COMPARISION ON THERMAL ANALYSIS OF ALUMINUM ALLOY 1199 FINS WITH ALUMINUM ALLOY 204 BY VARIATION TEMPERATURE DISTRIBUTION

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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, nothing but 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 determines 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. using these cooling fins is to cool the engine cylinder by any air. Transient thermal analysisThermal analysis is done on the fins to determine variation temperature distribution over time. The analysis is done using ANSYS. Analysis is conducted by varying material.Presently Material used for manufacturing fin bodyT is Grade Aluminum alloy 204 having the thermal conductivity 110-150W/mk. In our project we are conducting transient thermal analysis for above material, but for increasing the convection, we are going to replace above material with Aluminum alloy 1199 since it has Thermal conductivity of 240W/mk. We are conducting transient thermal analysis for above two materials and validating which material is best for fin body.

I.INTRODUCTION TO CYLINDER FIN BODY

COOLING SYSTEM FOR I.C. ENGINES

Internal combustion engines at best can transform about 25 to 35 percentage of the chemical energy in the fuel in to mechanical energy. About 35 percentage of the heat generated is lost in to the surroundings of combustion space, remainder being dissipated through exhaust' and radiation from the engine. The temperature of the burning gases in the engine cylinder is about 2000 to 2500° C. The engine components like cylinder head, cylinder wall piston and the valve absorb this heat. Such high temperatures are objectionable for various reasons state below.

Necessity for Engine Cooling

1) Engine valves warp (twist) due to over heating.
2) Damage to the materials of cylinder body and piston.
3) Lubricating oil decomposes to form gummy and carbon particles.
4) Thermal stresses are set up in the engine parts and causes distortion (twist or change shape) and cracking of components.
5) Pre – ignition occurs (i.e. ignition occurs before it is required to igniter due to the overheating of spark plug.
6) Reduces the strength of the materials used for piston and piston rings.
7) Overheating also reduces the efficiency of the engine.

To avoid the above difficulties, some form of cooling is provided to keep the temperature of engine at the desired level. It should be noted that if the engine becomes every cool the efficiency reduces, because starting the engine from cold requires more fuel.

Requirements of a good Cooling System

(i) It should remove only about 30% of the heat generated in the combustion chamber. Too much cooling reduces the thermal efficiency of the engine.
(ii) A good cooling system should remove heat at a faster rate when the engine is hot. During starting, the cooling should be very slow.

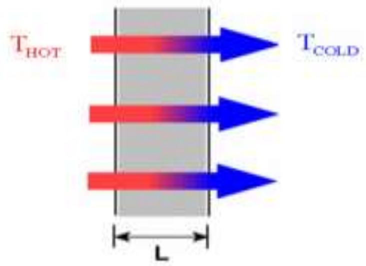
The components in the cylinder must be reasonably hot (250°C).

Over-cooling of the engine results in insufficient vaporization of fuel, loss of power, high fuel consumption, higher emissions, starting troubles, excessive formation of sludge, lower thermal efficiency and greater wear and tear of parts.

Conduction and convection

There are three mechanisms responsible for heat transfer: conduction, convection, and radiation. Conduction describes heat flowing inside a body, with the latter most often modeled as a CAD part or assembly. Convection and radiation both involve heat exchange between the solid body and the environment.

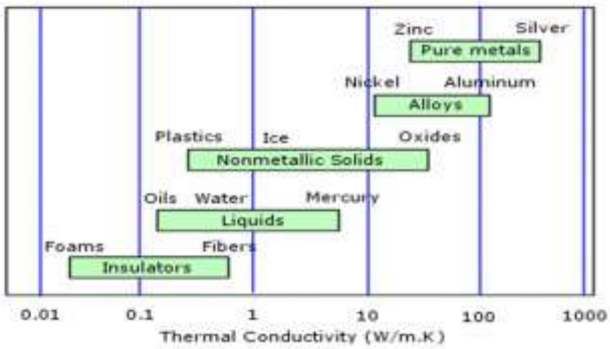
An example of heat transfer by conduction is heat flow across a wall. The amount of transferred heat is proportional to the temperature difference between the hot side THOT and the cold side TCOLD of the wall, to the area A of the wall, and to the reciprocal of the wall thickness L. The proportionality factor K, called thermal conductivity, is a well-known material property (Figure).



