# Effect of Thermal Loads on Cylinder Heads

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***Abstract****- A cylinder head is made of box type of section of considerable depth to accommodate ports of air and gas passages, inlet valve, exhaust valve and spark plug. The studs or bolts are screwed up tightly along with a metal gasket or asbestos packing to provide a leak proof joint between the cylinder and cylinder head. The cylinder head is subjected to temperatures due to combustion in cylinder and pressure on surface. In this project, Optimization method is taken as Optimization by Parameters. In this project parameter Thickness is varied for different materials aluminum alloys LM6, LM24, LM25. By varying above parameters maximum optimal convection rate is determined. Thermal analysis is done. 3D modeling is done in Pro/Engineer and analysis is done in Ansys*

## I. INTRODUCTION

In an internal combustion engine, the cylinder head (often informally abbreviated to just head) sits above the cylinders on top of the cylinder block. It consists of a platform containing part of the combustion chamber (usually, though not always), and the location of the poppet valves and spark plugs. In a flathead engine, the mechanical parts of the valve train are all contained within the block, and the head is essentially a flat plate of metal bolted to the top of the cylinder bank with a head gasket in between; this simplicity leads to ease of manufacture and repair, and accounts for the flathead engine's early success in production automobiles and continued success in small engines, such as lawnmowers. This design, however, requires the incoming air to flow through a convoluted path, which limits the ability of the engine to perform at higher revolutions per minute (rpm), leading to the adoption of the overhead valve (OHV) head design, and the subsequent overhead camshaft (OHC) design.

## II. APPLICATIONS

Internal combustion engines are most commonly used for mobile propulsion in vehicles and portable machinery. In mobile equipment, internal combustion is advantageous since it can provide high power-to-weight ratios together with excellent fuel energy density. Generally using fossil fuel (mainly petroleum), these engines have appeared in transport in almost all vehicles (automobiles, trucks, motorcycles, boats, and in a wide variety of aircraft and locomotives).

Where very high power-to-weight ratios are required, internal combustion engines appear in the form of gas turbines. These applications include jet aircraft, helicopters, large ships and electricgenerators.

## III. MATERIALS USED FOR CYLINDER HEAD

In car engines, one cylinder head is usually employed for all cylinders together. The cylinder heads on water-cooled diesel truck engines are usually made of cast iron. By contrast,all petrol and Diesel engines cars use aluminum cylinder heads due to the superior heat dissipation and lower weight. In cars , the cylinder head is normally made of aluminum even when the cylinder block is cast iron. The choice between cast iron oraluminium for the cylinder head is not simple. Aluminium has the advantages of light weight, high Thermal conductivity ,and ease of production to close tolerances by gravity or low-pressure diecasting.In trucks and large industrial engines , individual cylinder heads are often used on each cylinder for better sealing force distribution and easier maintenance and repair.On the other hand, aluminium is more expensive than iron, tooling for large quantity production is costly, porosity in the finished casting can present difficulties, aluminium is more easily damaged in service and rather more prone to Gasket blow-by failure, corrosion may present problems especially where there are copper components in the Cooling system and heat-resistant Valve seat inserts are essential

## IV. FAILURES OF CYLINDER HEAD

The cylinder head is a crucial part of all combustion engines, and cylinder head cracking can result in catastrophic damage to the engine. In some cases, cylinder head cracking may result in such severe injury to the engine that it must be replaced. As a result, most motorists try to prevent cylinder head cracking, as an ounce of prevention in this case is worth many pounds of cure. The causes of cylinder head cracking are all relatively simple and easy to prevent, except in the case of mechanical parts failure through no fault of the operator.

## V. DESIGN CALCULATIONS

**2.1 PRESSURE CALCULATIONS**

Bore x stroke = 67 x 62.4mm

Displacement = 220cc

Density of petrol $C_8H_{18}$ = 737.22 kg/m$^3$ at 60F

Density = 0.00000073722 kg/mm$^3$

T = 60F = 15.55°c =288.555K

Mass = 0.00000073722 x 220000

M=0.162 kg

Molecular weight for petrol =114.2285 g/mole

PV=mRT

P=mRT/V

$$P = \frac{0.162 \times 8.3143 \times 288.555}{0.11422 \times 0.0001495}$$

P=22760718.15 J/m$^3$=N/m$^2$

p=22.760 N/mm$^2$

**2.1.1 Thickness of cylinder wall**

$$t = \frac{P \times D}{2\sigma_c} + c$$

P= maximum gas pressure inside the cylinder

P=22.760N/mm$^2$

D= cylinder bore dia= 67mm

$\sigma_c$=permissible circumferential or hoop stress for cylinder material (35Mpa-100 Mpa)

