RESEARCH ARTICLE OPEN ACCESS

Modeling and Analysis of Cylinder Block by Carbon Material (FU4270) for V8 Engine

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ABSTRACT

Heat losses are a major limiting factor for the efficiency of internal combustion engines. Furthermore, heat transfer phenomena cause thermally induced mechanical stresses compromising the reliability of engine components. The ability to predict heat transfer in engines plays an important role in engine development. Today, predictions are increasingly being done with numerical simulations at an ever earlier stage of engine development. These methods must be based on the understanding of the principles of heat transfer.

In the present work V type multi cylinder engine assembly is modeled by CATIA V5. This model is imported to ANSYS and done the steady state thermal and Structural analysis for predicting thermal stress, temperature distribution by comparing with advance carbon material (FU 4270) from existing material (Aluminum).

Heat transfer is one major important aspect of energy transformation in internal combustion (IC) engines. Locating hot spots in a solid wall can be used as an impetus to design a better cooling system. Fast transient heat flux between the combustion chamber and the solid wall must be investigated to understand the effects of the non-steady thermal environment.

Keywords :- CFC, ANSYS

I. INTRODUCTION

Cylinder Numbering

Diverse engine makers use distinctive chamber numbering traditions, so to keep the article basic, It will be running with a standout amongst the most well-known frameworks, seen in Fig 1.1.

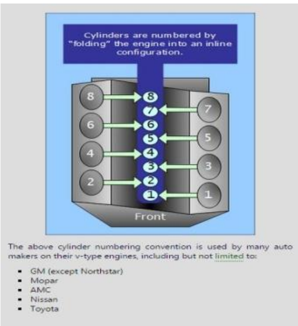


Fig 1.1No of cylinders showing in V8 Engine

Types of V8 Engines

There are two major types of V8 engine engines, which differ by crankshaft. **Flat plane , Cross plane**

Flat plane

The flat plane V8 is like two inline four chambers imparting a solitary crankshaft. At the point when seen from one end, the crankshaft seems to structure a level shape and the same sort of flat plane V8 engine is demonstrated

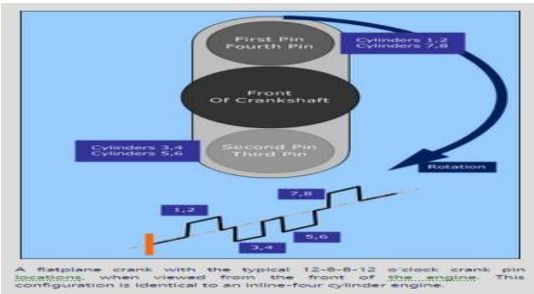


Fig 2 Flat plane type of V8 Engine

Cross plane

The other, significantly more regular sort is the cross plane V8 is demonstrated in Fig 1.3, which Cadillac concocted in 1923. The principal and fourth wrench pins are

180° separated, and the inward two are 180° separated from one another, and 90° separated from the pins on each one.

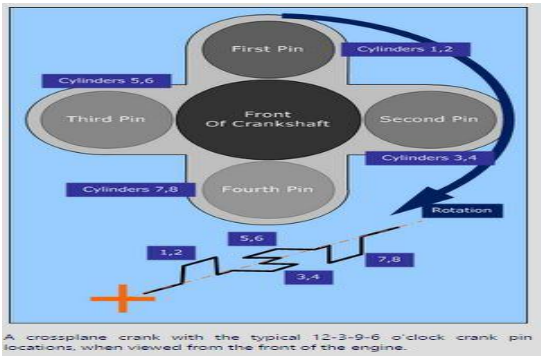


Fig 3 Cross plane type of V8 Engine

Cross Plane Crankshaft

The cross plane or cross-plane is a crankshaft outline for cylinder engines with a 90° plot (stage in wrench turn) between the wrench tosses.

Cross plane crankshaft could be utilized as a part of numerous chamber arrangements to have a uniformly divided terminating the length of the quantity of chambers is products of four in two-stroke engines, or products of eight in 4 stroke engines. Unless the wrench pins have big end stage balanced, the V-point necessity must be met for an equitably divided terminating on V setups as recorded underneath.

2 cycle: L4, L8, L12, L16, V4 (V-edge of 90°), V8 (45°,90° or 135°), V12 (30°,60°,90°,120° or 150°), V16 (22.5°,45°,67.5°,90°,112.5°,135° or 157.5°), flat4, flat8, flat12, flat16, and so forth.

