Comparison the Behavior of Cast Iron and Carbon Graphite as Piston Materials Applied Thermal Load as Heat Flux Using Finite Element Analysis

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Abstract – This paper describes the behavior of Carbon Graphite and Cast Iron applied heat flux value of 100 W/m^2.k on the top of the piston model and found the maximum and minimum temperature distribution, critical area and heat transfer result using finite element analysis technique. Piston of 100cc hero bike was taken for analysis and did reverse engineering using Dassault Systemes's Solidworks and the model was meshed in solidworks simulation module for analysis. The main motive is to find the critical temperature distribution area and behavior of carbon graphite and cast iron after applied the thermal load on both the materials turn by turn and find out the better material should be used for piston of IC engine to increase the engine performance.

Index Terms – Cast iron piston, analysis, heat transfer in piston, piston design , FEA method, Carbon Graphite thermal analysis.

1. INTRODUCTION

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. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. Piston features include the piston head, piston pin bore, piston pin, skirt, ring grooves, ring lands, and piston rings. The piston head is the top surface of the piston which is subjected to tremendous forces and heat during normal engine operation.

2. FINITE ELEMENT ANALYSIS METHOD

Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow and other physical effects. Finite element analysis shows whether a product will break, wear out or work the way it was designed. The finite element method (FEM) is a numerical method for solving problems of engineering and mathematical physics. It is also referred to as finite element analysis (FEA). ... To solve the problem, it subdivides a large problem into smaller, simpler parts that are called finite elements.

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:

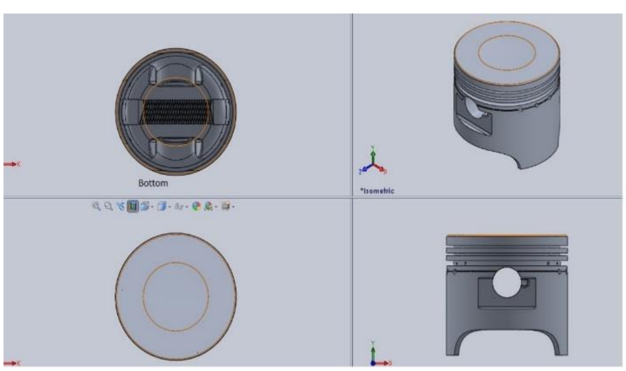


Figure 1. Model of Piston

7. BOUNDARY CONDITIONS AND LOADS

Applied Heat Flux value of 100 W/m^2.k on the top of piston.

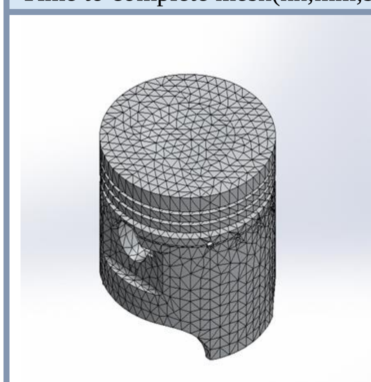
Note: Units, boundary conditions and loads will be same in both tests.