$$t = \frac{22.760 \times 67}{2 \times 100} = 7.6246 \text{ mm}$$

$ort = 0.045D + 1.6 = 4.165$

Thickness of dry liner = 0.03D to 0.035D=2.01 to 2.345mm

Thickness of water jacket wall=0.03D+1.6=3.61mm

Water space between the outer cylinder wall and inner jacket wall=0.08D+6.5=11.86mm

**2.1.2 Bore and length of cylinder**

Bore D=67mm

Stroke = 62.4mm=l

Length of cylinder L=1.15l=71.76 mm

**2.1.3 Cylinder flange and studs**

t=7.624mm

flange thickness=1.2t-1.4t

$t_f$=1.2 x 7.624=9.1488=9mm

$$\frac{\pi}{4}D^2P = n_s \times \frac{\pi}{4}(d_c)^2\sigma_t$$

$n_s$=number of studs

$n_s$=0.02D+4=5.34=5

$\sigma_t$=allowable tensile stress of studs=35 to 70 Mpa

$d_c$= core / minor dia(i.e) dia at the root of the thread

$$d_c{}^2 = \frac{D^2P}{n_s\sigma_t} = \frac{67^2 \times 22.760}{5 \times 35}$$

$d_c{}^2 = 583.826$

$d_c = 24.162 = 24mm$

The nominal/ major dia of stud/bolt

d= 0.75 $t_f$ to $t_f$

d=9mm

the distance of flange from centre of hole for the stud/bolt=d+6=15mm

or 1.5d=13.5mm

pitchofstuds/bolts =19$\sqrt{d}$ to 28.5$\sqrt{d}$=57-85.5

**2.1.4 Cylinder head**

Thickness of cylinder head

$t_h = D\sqrt{\frac{CP}{\sigma_C}}$

$\sigma_C$= allowable circumferential stress = 30 - 50 Mpa

$C$= constant = 0.1

$t_h = 67\sqrt{\frac{0.1 \times 22.760}{50}}$ = 14.294=14mm

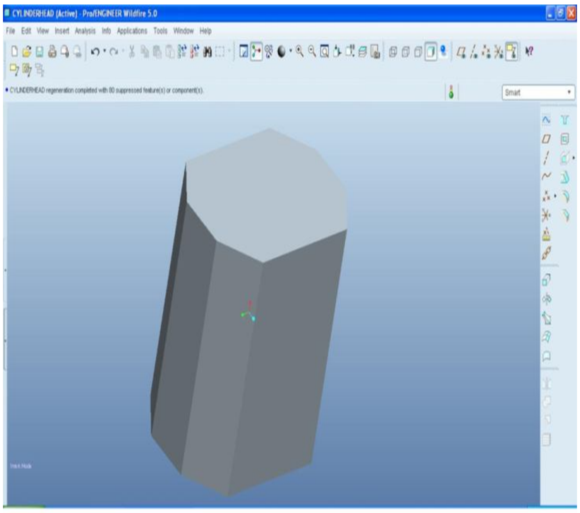
pitch circledia = D+3d(d=5)