4 cycle: L8, L16, V8 (V-edge of 90°), V16 (45°, 90° or 135°), flat8, flat16, and so forth. Then again, cross plane crankshaft has been utilized on other 4 stroke setups like L2, L4, V2 and V4 engines with unevenly divided terminating when its noticeable preference of littler optional (non-sinusoidal) vibration.

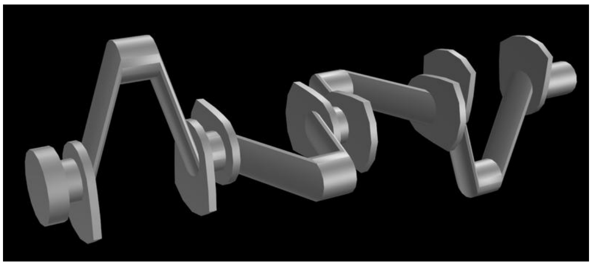


Fig 4 Cross Plane crankshaft

Carbon Piston

Carbon – carbon is a composite material of carbon fibers woven into and reinforcing a carbon matrix it can withstand temperatures in excess of 50000F. Researchers say carbon – carbon piston can tolerate extremely high operating temperatures, eliminating the need for coolant passages near the cylinder walls. And the material is far lighter than Aluminum. Carbon- carbon pistons shown in Fig 5 and values have half the weight of their Aluminum metal counterparts.

Fig .5 Carbon Piston

Carbon Materials (FU 4270)

The composition of Carbon material FU 4270 which will be used in high temperature applications and thermal is Carbon fibre rein forced carbon and the Carbon fibre reinforced carbon (CFC) consists of a matrix of pure carbon to which carbon or graphite fibers of only a few µm diameter are added and also the Carbon fiber-reinforced carbon (C/C) is a composite material consisting of carbon fiber reinforcement in a matrix of graphite.

Carbon Fabre reinforced Carbon is called as

CFC in GERMAN Language & C/C in ENGLISH

F is natural graphite, resin-bonded

U is special material

FU is a special type of material in Carbon material group.

The strength of carbon–carbon with unidirectional reinforcement fibres is up to 700 MPa. Carbon–carbon materials retain their properties above 2000°C. This temperature may be exceeded with the help of protective coatings to prevent oxidation. The material has a density between 1.6–1.98 g/cm3.

They are frequently only a tenth of the thickness of the diameter of a human hair (approx. 50 µm) and is shown in Fig 1.6. Despite this, they contribute a high degree of mechanical stability to the material, and the carbon matrix is capable of absorbing external forces and distributing these throughout the microstructure.

In addition to a high degree of strength and rigidity, CFC materials also exhibit pseudo ductile fracture characteristics and, consequently, provide the resistance to galling frequently absent in ceramics. Their mechanical strength is clearly demonstrated by the following example: Whereas traditional ceramics rapidly disintegrate into a thousand particles when subjected to blows or vibration, CFC composite materials can even be nailed to the wall without rupturing. CFC materials can resist temperatures up to 2700°C (in inert gas or a vacuum) and temperature fluctuations of 1500°C (excellent thermal shock behavior). Moreover, they are distinguished by good thermal and electrical conductivity and effective chemical resistance.

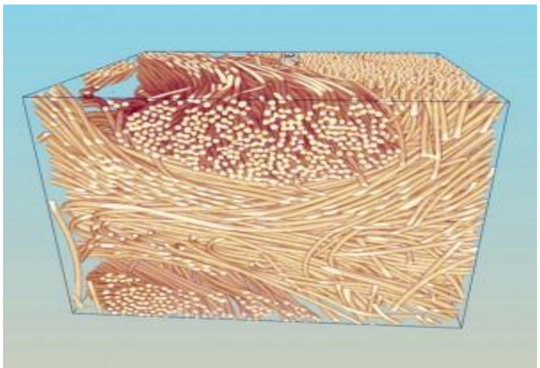


Fig 6 Carbon Fibre Reinforced Carbon

Table 1 Physical Properties of Carbon Materials

Mechanical &Thermal Properties	FU 4270
Bulk density g/cm3	1.8
Young's modulus /GPa	13
Bending strength /MPa	80-100
Compressive strength /MPa	150
Coefficient of thermal expansion /10⁻ 6 K⁻ 1	5
Thermal Conductivity W/mK	40

