

4.4 CIRCULAR FINALUMINUM ALLOY 204 with 3 mm fin thickness

Circular diameter of fin=145mm, $A_c = \frac{\pi}{4} d^2 = \frac{\pi}{4} 145^2$=16504.625mm^2=0.0165m^2

K=conductivity of fin material =120W/Mk, h=heat transfer coefficient=25w/m^{2}k=0.000025w/mm^{2}k, $p=2\pi r=2\pi(72.5) = 455.3mm = 0.4553m$

$m = \sqrt{\frac{hp}{kA_c}} == \sqrt{\frac{0.4553 \times 25}{120 \times 0.0165}}$ =2.39, $\theta=T-T_a=145^o k$

Where T=temperature of cylinder head=458^o k,T_a=atmospheric temperature=313^{o}k

X=distance measured from base of fin=65mm=0.065m

$\theta = \theta_o \times \left(\frac{k m \cosh[m(l-x)] + h[\sinh\{m(l-x)\}]}{k m \cosh(ml) + h[\sinh(ml)]}\right) 145 = \theta_o \times \left(\frac{120 \times 2.39 \times \cosh(2.39 \times 0.065) + 25 \sinh(2.39 \times 0.065)}{2.39 \times 120 \times \cosh(2.39 \times 0.13) + 25 \times \sinh(2.39 \times 0.13)}\right)$

$145 = \theta_o \times (1)$, $\theta_o = 145^o k$

Heat lost by fin$Q = KA_c m \theta_o \left(\frac{h\cosh ml + k m \sinh ml}{m k \cosh ml + h \sinh ml}\right)$

$=120 \times 0.0165 \times 2.39 \times 145 \left(\frac{25 \times \cosh(2.39 \times 0.13) + 120 \times 2.39 \sinh(2.39 \times 0.13)}{2.39 \times 120 \times \cosh(2.39 \times 0.13) + 25 \times \sinh(2.39 \times 0.13)}\right) = 269.98W$

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

Q_{max}=h (Pl) (t_0-t_a) = h (Pl)θ_o= 120×(0.455×0.13)×145 = 1029.2W

$\eta = (Qfin/Qmax) = (131.21/1029.2) \times 100 = 26.23$

Effectiveness of fin for 3mm

$\in = \frac{\text{heat lost with fin}}{\text{heat lost without fin}}$ $\epsilon = \sqrt{(pk/hA)} = \sqrt{(2k/hy)} = \sqrt{\{(2 \times 120)/(25 \times 0.003)\}} = 56.56$,Effectiveness of fin for 2.5mm
$\in = \frac{\text{heat lost with fin}}{\text{heat lost without fin}}$

$\epsilon = \sqrt{(pk/hA)} = \sqrt{(2k/hy)} = \sqrt{\{(2 \times 120)/(25 \times 0.0025)\}} = 61.96$

MAGNESIUM Circular diameter of

$,m = \sqrt{\frac{hp}{kA_c}} == \sqrt{\frac{0.4553 \times 25}{159 \times 0.0165}}$ =2.08 ,$\theta=T-T_a=145^o k$

Where T=temperature of cylinder head=458K, T_a=atmospheric temperature=313K

X=distance measured from base of fin=65mm=0.065m

$\theta = \theta_o \times \left(\frac{k m \cosh[m(l-x)] + h[\sinh\{m(l-x)\}]}{k m \cosh(ml) + h[\sinh(ml)]}\right) 145 = \theta_o \times \left(\frac{159 \times 2.08 \times \cosh(2.08 \times 0.065) + 25 \sinh(2.08 \times 0.065)}{2.08 \times 159 \times \cosh(2.08 \times 0.13) + 25 \times \sinh(2.08 \times 0.13)}\right)$

$145=\Theta_o\times(0.969)$, $\Theta_o=149.52^o k$, Heat lost by fin, $Q=KA_c m\Theta_o(\frac{hcoshml+kmsinhml}{mkcoshml+hsinhml})$

$=159\times 0.0165\times 2.08\times 149.52(\frac{25\times\cosh(2.08\times0.13)+159\times2.08\sinh(2.08\times0.13)}{2.08\times159\times\cosh(2.08\times0.13)+25\times\sinh(2.08\times0.13)})=272.47W$

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

$Q_{max}=h(Pl)(t_0-t_a) = h(Pl)\Theta_o= 159\times(0.4553\times0.13)\times149.52 = 1407.14$

$\eta = (Qfin/Qmax) = (272.47/1407.14)\times100 = 19.3$

Effectiveness of fin for 3mm thickness

$\in=\frac{\text{heat lost with fin}}{\text{heat lost without fin}}$, $\epsilon= \sqrt{(pk/hA)}= \sqrt{(2k/hy)}=\sqrt{\{(2\times159)/(25\times0.003)\}}=65.11$

Effectiveness for 2.5 mm

$\in=\frac{\text{heat lost with fin}}{\text{heat lost without fin}}\epsilon= \sqrt{(pk/hA)}= \sqrt{(2k/hy)}=\sqrt{\{(2\times159)/(25\times0.0025)\}}=71.33$

4.5 CURVED SURFACEALUMINUM ALLOY 204 – Thickness 3mm

Length of fin (L) =130mm=0.13mWidth of fin (b) =130mm=0.13mThickness y=3mm

2y=6mm=0.006m, Perimeter of fin (P) = 0.129m (taken from pro-e)

Cross sectional area of fin $A_c=b\times y=130\times6=780mm^2=0.00078m^2$

K=conductivity of fin material =120W/mK,h=heat transfer coefficient=25W/m²k=0.025w/mm²K

$m=\sqrt{\frac{hp}{kA_c}}==\sqrt{\frac{0.129\times25}{120\times0.00078}}=5.98$, $\Theta=T-T_a=145^o k$

Where T=temperature of cylinder head=458^0k,T_a=atmospheric temperature=313^0k

x=distance measured from base of fin=65mm=0.065m

$\Theta = \Theta_o\times(\frac{kmcosh[m(l-x)]+h[\sin h\{m(l-x)\}]}{kmcosh(ml)+h[sinh(ml)]})$, $145=\Theta_o\times(\frac{120\times5.98\times\cosh(5.98\times0.065)+25\sin h(5.98\times0.065)}{5.98\times120\times\cosh(5.98\times0.13)+25\times\sinh(5.98\times0.13)}$

$145=\Theta_o\times(0.975)$, $\Theta_o=148.71^0 k$

Heat lost by fin $Q=KA_c m\Theta_o(\frac{hcosh(ml)+kmsinh(ml)}{mkcosh(ml)+hsinh(ml)})$