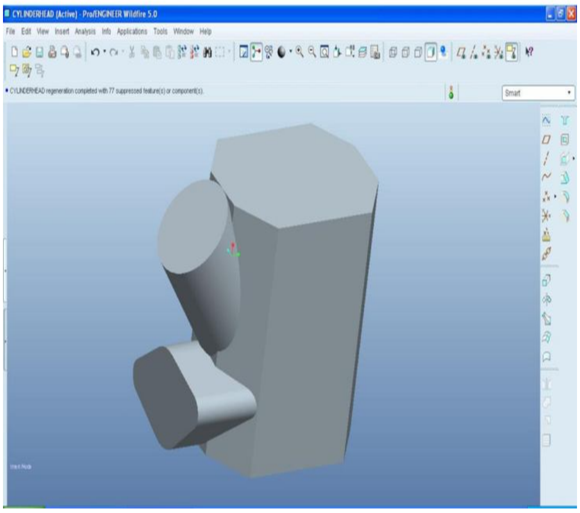
$D_P$=67+3 x9=94mm

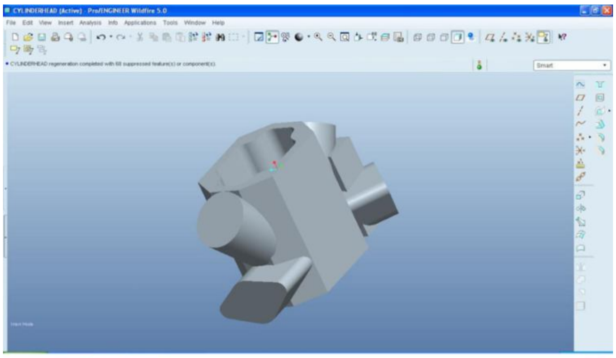
(pitch of the studs = $\frac{\pi \times D_p}{n_s}$= 59.061 =59)

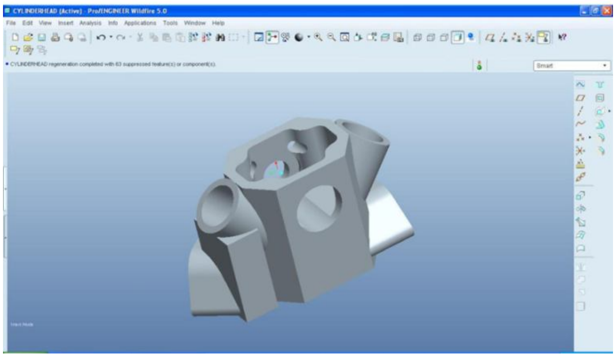
**CAD:**CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