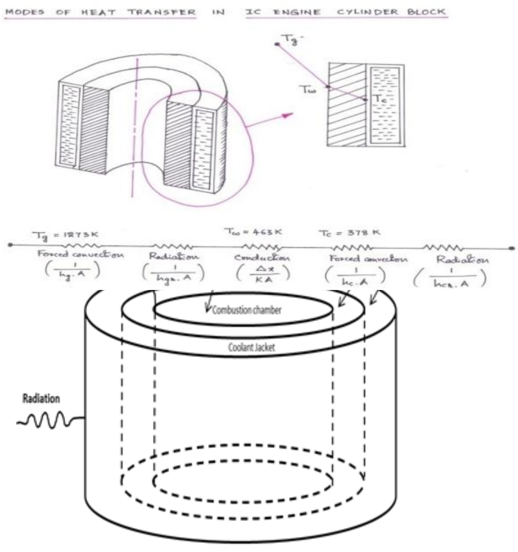
The above table 1 gives the typical physical properties of two carbon materials (FU 4270 and FU 2451) which are have been developed for use in different engines.

II. THEORETICAL CALCULATIONS

In the present chapter theoretical calculations are done based on their thermal conductivity is taken for two Carbon materials and the existing material Aluminum alloy and the resultant values tabulated.

Heat Transfer in intake system

Heat transfer through cylinder walls of an IC engine is followed by forced convection in combustion chamber, conduction in cylinder block, forced convection in coolant jacket and radiation from combustion of fuel (diesel or petrol) and coolant jacket.



Modes of Heat transfer in IC engine cylinder block

Formulas:

qg = hg(Tg-Tw) ; qgr = hgr(Tg-Tw) ; qw = k(Tw-Tc) ; qc = hc (Tc-Ti) ;
qcr = hcr(Tc-Ti);

Since hgr = ϵ σ((Tg) 2+ (Tw) 2) (Tg+Tw)
hcr = ϵ σ((Tc) 2+(Ti)2) (Tc+Ti) from Arora Domkundwar page No:19.45

Total heat flux induced in cylinder block q = Q/A = qg+qgr+qw+qc+qcr

Value of qcr is negligible due to forced convection of water

q= qg+qgr+qw+qc
q = U (Tg-Tc)

Therefore overall heat transfer coefficient

$$U = \frac{1}{\frac{1}{hg}+\frac{1}{hgr}+\frac{\Delta x}{k}+\frac{1}{hc}}$$

Where

qg & qc = Convective heat flux of combustion products and coolant jacket

qgr & qcr = Radiation heat flux produced by combustion products and from coolant jacket

qw = Conductive heat flux of cylindrical wall

hg & hc = Convective heat transfer coefficient of combustion products and coolant jacket

hgr & hcr = Radiation heat transfer coefficient combustion products and from coolant jacket

Calculations

Tg = Gas temperature = 1000 ˚c + 273 =1273K
Tc = Coolant temperature = 190 ˚c +273 = 463 K
Tw = Cylinder wall temperature = 105˚c + 273 = 368 K

Ti = Inlet temperature of water = 15 ˚c + 273 =298 K
Velocity of water =20 m/s
hg = 50 W/m2K
Δx = 0.025 m
Stefan-Boltzmann constant σ = 5.67 x 10-8 W/m2K4
Є = 1 (assuming black surface)

Radiation heat transfer coefficient

hgr = ϵ σ((Tg) 2+(Tw)2)(Tg+Tw)
= 1x5.67 x10-8 ((1273)2 + (463)2) (1273+463)
= 180.611 W/m2K

Convective heat transfer coefficient of coolant Jacket

hc = (Nu . K)/L
Where Nu = 0.59 Re0.25
L = characteristic length
Re = (ρ v D)/ μ
Where D = 0.1 m and length l = 0.091 m
Mean temperature Tf = (Tc +Ti)/2 = (105 + 15)/2 = 60 ˚C
At 60 ˚C water properties in heat transfer data book
ρ = 983.3 kg/m3 k = 0.654 Pr = 3.01 μ = 4.71 x 10 -4
Re = (983.3 x 20 x 0.1)/ 4.71 x 10 -4
= 4175371.55
Since it is laminar flow (106 -109)
Nu = 0.59 Re0.25 = 26.67
hc = (Nu . K)/L = (26.67 x 0.654)/0.091 = 191.67 W/m2K