$$Q_{CONDUCTION} = K A (T_{HOT} - T_{COLD}) / L$$

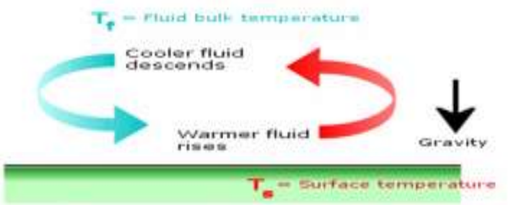
Heat is conducted through the wall from the higher to the lower temperature.

Thermal conductivity K varies widely for different materials; this factor is what differentiates between heat conductors and insulators (Figure).



CONDUCTION COEFFICIENTS FOR DIFFERENT MATERIALS

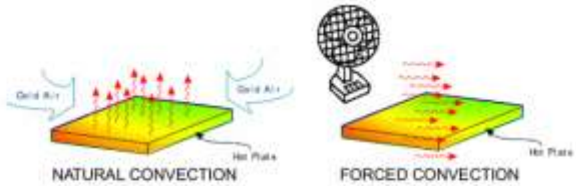
The mechanism of heat exchange between an external face of a solid body and the surrounding fluid such as air, steam, water, or oil is called convection. The amount of heat moved by convection is proportional to the temperature difference between the solid body face TS and the surrounding fluid TF, and to the area A of the face exchanging (dissipating or gaining) heat. The proportionality factor h is called the convection coefficient, also known as a film coefficient. Heat exchange between the surface of a solid body and its surrounding fluid requires movement of the fluid (Figure).



$$Q_{CONVECTION} = h A (T_S - T_F)$$

HEAT DISSIPATED BY CONVECTION ALWAYS REQUIRES MOVEMENT OF THE FLUID SURROUNDING THE BODY.

The convection coefficient strongly depends on the medium (e.g., air, steam, water, oil) and the type of convection: natural or forced. Natural convection can only take place in the presence of gravity because fluid movement is dependent on the difference between the specific gravity of cold and hot fluids. Forced convection is not dependent on gravity (Figures).

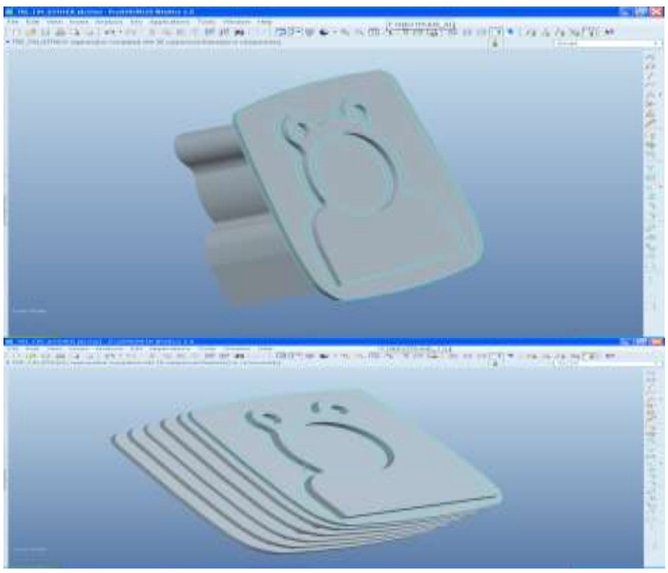


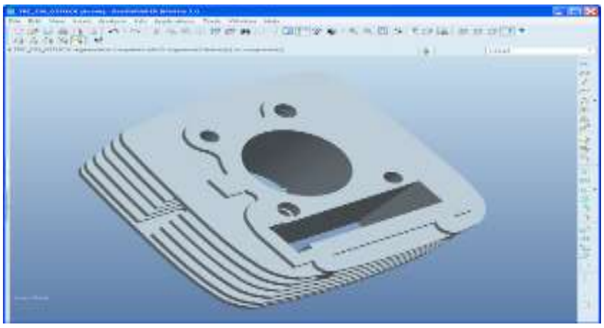
NATURAL CONVECTION IS INDUCED BY A DIFFERENCE IN HOT AND COLD FLUID DENSITY. IN FORCED CONVECTION, FLUID MOVEMENT IS FORCED, FOR EXAMPLE, BY A COOLING FAN.