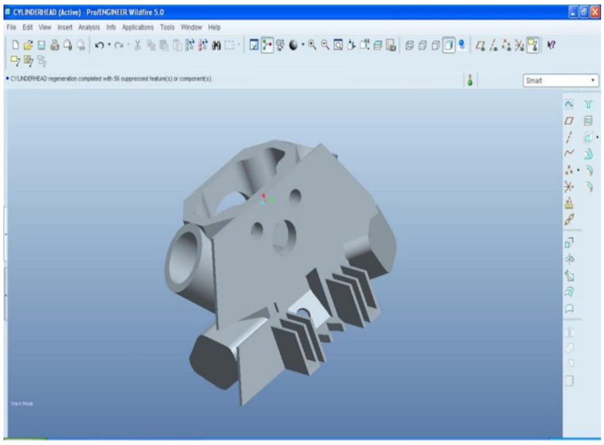
## VI. MODELS OF CYLINDER HEAD

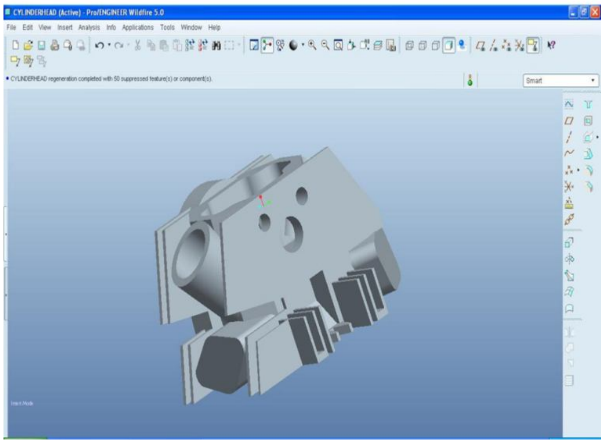


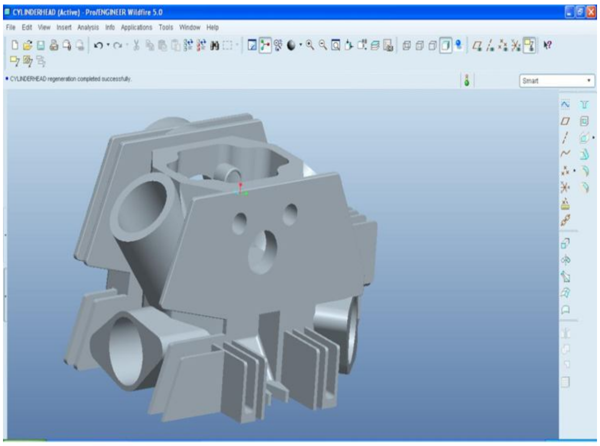


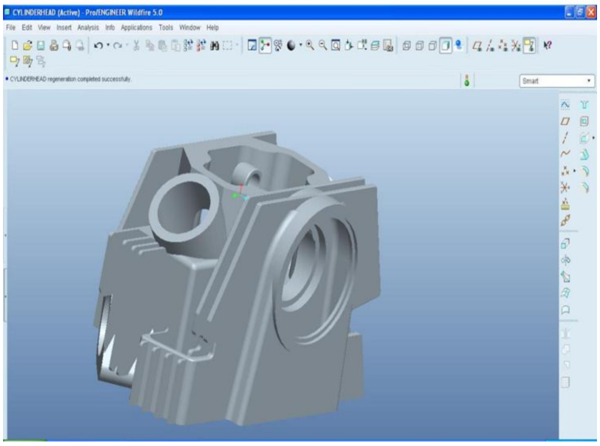




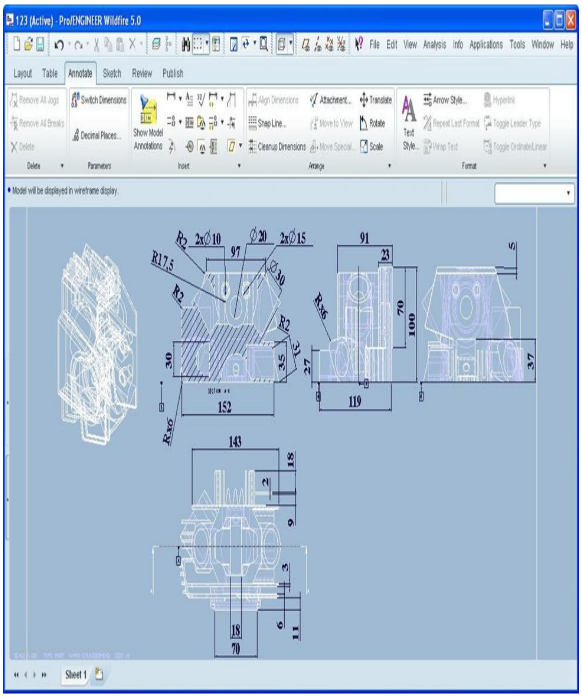








**2D DRAWING**



**FEA**

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition.In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

multiple loading conditions which may be applied to a system.

- Point, pressure, thermal, gravity, and centrifugal static loads
- Thermal loads from solution of heat transfer analysis
- Enforced displacements
- Heat flux and convection
- Point, pressure and gravity dynamic loads

Many FEA programs also are equipped with the capability to use multiple materials within the structure such as:

- Isotropic, identical throughout
- Orthotropic, identical at 90 degrees
- General anisotropic, different throughout

**Results of Finite Element Analysis**

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within

1. **PREPROCESSING**
2. **ANALYSIS**
3. **POST PROCESSING**

**ANSYS** is capable of both steady state and transient analysis of any solid with 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 transientThermal 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:

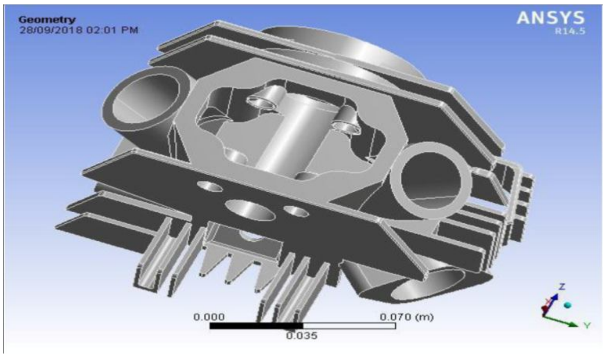
Convection

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

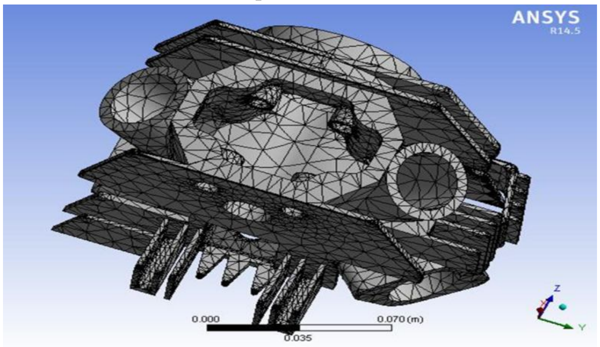
A steady-state thermal analysis may be either linear, with constant material properties; or nonlinear, with material properties that depend on temperature. The thermal properties of most material vary with temperature. This temperature dependency being appreciable, the analysis becomes nonlinear. Radiation 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.