Aluminum

Thermal conductivity is 28 W/m K

$$U_{al} = \frac{1}{\frac{1}{hg}+\frac{1}{hgr}+\frac{\Delta x}{k}+\frac{1}{hc}} = \frac{1}{\frac{1}{50}+\frac{1}{180.611}+\frac{0.025}{28}+\frac{1}{191.67}}$$

Ual = 31.59875
qtotal = Ual (Tg - Tc)
= 31.5975 x (1273-378)
qtotal = 28280.88 W/m2

FU 4270

Thermal conductivity is 40 W/m K

$$U_{al} = \frac{1}{\frac{1}{hg}+\frac{1}{hgr}+\frac{\Delta x}{k}+\frac{1}{hc}} = \frac{1}{\frac{1}{50}+\frac{1}{180.611}+\frac{0.025}{40}+\frac{1}{191.67}}$$

Ual = 31.8683842
qtotal = Ual (Tg - Tc)
= 31.8683842 x (1273-378)
qtotal = 28522.203 W/m2

Table .2 Theoretical values of Thermal Conductivity and Heat Transfer of materials

Material	Thermal Conductivity k (W/m K)	Heat Transfer q' (W/m2)
Aluminum	28	28280.88
FU 4270	40	28522.203

In table .2 shows the thermal conductivities of the carbon materials FU 4270 and FU 2451 and for existing material Aluminum alloy and the total heat transfer obtained from the above mathematical calculations are shown.

III. MODELING OF CYLINDER BLOCK

CATIA Models of Cylinder Block

Modeling of cylinder block in CATIA Part Design Module
To enter in to part design select New – Part – Enter name – ok.

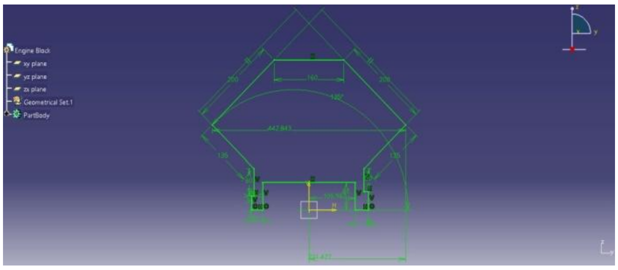


Fig 7 Sketch of a Cylinder Block

Fig 7 shows the sketch with dimensions of the cylinder block
To enter sketcher select sketch icon, select a plane as sketching plane.

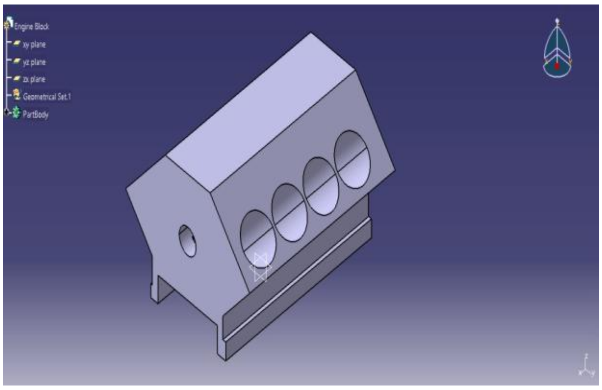


Fig 8 shows the isometric view cylindrical part design

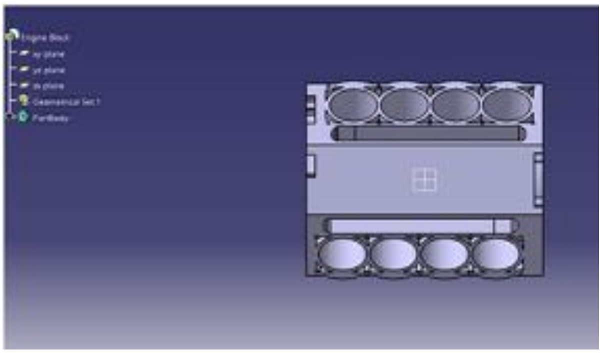


Fig 9 shows the Top view cylindrical part design

IV. ANALYSIS OF CYLINDER BLOCK

Steady-State Thermal (ANSYS)

It can utilize an enduring state warm investigation to focus temperatures, warm inclinations, hotness stream rates, and high temperature fluxes in a question that are brought on by warm loads that don't fluctuate after some time. A consistent state warm investigation figures the impacts of enduring warm loads on a framework or segment. Designs regularly perform a consistent state investigation before performing a transient warm examination, to help secure beginning conditions. A consistent state examination likewise can be the last venture of a transient warm investigation; performed after all transient impacts have lessened. You will arrange your consistent state warm examination in the Mechanical application, which utilizes the ANSYS solver to process the arrangement.