$=120\times0.000785\times5.98\times148.71\left(\frac{25\times\cosh(0.598\times0.13)+120\times5.98\sin h(5.98\times0.13)}{5.98\times120\times\cosh(5.98\times0.13)+25\times\sinh(5.98\times0.13)}\right)=69.84W$

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

$Q_{max}=h(Pl)(t_0-t_a) = h(Pl)\Theta_o= 120\times(0.129\times0.13)\times148.71 = 299.26$

$\eta = (Qfin/Qmax) = (69.84/299.26)\times100 = 23.33\%$

Effectiveness of fin for 3mm$\in=\frac{\text{heat lost with fin}}{\text{heat lost without fin}}$

ϵ= $\sqrt{(pk/hA)}$= $\sqrt{(2k/hy)}$=$\sqrt{\{(2\times 120)/(25\times 0.003)\}}$=56.56

ALUMINUM ALLOY 6061 – Thickness 3mm

Length of fin (L)=130mm=0.13m,Width of fin (b)=130mm=0.13m

Thickness y=3mm ,2y=6mm=0.006m

Perimeter of fin (P) =0.129mCross sectional area of fin ,A_c=b×y=130×6=780mm^2= 0.00078m^2

K=conductivity of fin material =180W/mKh=heat transfer coefficient =25W/m^{2}K

m= $\sqrt{\frac{hp}{kA_c}}$= $\sqrt{\frac{0.129\times 25}{180\times 0.00078}}$ =4.79Θ=T-T_a=145^{o}k

Where T=temperature of cylinder head=458^{o}kT_a=atmospheric temperature=313^{0}k

X=distance measured from base of fin=65mm=0.065m

$\theta=\theta_o\times\left(\frac{k m\cosh[m(l-x)]+h[\sinh\{m(l-x)\}]}{k m\cosh(ml)+h[\sinh(ml)]}\right)$,145= $\theta_o\times\left(\frac{180\times 4.79\times\cosh(4.79\times 0.065)+25\sinh(4.79\times 0.065)}{4.79\times 180\times\cosh(4.79\times 0.13)+25\times\sinh(4.79\times 0.13)}\right)$

145=θ_o×0.868, θ_o=166.94^{0}k

Heat lost by finQ=$KA_cm\theta_o\left(\frac{h\cosh ml+km\sinh ml}{mk\cosh ml+h\sinh ml}\right)$

=180×0.00078×4.79×166.94×$\left(\frac{25\times\cos h(4.79\times 0.13)+180\times 4.79\sinh(4.79\times 0.13)}{4.79\times 180\times\cosh(4.79\times 0.13)+25\times\sinh(4.79\times 0.13)}\right)$= 64.49$W$

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

Q_{max}=h (Pl) (t_0-t_a) = h (Pl)θ_o= 180×(0.129×0.13)×166.94 = 503.925w

η = (Qfin/Qmax) = (64.49/503.925) ×100 = 12.7%

Effectiveness of fin for 3mm∈=$\frac{\text{heat lost with fin}}{\text{heat lost without fin}}$

ϵ= $\sqrt{(pk/hA)}$= $\sqrt{(2k/hy)}$=$\sqrt{\{(2\times 180)/(25\times 0.003)\}}$=69.28

MAGNESIUM – Thickness 3mm

Length of fin (L)=130mm=0.13mWidth of fin (b) =130mm=0.13m

Thickness y=3mm,2y=6mm=0.0006m

Perimeter of fin (P) =0.129 Cross sectional area of fin, A_c=b×y=130×6=780mm =0.00078m^2

K=conductivity of fin material =159W/mK,h=heat transfer coefficient =25W/m^{2}K

m= $\sqrt{\frac{hp}{kA_c}}$= $\sqrt{\frac{0.127\times 25}{159\times 0.00078}}$ =5.059, Θ=T-T_a=145^{o}k

Where T=temperature of cylinder head=458^{o}k

T_a=atmospheric temperature=313°k, X=distance measured from base of fin=65mm=0.065m

$\Theta=\Theta_o\times\left(\frac{km\cosh[m(l-x)]+h[\sinh\{m(l-x)\}]}{km\cosh(ml)+h[\sinh(ml)]}\right)$

$145=\Theta_o\times\left(\frac{159\times5.05\times\cosh(5.05\times0.065)+25\sinh(5.05\times0.065)}{5.05\times159\times\cosh(5.05\times0.13)+25\times\sinh(5.05\times0.13)}\right)$, $145=\Theta_o\times0.86$, $\Theta_o=168.41$°k

Heat lost by fin $Q=KA_cm\Theta_o\left(\frac{h\cosh ml+km\sinh ml}{mk\cosh ml+h\sinh ml}\right)$

$=159\times0.000784\times5.06\times168.41\left(\frac{25\times\cosh(5.06\times0.13)+159\times5.06\sinh(5.06\times0.13)}{5.06\times159\times\cosh(5.06\times0.13)+25\times\sinh(5.06\times0.13)}\right)=62.76W$

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

$Q_{max}=h\,(Pl)\,(t_0-t_a) = h\,(Pl)\,\Theta_o= 159\times(0.129\times0.13)\times168.41 = 449.05$

$\eta = (Qfin/Qmax) = (62.76/449.05)\times100 = 13.9\%$

Effectiveness of fin for 3mm $\epsilon=\frac{\text{heat lost with fin}}{\text{heat lost without fin}}$

$\epsilon=\sqrt{(pk/hA)}=\sqrt{(2k/hy)}=\sqrt{\{(2\times159)/(25\times0.003)\}}=65.11$

5. Types of Engineering Analysis

- Structural analysis, Vibrational analysis, Fatigue analysis, Heat Transfer analysis.

5.1Finite Element Analysis In practice, a finite element analysis usually consists of three principal steps:

- **Preprocessing**: The user constructs a model of the part to be analyzed in which the geometry is divided into a number of discrete sub regions, or elements," connected at discrete points called nodes." Certain of these nodes will have fixed displacements, and others will have prescribed loads. .
- **Analysis**: The dataset prepared by the preprocssor is used as input to the finite element code itself, which constructs and solves a system of linear or nonlinear algebraic equations.
- **Post processing**: In the earlier days of finite element analysis, the user would pore through reams of numbers generated by the code, listing displacements and stresses at discrete positions within the model. It is easy to miss important trends and hot spots this way, and modern codes use graphical displays to assist in visualizing the results.

6. INTRODUCTION TO ANSYS

Generic Steps to Solving any Problem in ANSYS.

Build Geometry Construct a two or three dimensional representation of the object to be modeled and tested using the work plane coordinate system within ANSYS.

Define Material Properties Now that the part exists, define a library of the necessary materials that compose the object (or project) being modeled. This includes thermal and mechanical properties.