**THERMAL ANALYSIS OF CYLINDER HEAD**

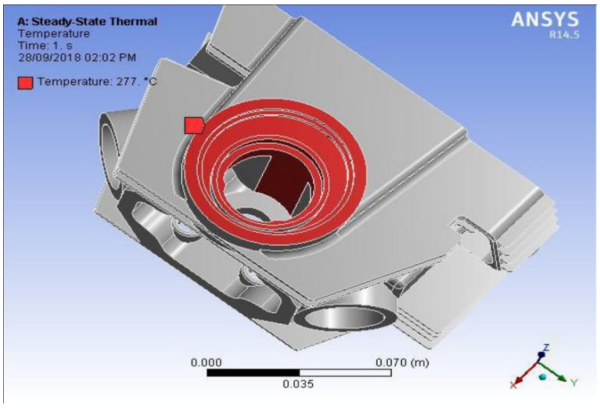
**MATERIAL - LM 6 THICKNESS OF FIN- 2mm**



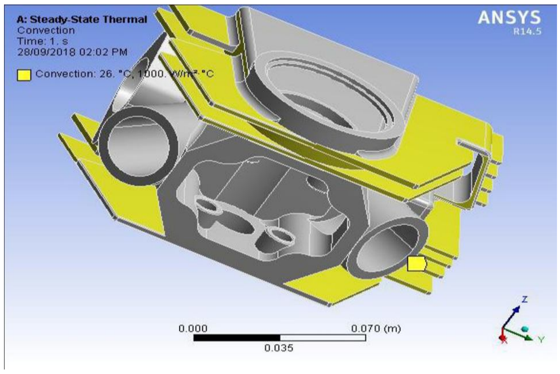

Import Model



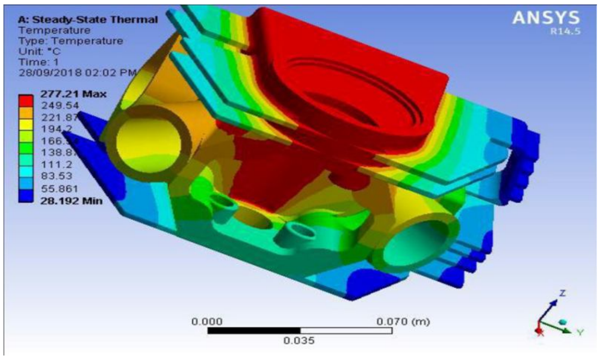

Mesh Model




Temperature

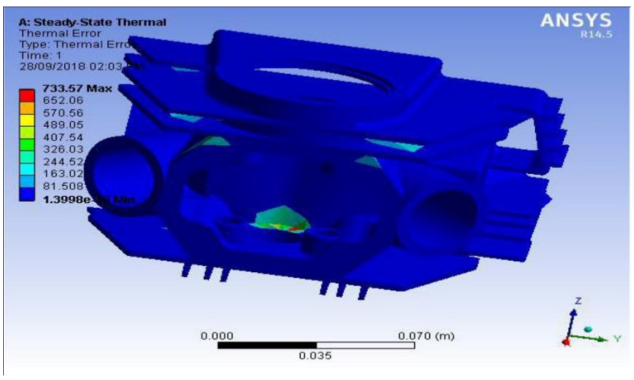



Convection




Total temperature

Total heat flux



Thermal Error

## VII. RESULTS

1 mm THICKNESS OF FINS

| | TEMPERATURE ($^0$C) | HEAT FLUX(W/m$^2$) | THERMAL ERROR |
|---|---|---|---|
| LM6 | 277.02 | 3.5556E6 | 189.91 |
| LM24 | 277.02 | 2.7493E6 | 154.33 |
| LM25 | 277.02 | 3.692E6 | 195.46 |