- Add a consistent state warm examination format by dragging the layout from the Toolbox into the Project Schematic or by twofold clicking the format in the Toolbox.
- Load the geometry by right-clicking on the Geometry cell and picking Import Geometry.
- View the geometry by right-clicking on the Model cell and picking Edit, or twofold clicking the Model cell. On the other hand, you can right click the Setup cell and select Edit This step will dispatch the Mechanical application.
- In the Mechanical application window, finish your consistent state warm examination utilizing the Mechanical application's devices and gimmicks. See Steady-State Thermal Analysis in the Mechanical application help for more data on directing a relentless state warm investigation in the Mechanical app.

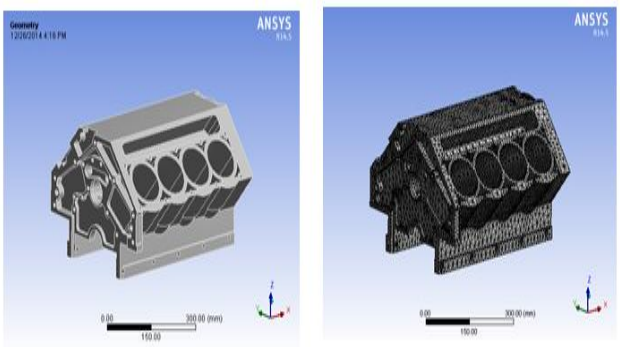


Fig 10 Geometry & Meshing of Cylinder Block

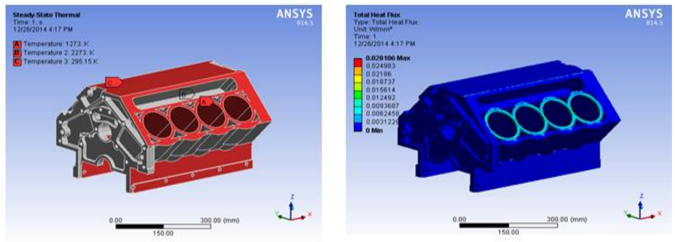
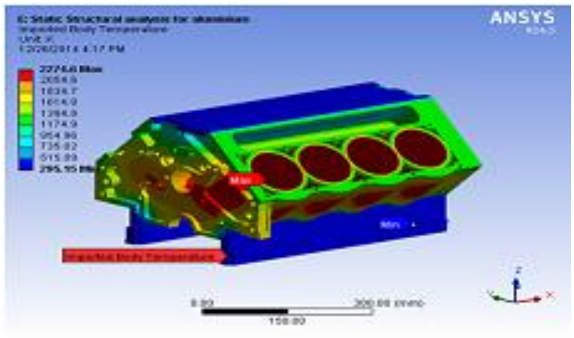
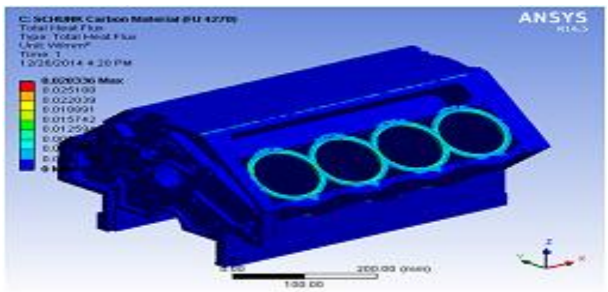


Fig 11 Steady state & Total Heat Flux



The above Fig 12 shows the temperatures induced in the cylinder block and maximum temperature is 2274.6 K and Minimum Temperature is 295.15 K.



The above Fig 13 shows Equivalent Stress is generated in the cylinder block along the axial direction and max stress is generated as 75.172MPa and min stress as 0.0014682 MPa.

