Thermal load analysis and comparison of Total Heat Flux and Temperature Distribution between Carbon Graphite and Cast Iron Pistons of IC engine using FEA technique

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Abstract – This paper describes the results of thermal load analysis and comparison between piston made of Cast Iron and Carbon Graphite. In this paper, example of Piston took from 100 cc hero bike and reverse engineering was done in Solidworks software and the main motive is to find the temperature difference and the total heat flux using Finite element analysis technique in solidworks simulation software and other motive is to find the critical area as well as advantages and disadvantages of both the materials.The temperature load of 200 degree Celsius has been applied on the top of the piston and meshed in solidworks simulation software.

Index Terms – Piston analysis, thermal load on piston, cast alloy steel piston, piston properties, Finite element method, analysis on piston.

1. INTRODUCTION

Piston is a cylindrical member which is placed inside cylinder and on the combustion gases exerts pressure. It is made up of cast iron, alloy steel, aluminum alloy. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. It absorbs the side thrust resulting from obliquity of the connecting rod. It also dissipates the large amount of heat generated by the combustion gases form the combustion chamber to the cylinder wall. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall.

2. FEA (FINITE ELEMENT ANALYSIS)

Finite element analysis (FEA) is the modeling of products and systems in a virtual environment, for the purpose of finding and solving potential (or existing) structural or performance issues. FEA is the practical application of the finite element method (FEM), which is used by engineers and scientist to mathematically model and numerically solve very complex structural, fluid, and metaphysics problems. FEA software can be utilized in a wide range of industries, but is most commonly used in the aeronautical, biomechanical and automotive industries.

3. VOLUMETRIC PROPERTIES

Table 1: Gray Cast Iron

S NO	PROPERTIES	VALUE
1	MASS	0.196 kg
2	VOLUME	2.72e-005m^3
3	DENSITY	7200 kg/m^3
4	WEIGHT	1.92 N

Table 2: Carbon Graphite

S NO	PROPERTIES	VALUE
1	MASS	0.060 kg
2	VOLUME	2.72e-005m^3
3	DENSITY	2240 kg/m^3
4	WEIGHT	0.59 N

4. MECHANICAL PROPERTIES

Table 3: Carbon Graphite

S NO	PROPERTIES	VALUE
1	POISSONS RATIO	0.28
2	THERMAL EXPANSION COEFFICIENT	1.3e-005/K
3	DENSITY	2240 kg/m^3
4	THERMAL CONDUCTIVITY	168 W/(m-K)
5	SPECIFIC HEAT	44 J (kg-K)

Table 4: Gray Cast Iron

S NO	PROPERTIES	VALUE
1	POISSONS RATIO	0.27
2	THERMAL EXPANSION COEFFICIENT	1.2e-005/K
3	DENSITY	7200 kg/m^3
4	THERMAL CONDUCTIVITY	45 W/(m-K)
5	SPECIFIC HEAT	510 J (kg-K)

5. ENGINE SPECIFICATIONS

Type	Air cooled, 4 - stroke single cylinder OHC
Displacement	97.2 cc
Max. Power	6.15kW (8.36 Ps) @8000 rpm
Max. Torque	0.82kg - m (8.05 N-m) @5000 rpm
Max. Speed	87 Kmph
Bore x Stroke	50.0 mm x 49.5 mm
Carburetor	Side Draft , Variable Venturi Type with TCIS
Compression Ratio	9.9 : 1
Starting	Kick / Self Start
Ignition	DC - Digital CDI
Oil Grade	SAE 10 W 30 SJ Grade , JASO MA Grade
Air Filtration	Dry , Pleated Paper Filter
Fuel System	Carburetor
Fuel Metering	Carburetion

6. REVERSE ENGINEERING THE PISTON

With the help of measuring instruments like vernier caliper etc. the dimensions of the model piston were measured. By using this measurement 3D model of the piston were drawn using Solidworks 3D modeling software as below:

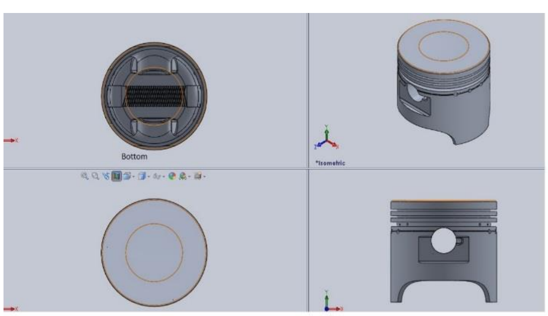

Figure 1. Model of Piston

7. BOUNDARY CONDITIONS AND LOADS

Applied Temperature value of 473 degree kelvin on the top of piston

Note: Units, boundary conditions and loads will be same in both tests.

8. MESHING OF PISTON

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	2.94563 mm
Tolerance	0.147281 mm
Mesh Quality	High

Mesh Information – Details

Total Nodes	26221
Total Elements	14224
Maximum Aspect Ratio	90.342
% of elements with Aspect Ratio < 3	84
% of elements with Aspect Ratio > 10	0.443
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:07

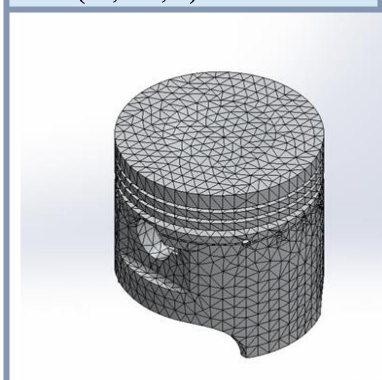

Figure 2: Meshed Model

9. STUDY PROPERTIES

Study name	Study 1
Analysis type	Thermal(Transient)

Mesh type	Solid Mesh
Solver type	Direct sparse solver
Solution type	Transient
Total time	1 Seconds
Time increment	0.1 Seconds
Contact resistance defined?	No
Result folder	DEFAULT

10. UNITS

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

11. RESULTS AND DISCUSSIONS

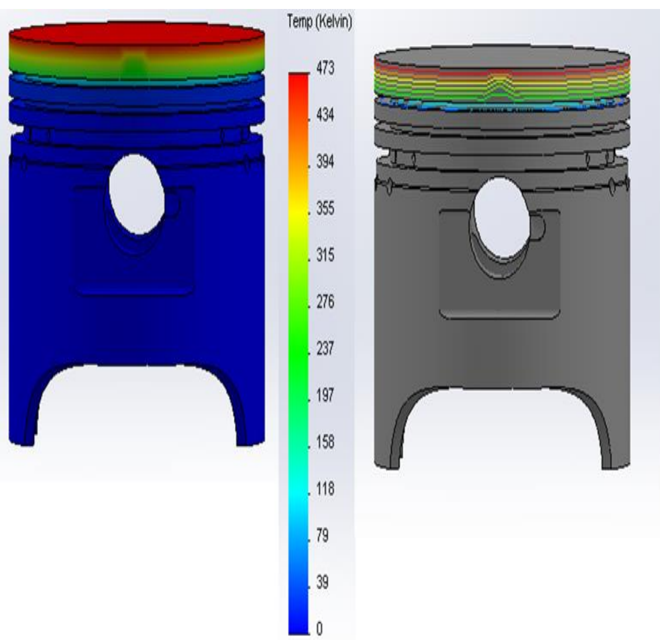

Figure 3. Temperature Distribution for Cast Iron

Figure (3): Maximum temperature shows on the top of the piston and distribute of temperature shown till 1st piston ring groove due to heat produce by the gases in cylinder block.

Figure (4): Maximum temperature 473 deg. kelvin shows on the top of the piston and distribution of temperature till last due to heat produce by the gases in cylinder block.