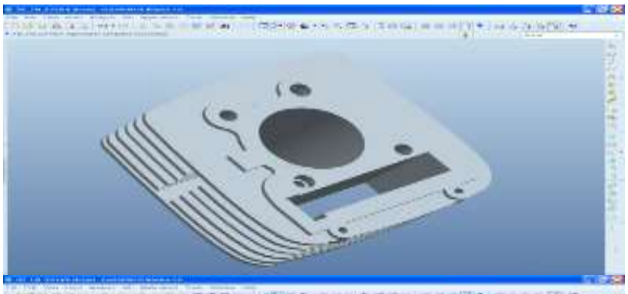
Medium	Heat Transfer Coefficient h ($W/m^2 . K$)
Air (natural convection)	5-25
Air/superheated steam (forced convection)	20-300
Oil (forced convection)	60-1800
Water (forced convection)	300-6000
Water (boiling)	3000-60,000
Steam (condensing)	6000-120,000

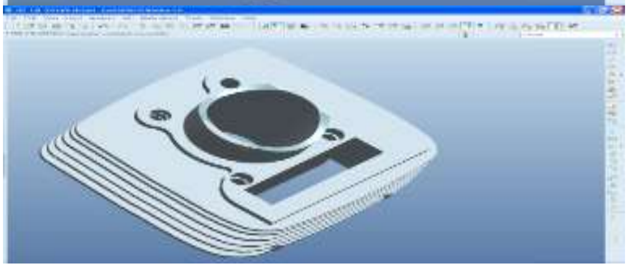
HEAT CONVECTION COEFFICIENTS FOR DIFFERENT MEDIA AND FOR DIFFERENT TYPES OF CONVECTION.

MODEL OF PISTON BORE FIN BODY

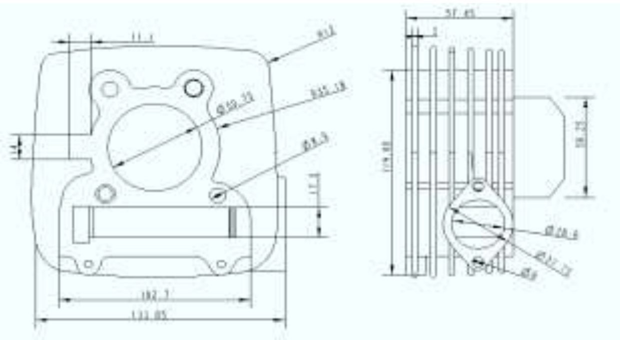








2D DRAWING



HEAT TRANSFER THROUGH FINS

ALUMINUM ALLOY 204

Length of fin (L)=130mm=0.13m
Width of fin (W)=130mm=0.13m
Thickness δ=3mm
2δ=6mm=0.0006m
Perimeter of fin (P) =2W+4δ
=2×130+4×3=272mm=0.272m
Cross sectional area of fin A_c=L×W=130×130=16900mm^2
=0.0169m^2
K=conductivity of fin material =120w/mk
=0.12w/mmk
h=heat transfer coefficient =25w/m^{2}k=0.025w/mm^{2}k

$m=\sqrt{\frac{hp}{kA_c}}==\sqrt{\frac{0.272\times 25}{120\times 0.0169}}$ =1.831 1/m^2

Θ=T-T_a=145k
Where T=temperature of cylinder head=458k
T_a=atmospheric temperature=313k
x=distance measured from base of fin=65mm=0.065m

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

$145=\Theta_o\times$
$\left(\frac{25\times cos25\times 1.831\times 0.13+120\times 1.831\ sin\ 25\times 1.831\times 0.13}{1.831\times 120\times cos25\times 1.831\times 0.13+25\times sin25\times 1.831\times 0.13}\right)\times$
$sin25\times 1.831\times 0.065$