Generate Mesh At this point ANSYS understands the makeup of the part. Now define how the modeled system should be broken down into finite pieces.

Apply Loads Once the system is fully designed, the last task is to burden the system with constraints, such as physical loadings or boundary conditions.

Obtain Solution This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved.

Present the Results After the solution has been obtained, there are many ways to present ANSYS' results, choose from many options such as tables, graphs, and contour plots.

7. THERMAL ANALYSIS

Thermal Analysis is also often used as a term for the study of Heat transfer through structures. Many of the basic engineering data for modeling such systems comes from measurements of heat capacity and Thermal conductivity. Many heat transfer applications such as heat treatment problems, electronic package design, nozzles, engine blocks, pressure vessels, fluid-structure interaction problems, and so on involve transient thermal analysis

7.1THERMAL ANALYSIS OF FIN BODY

7.1.1RECTANGULAR FINALUMINUM ALLOY 204 –3mm

MODEL IMPORTED FROM PRO/ENGINEER

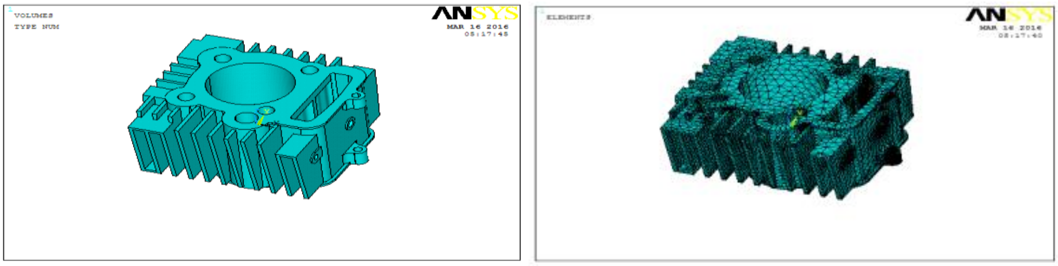


Fig.no1a. Model imported from PRO/Engineer b. Meshed of Al Alloy204 3mm (Rec)

MATERIAL PROPERTIES: Thermal Conductivity – 120 w/mk,Specific Heat – 0.963 J/gm°c, Density – 2.8 gm/cc, **APPLIEDLOADS:** Temperature -558°K,Film Coefficient – 25 w/m²K,Bulk Temperature – 313 °k ,**RESULTS:**NODAL TEMPERATURE

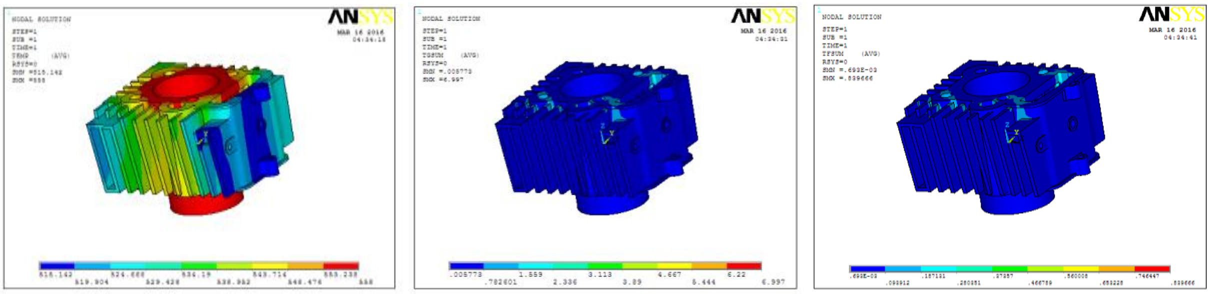


Fig.no2 a. Nodal Temperature in °k b. Thermal gradient °K/mm c.Thermal flux W/mm²

RECTANGULAR FINALUMINUM ALLOY 6061 – 3mm

MATERIAL PROPERTIES: Thermal Conductivity – 180 w/mk,Specific Heat – 0.896 J/gm ºC

Density – 2.7 gm/cc, LOADS: Temperature -558°K,Film Coefficient – 25 w/m²K,Bulk Temperature – 313 °K

RESULTS:

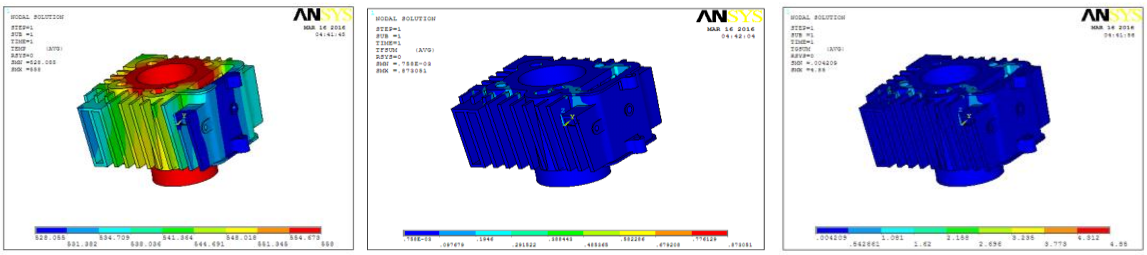


Fig.no 3 a.Nodal Temperature in ⁰K b. Thermal gradient °K/mm c. Therrmal heat flux W/mm²

RECTANGULAR FIN MAGNESIUM – 3mm Thickness

MATERIAL PROPERTIES: Thermal Conductivity – 159 w/mk Specific Heat – 1.45 J/gm ºC

Density – 2.48gm/cc, LOADS: Temperature -558ºKFilm Coefficient – 25 w/m² K,Bulk Temperature – 313ºKLoad Step opts – Write LS file – Ok, **RESULTS:**

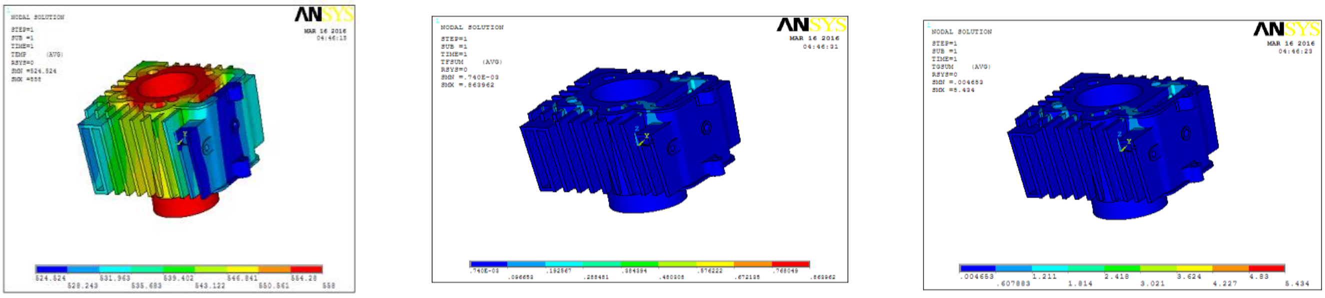


Fig.no 4 a. Nodal Temperature in ⁰K, b. Thermal gradient ºK/mm, c.Thermal heat flux W/mm²