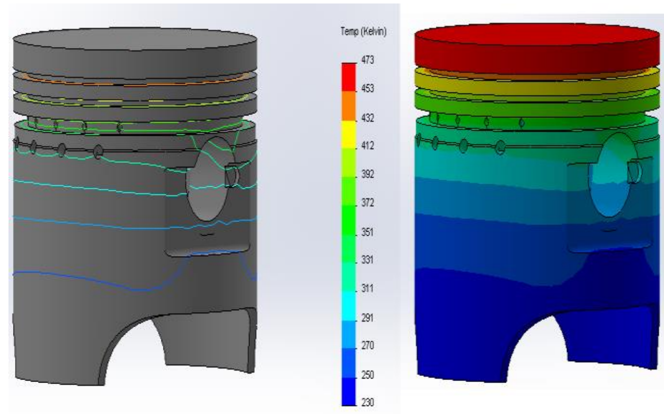

Figure 4. Temperature Distribution for Carbon Graphite

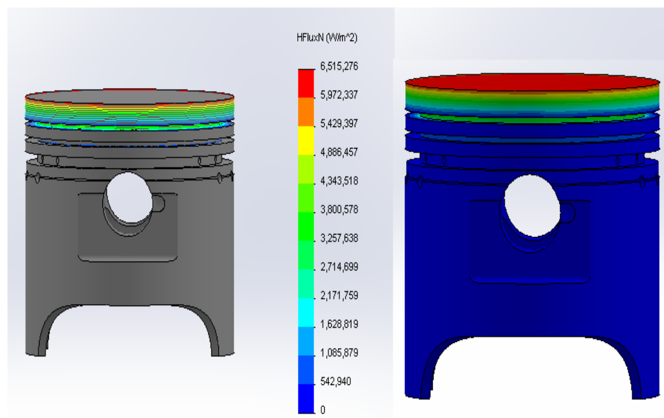

Figure (5) Total Heat Flux for Gray Cast Iron

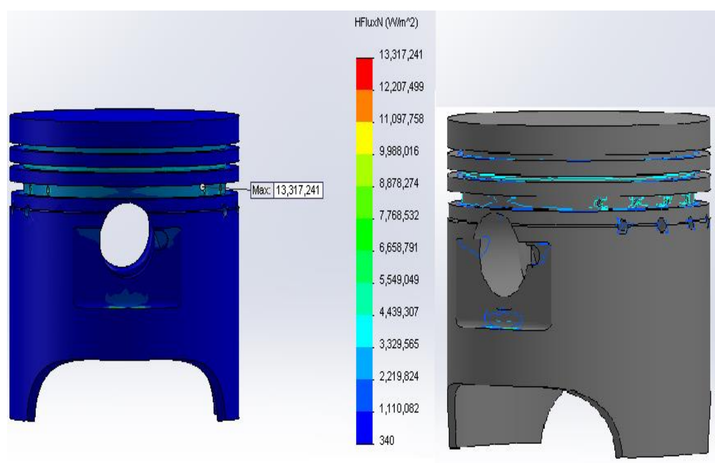

Figure (6) Total Heat Flux for Carbon Graphite

Figure (5): It shows the maximum Total heat flux in the piston due to the application of gases is 6.51 MW/m^2 which is observed on the top of the piston and heat flow graphics shown till the 2nd piston ring groove.

Figure (6): It shows the maximum Total heat flux in the piston due to the application of gases is 3.31 MW/m^2 which is observed on the 3rd groove of piston ring and heat flow graphics shown till just down the piston pin hole.

12. CONCLUSION

According to the results maximum heat transfer occurs in the piston made of Carbon Graphite as compared to Gray Cast Iron due to the higher thermal conductivity.Furthermore, according to volumetric properties, Carbon Graphite material is much lighter than Gray Cast Iron .

Moreover, Other advantage of carbon graphite piston is that Carbon shows an excellent resistance to thermal shock and exhibits self -lubricant properties which increase the operational reliability of the engine and result in reduced lubricant consumption.

Carbon graphite has slightly high thermal expansion coefficient as compared to cast iron which does not much matter .On the other hand, Carbon Graphite Piston reduces hydrocarbons emission and it is the sign of good fuel ignition.

At last, according to the upper results and attractive qualities in carbon graphite shows the much better than Gray Cast Iron as Piston material and suitable for IC engine.

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