145=$\Theta_o\times$ (0.0109)
Θ_o=13302.75

Heat lost by fin

$Q=KA_cm\Theta_o\left(\frac{hcoshml+kmsinhml}{mkcoshml+hsinhml}\right)$
=120
$\times 0.0169\times 1.831\times$
$13302.75\left(\frac{25\times cos25\times 1.831\times 0.13+120\times 1.831\times sin\ 25\times 1.831\times 0.13}{1.831\times 120\times cos25\times 1.831\times 0.13+25\times sin25\times 1.831\times 0.13}\right)$

$=49396.67\times\left(\frac{47.644}{221.12}\right)=10643.001w/m$

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

$B_i=\frac{h\times\delta}{k}=\frac{25\times 0.003}{120}=6.25\times 10^{-4}$

$\epsilon=\frac{1}{\sqrt{6.25\times 10^{-4}}}\left(\frac{\sqrt{6.25\times 10^{-4}}+\tan25\left(\sqrt{6.25\times 10^{-4}}\times 0.13\right)}{1+\sqrt{6.25\times 10^{-4}}+\tan25\left(\sqrt{6.25\times 10^{-4}}\times 0.13\right)}\right)=$
1.124

Effectiveness should be more than 1.

ALUMINUM ALLOY 1199

Length of fin (L)=130mm=0.13m
Width of fin (W)=130mm=0.13m
Thickness δ=3mm
2δ=6mm=0.0006m
Perimeter of fin (P) =2W+4δ
=2×130+4×3=272mm=0.272m
Cross sectional area of fin A_c=L×W=130×130=16900mm^2
=0.0169m^2
K=conductivity of fin material =240w/mk
=0.24w/mmk
h=heat transfer coefficient =25w/m^{2}k=0.025w/mm^{2}k

$m=\sqrt{\frac{hp}{kA_c}}==\sqrt{\frac{0.272\times 25}{240\times 0.0169}}$ =1.295 per m^2

Θ=T-T_a=145k
Where T=temperature of cylinder head=458k
T_a=atmospheric temperature=313k
x=distance measured from base of fin=65mm=0.065m

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

$145=\Theta_o \times (\frac{25\times cos25\times1.295\times0.13+240\times1.295\ sin\ 25\times1.295\times0.13}{1.295\times240\times cos25\times1.295\times0.13+25\times sin25\times1.295\times0.13}) \times sin25\times1.295\times0.065$

$\Theta_o=25794.28$

Heat lost by fin

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

$=240\times0.0169\times1.295\times25794.28\left(\frac{25\times cos25\times1.295\times0.13+240\times1.295\times sin\ 25\times1.295\times0.13}{1.295\times240\times cos25\times1.295\times0.13+25\times sin25\times1.295\times0.13}\right)$

$=20741.1581 w/m$

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

$B_i=\frac{h\times\delta}{k}=\frac{25\times0.003}{240}=3.125\times10^{-4}$

$\epsilon=\frac{1}{\sqrt{3.125\times10^{-4}}}\left(\frac{\sqrt{3.125\times10^{-4}}+\tan25(\sqrt{3.125\times10^{-4}}\times0.13)}{1+\sqrt{3.125\times10^{-4}}+\tan25(\sqrt{3.125\times10^{-4}}\times0.13)}\right)$

$=1.1348$

Effectiveness should be more than 1.