Thermal analysis for 1mm Thickness of Fins

1.5 mm THICKNESS OF FINS

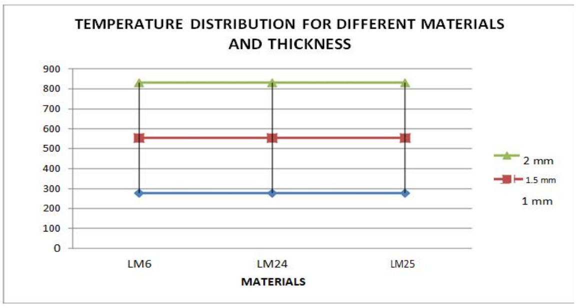
| | TEMPERATURE ($^0$C) | HEAT FLUX(W/m$^2$) | THERMAL ERROR |
|---|---|---|---|
| LM6 | 277.02 | 3.3291E6 | 151.5 |
| LM24 | 277.02 | 2.4935E6 | 338.09 |
| LM25 | 277.02 | 3.3761E6 | 379.7 |

Thermal analysis for 1.5mm Thickness of Fins

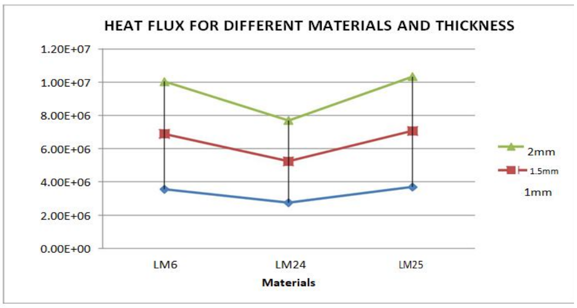
2 mm THICKNESS OF FINS

| | TEMPERATURE ($^0$C) | HEAT FLUX(W/m$^2$) | THERMAL ERROR |
|---|---|---|---|
| LM6 | 277.21 | 3.1534E6 | 733.57 |
| LM24 | 277.31 | 2.4539E6 | 645.53 |
| LM25 | 277.2 | 3.2649E6 | 745.87 |

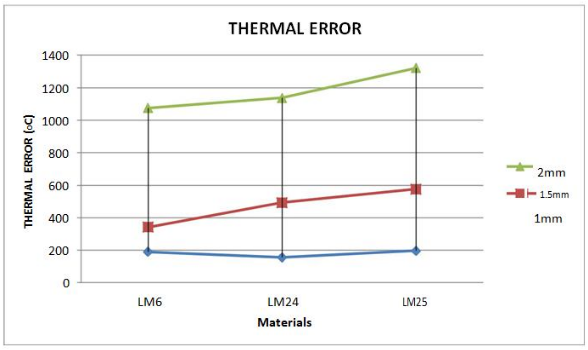
Thermal analysis for 2mm Thickness of Fins




Graph Representing Summary of temperature




heat flux




Thermal Error

## VIII. CONCLUSION

In this thesis a cylinder head is optimized for its material and thickness using thermal analysis. Thicknesses observed are 2mm, 1.5mm and 1mm for different aluminum alloys LM6, LM24 and LM25.Modeling is done in Pro/Engineer and analysis is done in Ansys.

By observing the analysis results, heat flux is more for LM 25 aluminum alloy than other materials so heat transfer rate is more. The heat transfer rate is increasing by increasing the thickness of the fin. So using 1mm thickness is better than 1.5mm and 2mm

## REFERENCES

[1] Marcel Davis, RadekTichanek, Mirsolav spaniel, “Study of heat transfer analysis of diesel engine head” ActaPolytechnica Vol. 43 No. 5/2003 [2001]

[2] M.Fadaei, H.Vafadar, A.Noorpoor, “Thermo-mechanical analysis of cylinder head using multifield approach” ScientiaIranica B (2011) 18 (1), 66–74 [2010]

[3] C.Donoselli, C.Gorla, “Experimental evaluation of thermal characteristics of internal combustion engine cylinder liner” Journal of Metallurgical science and technology [1998].

[4] Quingzhao Wang, “Numerical analysis of cooling effect of a cylinder head water jacket “Thesis of GIT” [2005]

[5] turbine blade”, Deep Sea Offshore Wind R&D Seminar Royal Garden Hotel, Trondheim, Norway