RECTANGULAR FIN: ALUMINUM ALLOY 204 – 2.5mm

MODEL IMPORTED FROM PRO/ENGINEER

Fig.no 5 a. Model Imported from PRO/engineer b. Meshed of Al-Alloy 204-2.5 mm (Rec)

MATERIAL PROPERTIES: Thermal Conductivity – 120 w/mk Specific Heat – 0.963 J/gm ºC

Density – 2.8 gm/cc,

APPLIED LOADS: Temperature -558⁰K,Film Coefficient – 25 w/m²K,Bulk Temperature – 313º K,

RESULTS

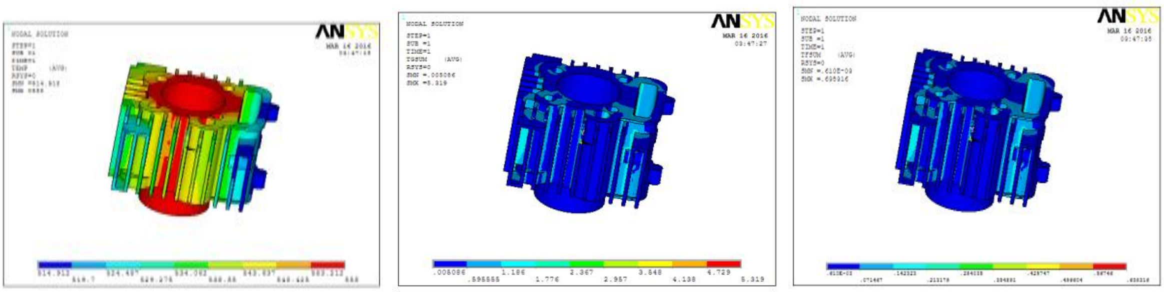


Fig no 6 a. Nodal Temperature in ºK, b.Thermal gradient ºK/mm, c.Thermal heat flux W/mm²

RECTANGULAR FINALUMINUM ALLOY 6061 – 2.5mm

MATERIAL PROPERTIES: Thermal Conductivity – 180 w/mk Specific Heat – 0.896 J/gm ºC

Density – 2.7 gm/cc, **APPLIED LOADS**: Temperature -558ºKFilm Coefficient – 25 w/m² K

Bulk Temperature – 313^o K,

RESULTS:

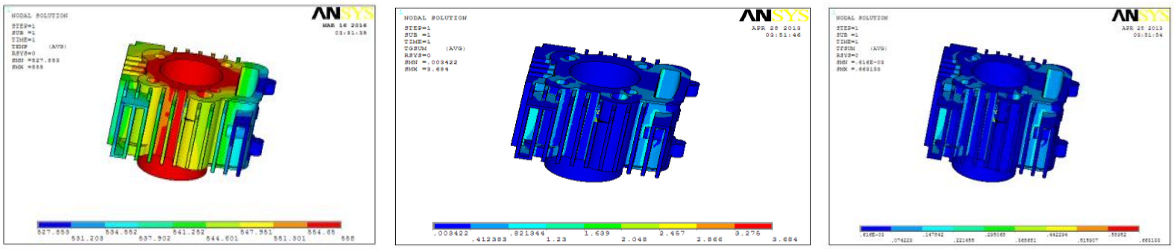


Fig.no 7 a. Nodal Temperature in ^{0}K b. Thermal Gradient in ^{0}K/mm, c.Thermal heat fluxW/mm^2

MAGNESIUM – 2.5mm, MATERIAL PROPERTIES: Thermal Conductivity – 159 w/mk, Specific Heat – 1.45 J/gm ^oC, Density – 2.48 gm/cc**, APPLIED LOADS:** Temperature -558^oKFilm Coefficient – 25 w/m^{2}K,Bulk Temperature – 313^ok
RESULTS:

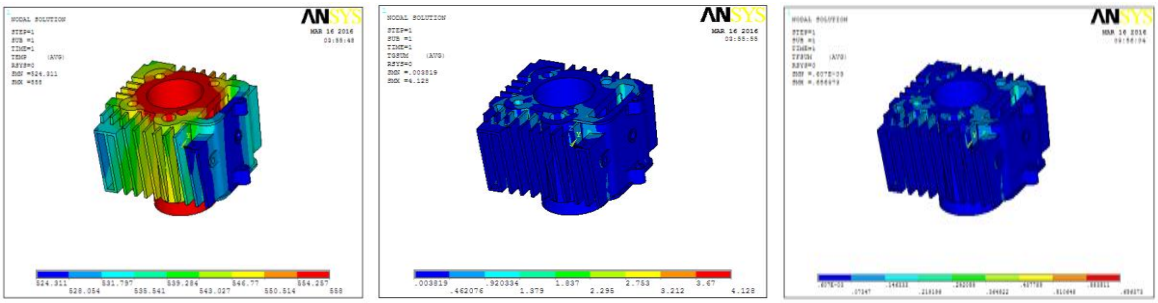


Fig no 8 a. Nodal Temperature in ^{0}K, b. Thermal Gradient in ^{o}K/mm^2, c.Thermal heat flux W/mm^2

8. RESULTS TABLE (RECTANGULAR FIN)

	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)	6.997	4.85	5.434	5.319	3.684	4.128
Thermal Flux (w/mm^2)	0.839666	0.873051	0.863962	0.638316	0.66133	0.656373

Table no 1 a. Nodal temperature(^{o}K), b. Thermal Gradient (^{o}K/mm) c. Thermal Flux(W/mm$^{2)}$

9. CIRCULAR FIN ALUMINUM ALLOY 204 –3mm MODEL IMPORTED FROM PRO/E

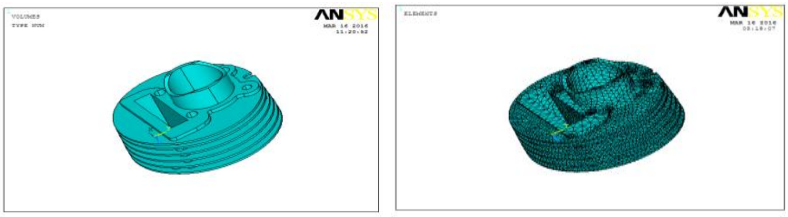


Fig. no9 a.Model Imported from PRO/E, b.Meshed model of Al-Alloy 204-3mm Circular fin