Thermal Flux and Gradient Calculations

Contact area A = 12957.3 mm^2

Fin area = 8402.86 mm^2

Cylinder out side area =15825.27 mm^2

Over all surface area = 8402.86 + 15825.27

= 24228.13mm^2

T_i Inside temperature = 458K

T_o Outside temperature =313K

ΔT = 145K

d = 50.75 mm

Aluminum 204: Film coefficient = U = 0.019w/mm^2K

Aluminum 1199: Film coefficient = U = 0.0243 w/mm^2K

Heat flux for Al 204

Heat flow q = UAΔT

= 0.019x12957.3 x145

= 35697.3615w

Heat Flux h = q/a =35697.3615/24228.13= 1.473 w/mm^2

Heat flux for Al 1199

Heat flow q = UAΔT

= 0.0243x12957.3x145

= 45655.04655w

Heat Flux h = q/a =45655.04655/24228.13= 1.884 w/mm^2

T_G Temperature gradient = $\frac{\Delta T}{d}$

= 145/50.75=2.857K/mm

INTRODUCTION TO ANSYS

Ansys is a general purpose finite element modeling package for
numerically solving a wide variety of mechanical, electrical problems.

These problems include:
1. Static/Dynamic structural analysis(both linear and non linear)
2. Fluid analysis
- laminar flow
- turbulent flow
3. Acoustic analysis
4. Electro magnetic analysis
5. Model analysis
6. Thermal analysis
- conduction
- convection
- radiation
7. Transient thermal analysis
8. Buckling analysis
9. Spectrum analysis
10. Harmonic analysis

Static analysis: In this type of problem we determine the lastic data deflections and stresses at critical points due to a system to external forces acting on structure nodal Modal analysis: In this type of problem we determine the vibration characteristics Harmonic analysis: We will determine the response of structure to harmonically time varying loads. Buckling analysis: We determine the buckling loads and also buckling shape.Thermal analysis: In this we determine low thermal stresses are there in given structure.Fluid analysis: In this we can see how a comprehensive got that fluid flows through a given number under given condition.

Steps involved in ansys:

In general, a finite element solution can be broken into the followingthese
categories.

1. Preprocessing module: Defining the problem
The major steps in preprocessing are given below
- defining key points /lines/areas/volumes
- define element type and material /geometric /properties
- mesh lines/areas/volumes/are required
The amount of detail required will depend on the dimensionality of the analysis (i.e. 1D, 2D, axis, symmetric)
2. Solution processor module: assigning the loads ,constraints and solving
Here we specify the loads (point or pressure), constraints (translation,
rotational) and finally solve the resulting set of equations.
3. Post processing module: further processing and viewing of results
In this stage we can see:
List of nodal displacement
Elements forces and moments
Deflection plots

Stress contour diagrams

THERMAL ANALYSIS

ANSYS is capable of both steady state and transient analysis of any solid wh thermal boundary conditions. Steady-state thermal analyses calculate the effects of steady thermal loads

on a system or component. Users often perform a steady-state analysis before doing a transient thermal analysis, to help establish initial conditions. A steady-state analysis also can be the last step of a transient thermal analysis; performed after all transient effects have diminished. ANSYS can be used to determine temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by thermal loads that do not vary over time. Such loads include the following:

- Convection
- Radiation
- Heat flow rates
- Heat fluxes (heat flow per unit area)
- Heat generation rates (heat flow per unit volume)
- Constant temperature boundaries

A steady-state thermal analysis may be either linear, with constant material properties; or nonlinear, with material properties that depend on temperature. The thermal properties of most material vary with temperature. This temperature dependency being appreciable, the analysis becomes nonlinear. Radiation boundary conditions also make the analysis nonlinear. Transient calculations are time dependent and ANSYS can both solve distributions as well as create video for time incremental displays of models.

TRANSIENT THERMAL ANALYSIS

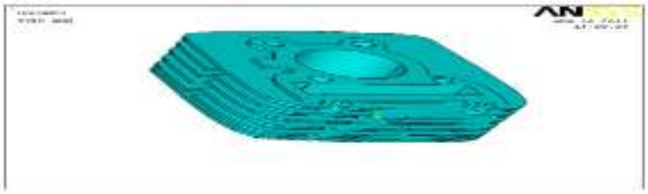
Transient thermal analyses determine temperatures and other thermal quantities that vary over time. The variation of temperature distribution over time is of interest in many applications such as with cooling of electronic packages or a quenching analysis for heat treatment. Also of interest are the temperature distribution results in thermal stresses that can cause failure. In such cases the temperatures from a transient thermal analysis are used as inputs to a structural analysis for thermal stress evaluations.