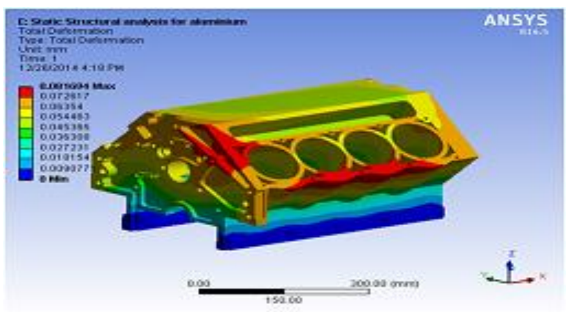
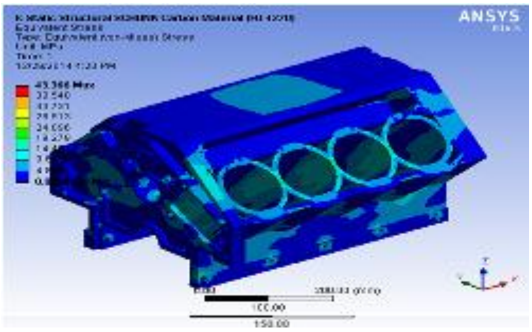
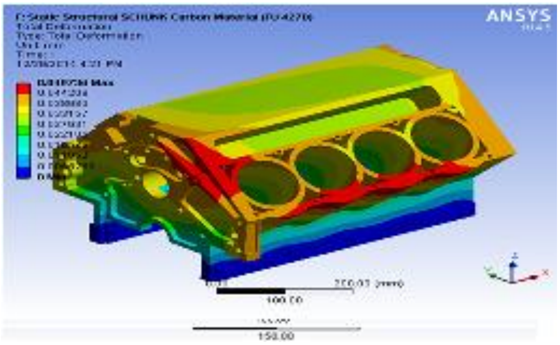


Fig 14 Total deformation generated in cylinder block



The above Fig 15 shows the Equivalent stress generated in cylinder block and maximum stress in 43.366 MPa and Minimum stress is 0 MPa.



The above Fig 16 shows the total deformation induced in the cylinder block for FU 4270 material.

V. RESULTS AND DISCUSSION

In the present work modeling of V8 engine cylinder block was done using CATIA V5. This model was imported to ANSYS Work Bench and done the steady state thermal analysis and calculated the heat flux, normal stress, equivalent stress and deformation for the carbon materials FU 4270 and FU 2451 and compare these results with existing Aluminum and proposed the suitable material.

By doing the steady state thermal analysis using ANSYS work bench 14.5 V and by calculating the convective heat transfer amount through cylinder walls from the theoretical calculations, and calculated the heat flux and equivalent stress, normal stress and the total deformation produced for the cylinder block for Aluminum, FU 4270 along with their thermal conductivities, and their results are given in Table 3

Parameters	**Aluminum(k= 28)**		**FU 4270 (k= 40)**	
	Max	**Min**	**Max**	**Min**
Temperature (K)	2274.6	295.15	2274.6	295.35
Total Heat Flux(W/m^2)	0.028106	0	0.028336	0
Imported Body Temperature (K)	2274.6	295.15	2274.6	295.15
Equivalent Stress(MPa)	75.172	0.014682	43.366	0.0088
Normal Stress(MPa)	31.15	-31.583	18.701	-18.972
Shear Stress(MPa) at XY Plane	14.521	-12.03	8.7421	-7.7247
Total Deformation (mm^2)	0.081694	0	0.049736	0

Material	Mathematical Heat Flux q' (W/m^2)	Analytical (FEA) Heat Flux q'' (W/m^2)	% Error
Aluminum	28280.88	28106	0.62
FU 4270	28522.20	28336	0.66
FU 2451	28712.83	28624	0.31

Table 4 Validation of Heat Flux by Mathematical and Analytical calculations

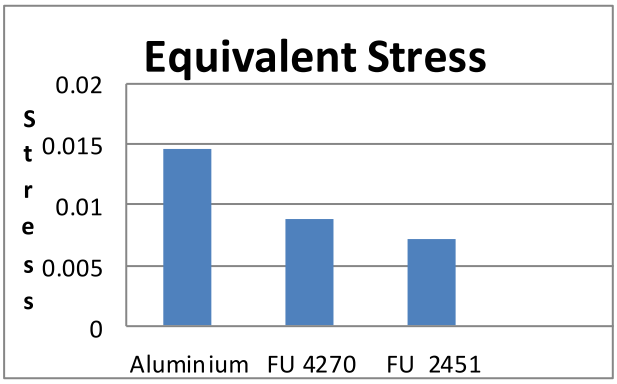


Fig 17 Stress comparison for Aluminum, FU 4270,
The above Fig 17 shows the Graph comparison of Equivalent Stress for Aluminum, FU 4270