MATERIAL PROPERTIES: Thermal Conductivity – 120 w/mk, Specific Heat – 0.963 J/gm ºC, Density – 2.8 gm/cc **APPLIED LOADS**: Temperature -558ºK,Film Coefficient – 25w/m^{2}K,BulkTemperature313^{0}K ,**RESULTS:**

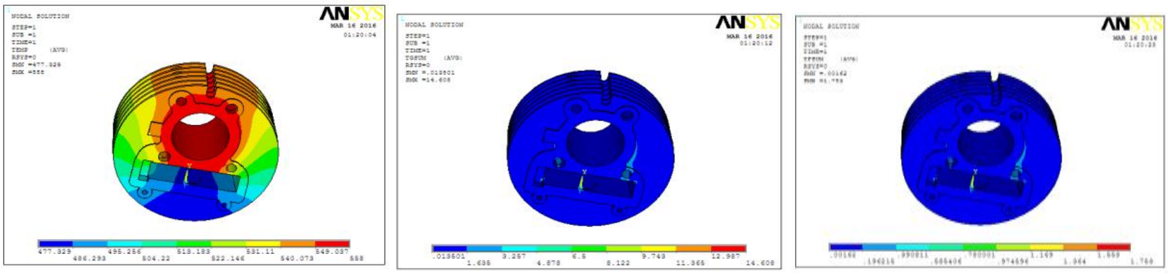


Fig.no10 a. Nodal Temperature in ºK b. Thermal Gradient in ^{0}K/mm c. Heat flux W/mm^2

ALUMINUM ALLOY 6061 – 3mm Thickness(CIRCULAR FIN)

MATERIAL PROPERTIES: Thermal Conductivity – 180 w/mk Specific Heat – 0.896 J/gm ºC

Density – 2.7 gm/cc, **LOADS:** Temperature -558ºK,Film Coefficient – 25 w/m^{2}K**,**Bulk Temperature – 313º K,

RESULTS:

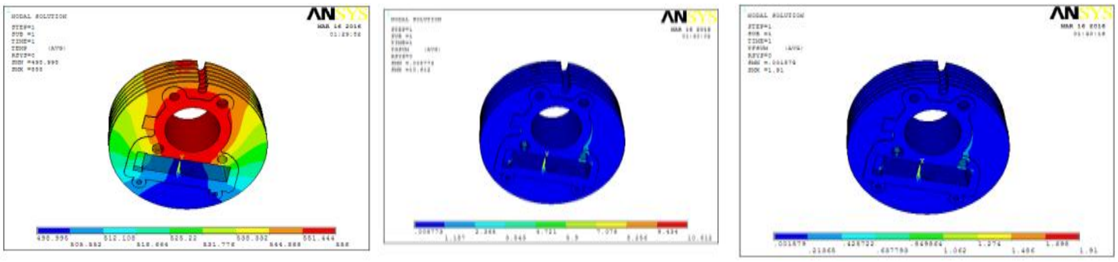


Fig.no11 a. Nodal temperature in ºK, b.Thermal Gradient in ºK/mm,c.Thermal flux W/mm^2

MAGNESIUM – 3mm (CIRCULAR FIN)

MATERIAL PROPERTIES: Thermal Conductivity – 159 w/mk, Specific Heat – 1.45 J/gm ºC

density – 2.48 gm/cc, **LOADS**:Temperature -558ºK,Film Coefficient – 25 w/m^{2}K,Bulk Temperature – 313º K **RESULTS:**

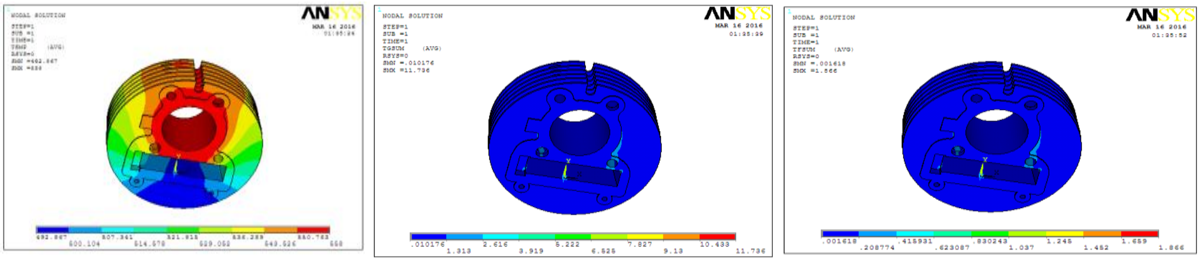


Fig.no 12 a. Nodal Temperature in °K, b.Thermal gradient in °K/mm, c.Thermal flux W/mm²

ALUMINUM ALLOY 204 – 2.5mm (CIRCULAR FIN)

MODEL IMPORTED FROM PRO/E

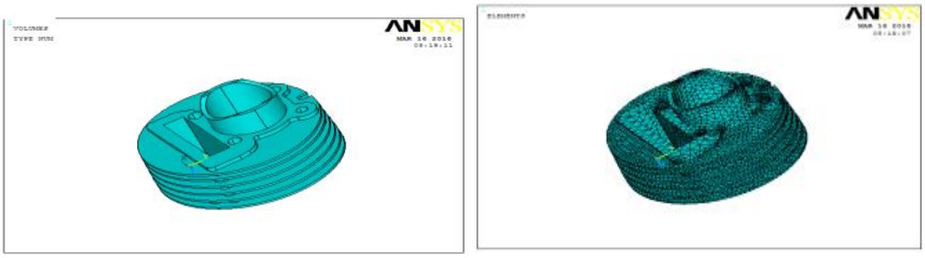


Fig.no13 a. Model Imported from PRO/E b.Al-Alloy 204 2.5mm(circular)

MATERIAL PROPERTIES: Thermal Conductivity – 120 w/mk,Specific Heat – 0.963 J/gm ºC

Density – 2.8 gm/cc ,**LOADS:** Temperature -558°K,Film Coefficient – 25 w/m²K,Bulk Temperature – 313° K,

RESULTS:

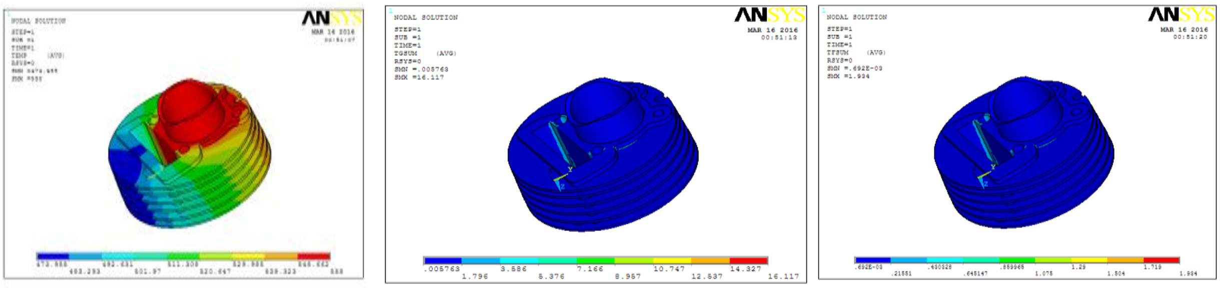


Fig.no14 a. Nodal Temperature in °K, b.Thermal gradient °K/mm, c.Thermal heat flux W/mm²

ALUMINUM ALLOY 6061 – 2.5mm (CIRCULAR FIN)

MATERIAL PROPERTIES: Thermal Conductivity – 180 w/mk Specific Heat – 0.896 J/gm ºC

Density – 2.7 gm/cc, **LOADS:** Temperature -558°KFilm Coefficient – 25 w/m²KBulk Temperature – 313° K

RESULTS:

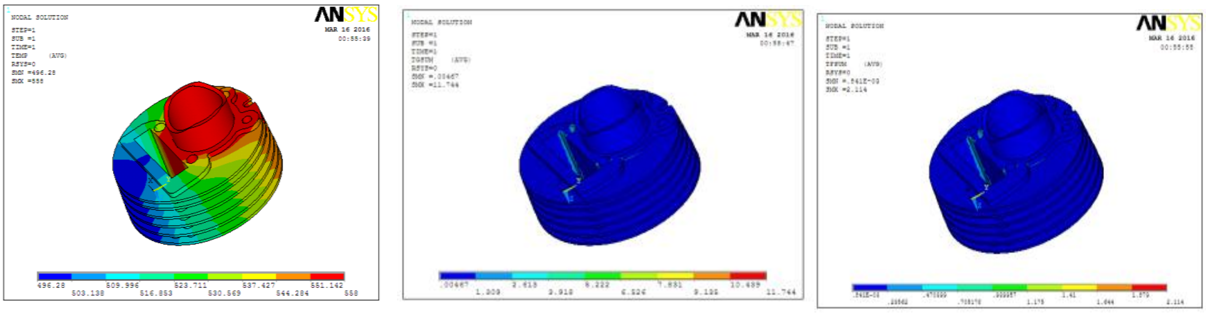


Fig.no15a. Nodal Temperature in ^{0}K,b. Thermal Gradient in ^{o}K/mm, c. Thermal Heat Flux in W/mm^2

MAGNESIUM – 2.5mm Thickness(CIRCULAR FIN)

MATERIAL PROPERTIES: Thermal Conductivity – 159 w/mk, Specific Heat – 1.45 J/gm ºC

Density – 2.48 gm/cc, **LOADS:** Temperature -558^{o}K, Film Coefficient – 25 w/m^{2}K,Bulk Temperature – 313^o K,

RESULTS:

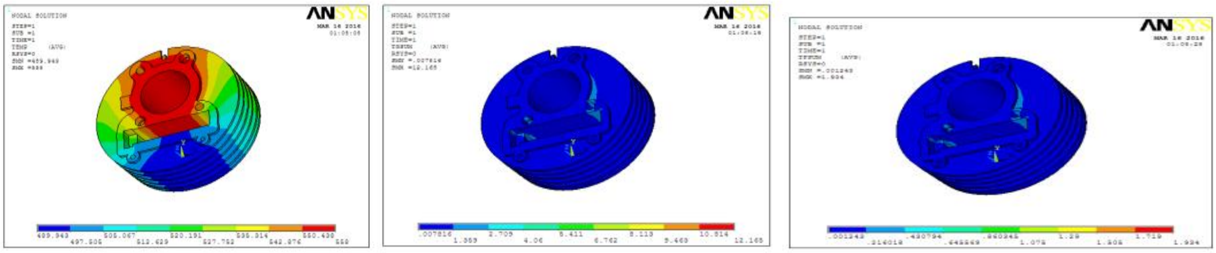


Fig.no 16a.Nodal Temperature in ^{o}K b.Thermal Gradient in ^{o}K/mm c. Thermal Heat Flux in W/mm^2

10. Circular Fins

	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)	14.608	10.612	11.736	16.117	11.744	12.165
Thermal Flux (w/mm^2)	1.753	1.91	1.866	1.934	2.114	1.934

Table no 2 of Nodal Temperature(^{o}K),Thermal Gradient(^{o}K/mm)&Thermal Flux(W/mm^2)

11. CURVED FIN ALUMINUM ALLOY 204 –3mm, MODEL IMPORTED FROM PRO/E

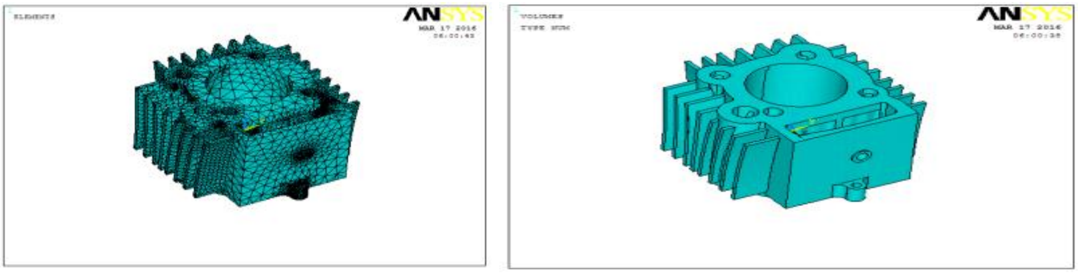
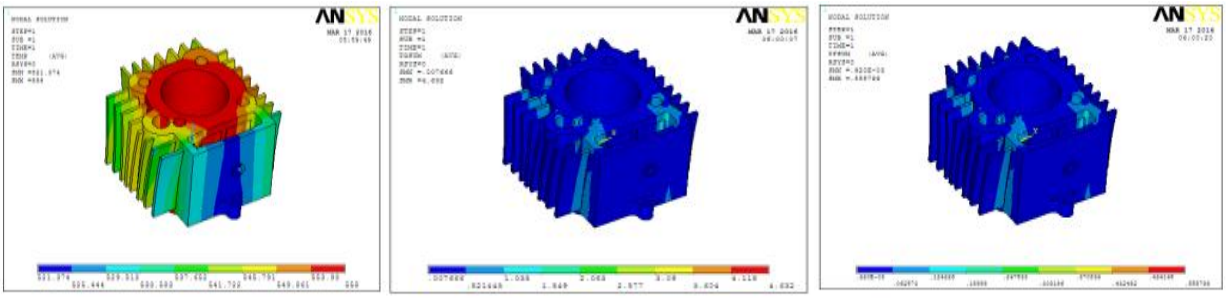