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 analyses.

A transient thermal analysis can be either linear or nonlinear. Temperature dependent material properties (thermal conductivity, specific heat or density), or temperature dependent convection coefficients or radiation effects can result in nonlinear analyses that require an iterative procedure to achieve accurate solutions. The thermal properties of most materials do vary with temperature, so the analysis usually is nonlinear.

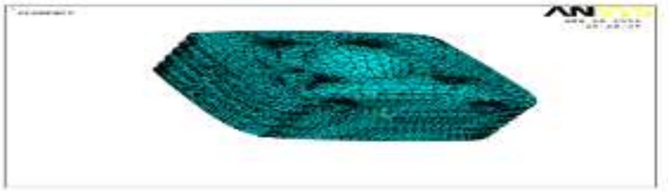
TRANSIENT THERMAL ANALYSIS
ALUMINUM ALLOY 1199

MODEL IMPORTED FROM PRO/ENGINEER

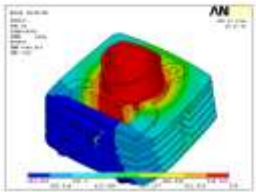


MATERIAL PROPERTIES:
Thermal Conductivity – 240 w/mk
Specific Heat – 0.9 J/g ºC
Density – 2.7 g/cc

MESHED MODEL

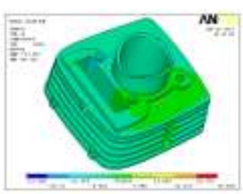


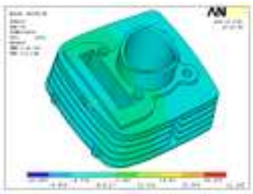
Solution – New Analysis – Transient – Ok
Soln Ctrl – Specify Time at end of load step – 3600secs
No. Of Steps – 10 – Ok
LOADS:
Temperature -558 K
Film Coefficient – 25 w/m^2 K
Bulk Temperature – 313 K
Load Step opts – Write LS file – Ok
Soln Ctrl – Specify Time at end of load step – 36000secs
No. Of Steps – 10 – Ok
Load Step opts – Write LS file 2 – Ok



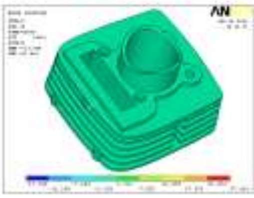
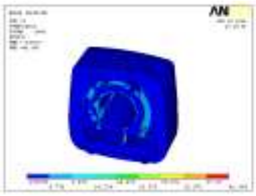
Solution – Solve – From LS files – Start with 1 End with 2 – O

RESULTS:
NODAL TEMPERATURE
THERMAL GRADIENT
X – Direction Y- Direction



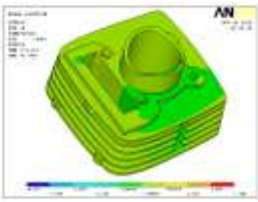
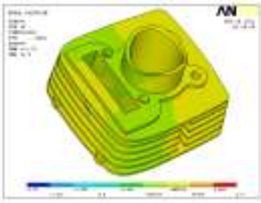


Z – Direction SUM

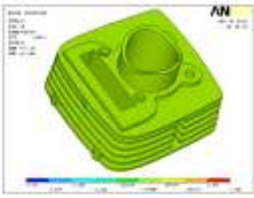
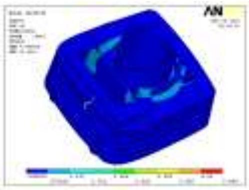



THERMAL FLUX

X- Direction Y- Direction

Z- Direction SUM

ALUMINUM ALLOY 204

MATERIAL PROPERTIES:

Thermal Conductivity – 120 w/mk

Specific Heat – 0.963 J/g ºC

Density – 2.8 g/cc

Solution – New Analysis – Transient – Ok

Soln Ctrl – Specify Time at end of load step – 3600secs

No. Of Steps – 10 – Ok

LOADS:

Temperature -558 K

Film Coefficient – 25 w/m^2 K

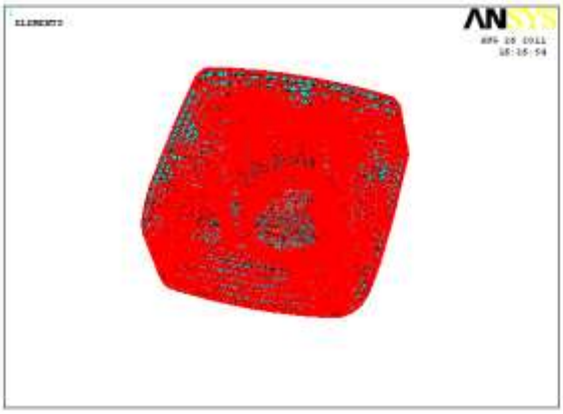
Bulk Temperature – 313 K

Load Step opts – Write LS file – Ok

Soln Ctrl – Specify Time at end of load step – 36000secs

No. Of Steps – 10 – Ok

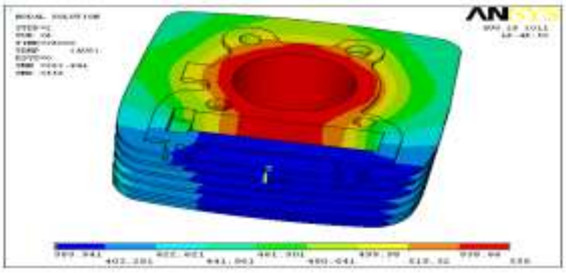
Load Step opts – Write LS file 2 – Ok



Solution – Solve – From LS files – Start with 1 End with 2 - Ok

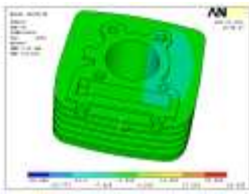
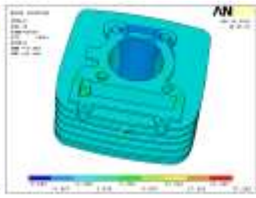
RESULTS:

NODAL TEMPERATURE

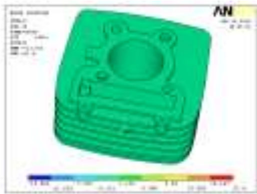
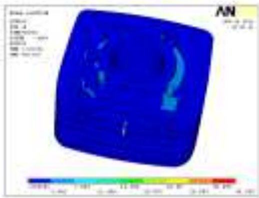


THERMAL GRADIENT

X – DIRECTION Y – DIRECTION

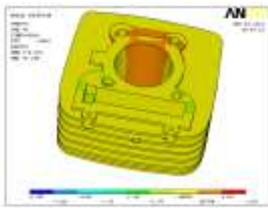
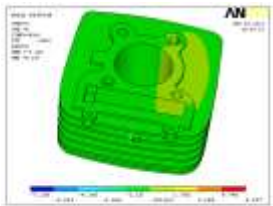



Z – DIRECTION SUM

THERMAL FLUX

X – DIRECTION Y – DIRECTION

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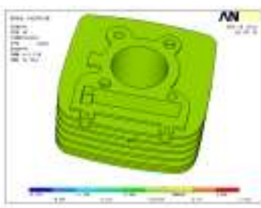
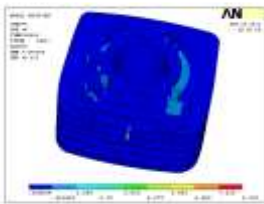
z-DIRECTION SUM

RESULTS TABLE

	ALUMINUM ALLOY 1199	ALUMINUM ALLOY 204
NODAL TEMPERATURE	558	558
THERMAL GRADIENT	42.369	34.303
THERMAL FLUX	5.084	8.233

CONCLUSION

In our project we have modeled a cylinder fin body for a 150cc engine in Pro/Engineer.

Transient thermal analysis is done on the cylinder fin body using Aluminum 204 and Aluminum1199 alloy.

As per the analysis images, thermal conductivity is more for Aluminum Alloy 1100 than Aluminum Alloy 204 alloy. So for cylinder fin body Aluminum Alloy 1100 is best.

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