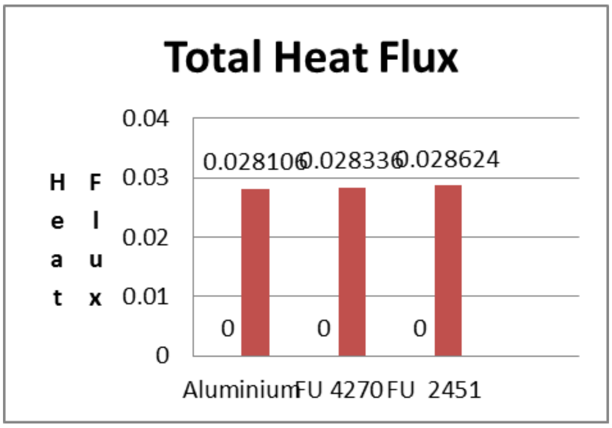


Fig 18 heat Flux comparison for Aluminum, FU 4270
The above Fig 18 shows the Graph comparison of total heat flux for Aluminum, FU 4270

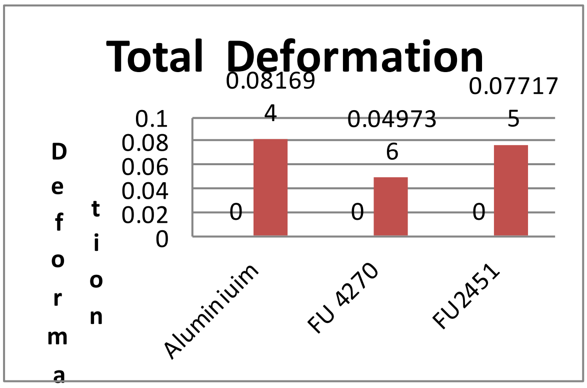


Fig 19 Deformation comparison for Aluminum, FU 4270 and FU 2451
The above 19 shows the Graph comparison of Deformation for Aluminum, FU4270 and

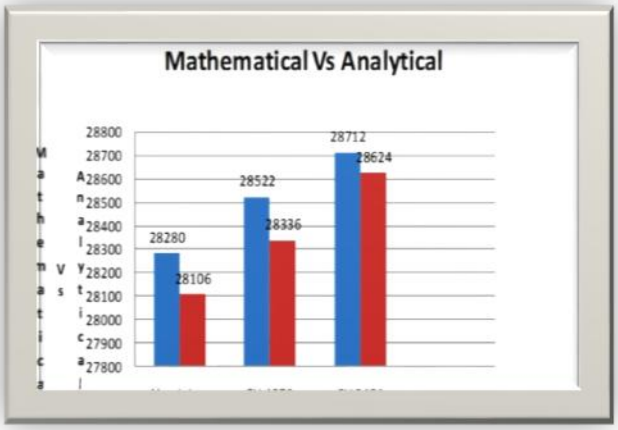


Fig 20 Resultant Graph between Analytical Flux Vs Mathematical Heat Flux

The above Fig 20 shows the graph comparison for analytical heat flux and mathematical heat flux for Aluminum, FU 4270 and FU 2451.

From the above graphs by comparing for the FU 4270 and FU 2451 carbon materials with existing material Aluminum alloy, it is concluded that thermal stress, temperature distribution and heat flux are lower in FU 4270 Material, so this is best material for quick transient hotness exchange between the burning chamber and the cylindrical wall.

VI. CONCLUSION

It is important transient hotness exchange between the burning chamber and cylinder wall in V8 engine, transient hotness exchange depends largely on the materials of the cylindrical block. In the present work transient hotness exchange between the burning chamber and cylinder wall is compared for three different materials. For this first modelling of V8 cylinder block was done using CATIA V5, and analysis was done using ANSYS. Theoretical values of the thermal stresses, temperature distribution, normal stresses, heat flux and deformation are also calculated, and compared with ANSYS values.

By comparing for the FU 4270 and FU 2451 carbon materials with existing material Aluminium alloy, it is concluded that thermal stress, temperature distribution and heat flux are lower in FU 4270 Material, so this is best material for quick transient hotness exchange between the burning chamber and the cylindrical wall.

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