Fig.no 17 .Meshed of Al-Alloy 3mm curved fin b. Model imported from PRO/E

MATERIAL PROPERTIES: Thermal Conductivity – 120 w/mk**,** Specific Heat – 0.963 J/gm ºC**,** Density – 2.8 gm/cc, **APPLIED LOADS:** Temperature -558ºK, Film Coefficient – 25 w/m²K,Bulk Temperature – 313º K , **RESULTS:**



Figno 18 a.Nodal Temperature in ºK, b. Thermal gradient ºK/mm, c Thermal flux W/mm²

ALUMINUM ALLOY 6061 – 3mm (CURVED FIN)

MATERIAL PROPERTIES: Thermal Conductivity – 180 w/mk**,**Specific Heat – 0.896 J/gm ºC
Density – 2.7 gm/cc, **LOADS:** Temperature -558ºK, Film Coefficient – 25 w/m²K**,**Bulk Temperature – 313º K ,

RESULTS:

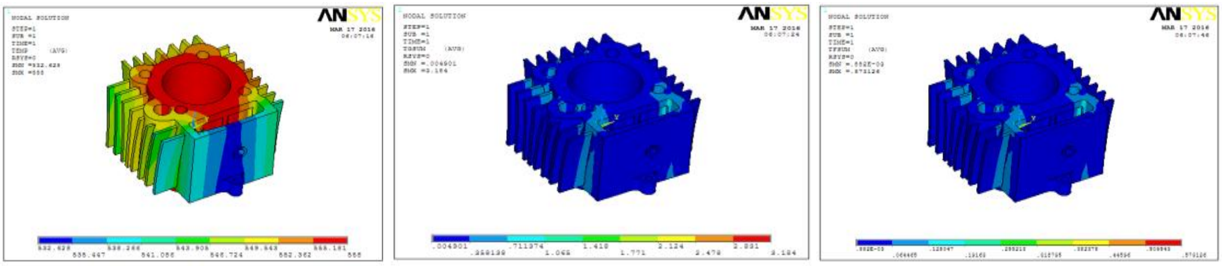


Fig.no 19 a.Nodal Temperature in ºK,b. Thermal Gradient in ⁰K/mm, c.Thermal Heat flux W/mm²

MAGNESIUM – 3mm (CURVED FIN)

MATERIAL PROPERTIES: Thermal Conductivity – 159 w/mk**,** Specific Heat – 1.45 J/gm ºC
Density – 2.48 gm/cc, **LOADS:** Temperature -558ºK, Film Coefficient – 25 w/m²K,Bulk Temperature – 313º K,**RESULTS:NODAL TEMPERATURETHERMAL GRADIENT**

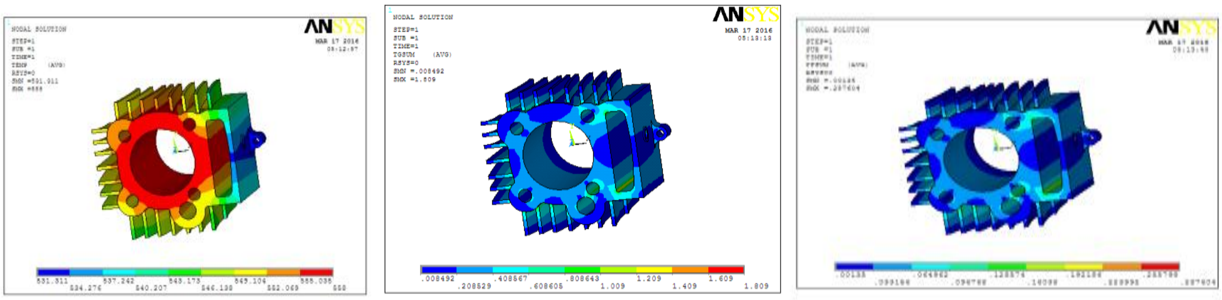


Fig.no20 a. Nodal temperature in ^{o}k,b. Thermal Gradient in ^{o}k/mm, c.Thermal Flux W/mm^{2}

ALUMINUM ALLOY 204 – 2.5mm (CURVED FIN),MODEL IMPORTED FROM PRO/ENGINEER

Fig.no 21 a.Model imported from PRO/E b.Meshed model of Al-Alloy-204-2.5mm (curved fin)

MATERIAL PROPERTIES: Thermal Conductivity – 120 w/mk
Specific Heat – 0.963 J/gm ºC Density – 2.8 gm/cc
LOADS: Temperature -558^{o}K, Film Coefficient – 25 w/m^{2}K,Bulk Temperature – 313^{o} K

RESULTS:

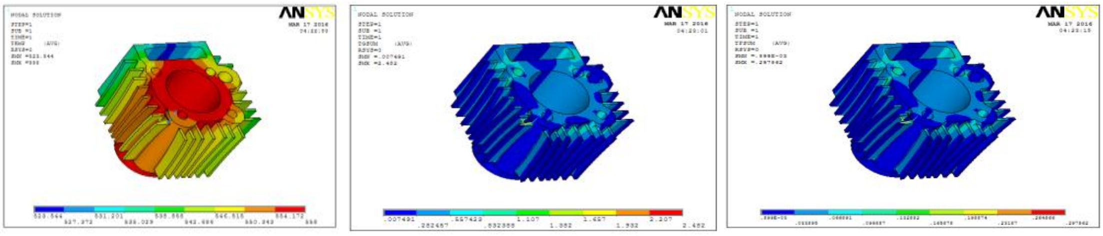


Fig.no22 a. Nodal Temperature in ^{0}k b.Thermal Gradient in ^{o}K/mm c. Thermal Flux in W/mm^{2}

ALUMINUM ALLOY 6061 – 2.5mm Thickness
MATERIAL PROPERTIES: Thermal Conductivity – 180 w/mk Specific Heat – 0.896 J/gm ºC
Density – 2.7 gm/cc, **LOADS:** Temperature -558^{o}K,Film Coefficient – 25 w/m^{2}K**,**Bulk Temperature – 313^{o} K ,

RESULTS:

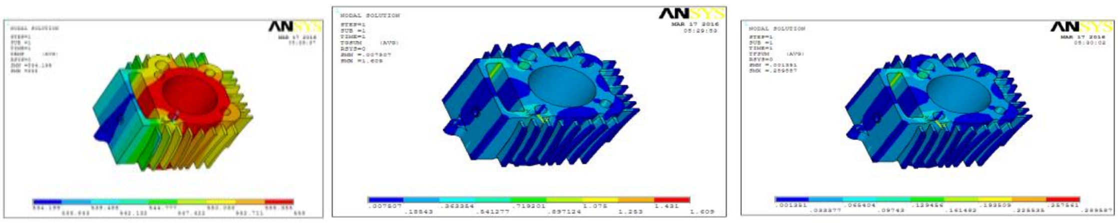


Fig.no 23 a. Nodal Temperature in ^{o}K, **b.**Thermal Gradient in ^{o}k/mm c. Thermal Flux in W/mm^{2}

MAGNESIUM – 2.5mm (CURVED FIN)

MATERIAL PROPERTIES: Thermal Conductivity – 159 w/mk, Specific Heat – 1.45 J/gm ºC

Density – 2.48 gm/cc, **LOADS:** Temperature -558 K Film Coefficient – 25 w/m²KBulk Temperature – 313 K,

RESULTS:

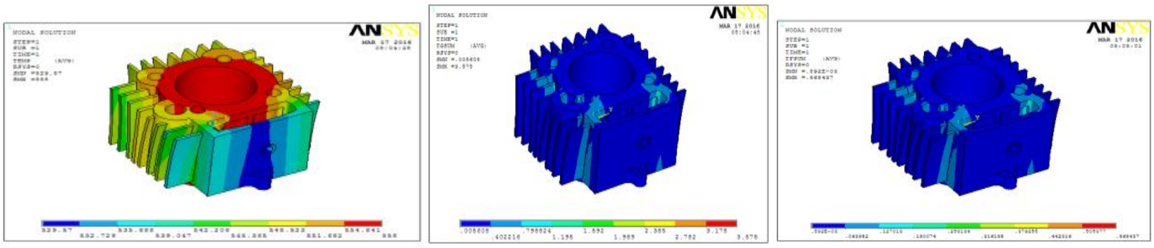


Fig.no24 a. Nodal Temperature in °k, b.Thermal Gradient in° k/mm c. Thermal Flux in W/mm²

12. Curved Fins(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)	4.632	3.184	1.809	2.482	1.609	3.575
Thermal Flux (w/mm²)	0.555799	0.573126	0.287604	0.297862	0.289587	0.568437

Table no 3 Results of Nodal Temp(°k),Thermal Gradient(°k/mm)&Thermal Flux(w/mm²)

13. MASS OF CYLINDER FINS

13.1THICKNESS 3mm FINS

	Al 204	Al 6061	Mg
Rectangular	1.0100279Kg	9.7395552 e^{-1} Kg	8.9459618 e^{-1}Kg
Circular section	1.1846582 Kg	1.1423490Kg	1.0492687 Kg
Curved fins	8.9376056 e^{-1}Kg	8.6184054 e^{-1} Kg	7.9161649 e^{-1}Kg

13.2 THICKNESS 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
Circular section	1.1204059 Kg	1.0803914 Kg	9.9235955 e^{-1} Kg
Curved fins	9.2521898 e^{-1} Kg	8.927545 e^{-1} Kg	8.1947967 e^{-1} Kg

14. CONCLUSION In this project we have designed a cylinder fin body used in a 150cc Hero Honda Motor cycle and modeled in parametric 3D modeling software Pro/Engineer. Present used material for fin body is Aluminum alloy 204. We are replacing with Aluminum alloy 6061 and magnesium alloy. The shape of the fin is rectangular; we have changed the shape with circular and curve shaped. The default thickness of fin is 3mm; we are reducing it to 2.5mm.In this project we have designed a cylinder fin body used in a 100cc Hero Honda Motor cycle .

1. 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.
2. 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 6061 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 curved fins is better than other geometries.
3. So we can conclude that using material Aluminum alloy 6061 is better, reducing thickness to 2.5mm is better and using fin shape circular by analysis and fin shape curved by weight is better.
4. We have also done theoretical calculations to determine the heat lost and effectiveness.

ACKNOWLEDGEMENT

The authors can acknowledge any person/authorities in this section. This is not mandatory.

15. REFERENCES

[1].J. P. Hallman, A text book of Heat Transfer, TM
[2] D.Q. Kern, A.D. Kraus, Extended Surface Heat Transfer, McGraw Hill Book Company, 1972
[3].Poulikakos, A. and Bejan, A., "Fin Geometry for Minimum Entropy Generation in Forced Convection" ASME Journal of Heat Transfer, Vol 104, pp. 616-623.
[4].Incropera F. P., DeWitt D. P.,1996, "Fundamentals of heat and mass transfer", 4th Edition, John Wiley & Sons, Pg. No. : 147-172.
[5]. P. K. Nag, 2006, "Heat & Mass Transfer", 2nd Edition, Tata McGraw Hill Co. Pg. No.: 86-108 & 425-449
[6]. J. P. Holman, 2004, "Heat Transfer", 9th Edition, Tata McGraw Hill Co," Pg. No. 43-53 & 315-350
[7].Incropera F. P., DeWitt D. P.,1996, "Fundamentals of heat and mass transfer", 4th Edition, John Wiley & Sons, Pg. No. : 147-172.
[8]. G.D. Raithby, K.G.T. Holland's, ''Natural convection, handbook of heat transfer fundamentals,'' 2nd ed., W. M. Rohsenow, J. P. Hartnett and E. N. Ganic, eds, McGraw-Hill, New York, 1985.
[9]. J.R. Bodoia, J.F. Osterle, "The development of free convection between heat vertical plates," ASME J. Heat Transfer, vol. 84, 1962, pp. 40-44
[10]. Vollaro A.D.L, Grignaffini S, Gugliermetti F, "Optimum Design of Vertical Rectangular Fin Arrays", International Journal of Thermal Sciences 38, 525-259, (1999).
[11]. Sane N. K, and Sukhatme S. P, 1974, "Natural Convection Heat Transfer from Short Horizontal Rectangular Fin Arrays," Fifth International Heat Transfer Conference, Tokyo, Sept.
[12]. Jones, C. D, and Smith, L. F, 1970, "Optimum Arrangement of Rectangular Fins on Horizontal Surface for Free Convection Heat Transfer," ASME Paper No. 69-HT-44.
[13. Mitre J.F, Santana L.M, Damian R.B "numerical study of turbulence heat transfer in 3d channels" Applied Thermal Engineering, 2010, pp (2796-2803) Department of Mechanical Engineering.