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

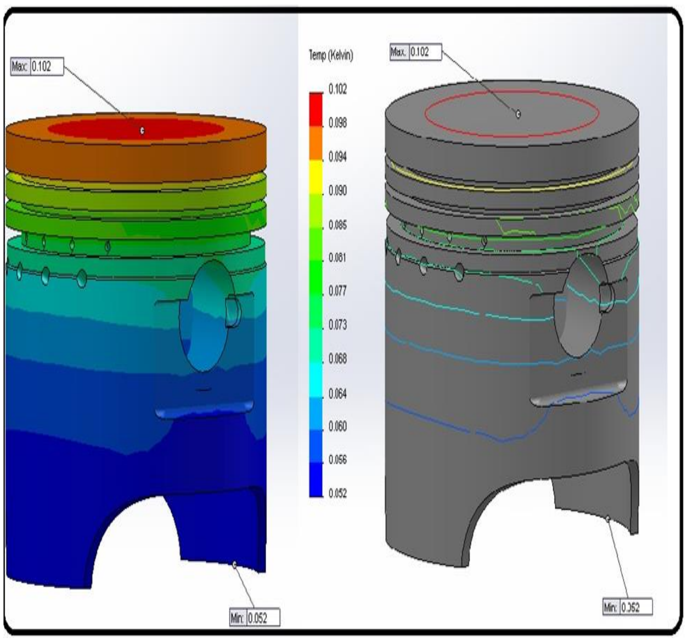


Figure 3. Temperature Distribution result for piston made of Carbon Graphite

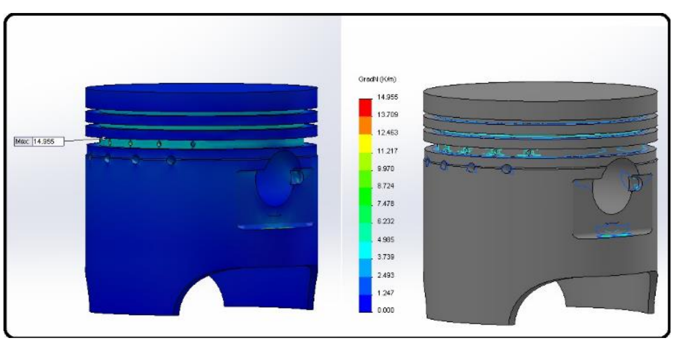


Figure 4. Resultant Temperature Gradient result for piston made of Carbon Graphite

Figure 3. The result says the maximum temperature occur on the center portion of the top of the piston minimum in the last area of length and shown excellent distribution due to the heat generated for compression of gases in the combustion chamber of IC engine.

Figure 4. The result shows in the resultant temperature gradient which shows the heat transfer properly till the area just below the piston pin hole due to combustion of gases in the chamber.

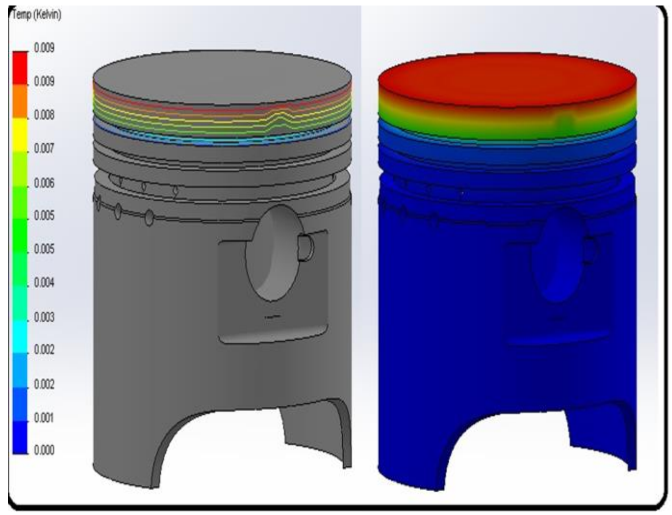


Figure 5. Temperature Distribution for Cast Iron

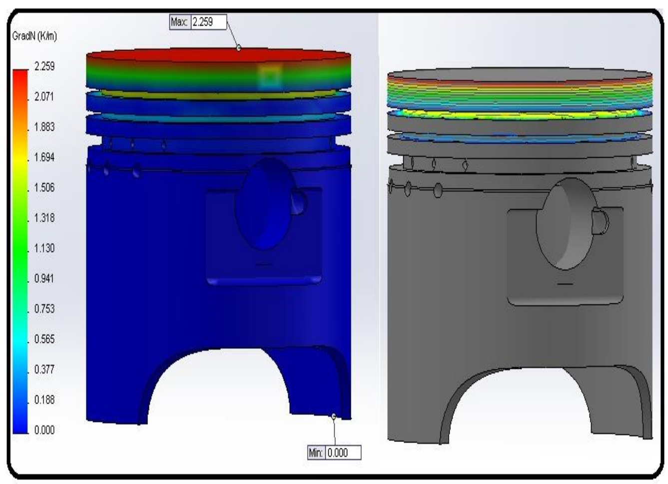


Figure 6. Resultant Temperature Gradient result for piston made of Cast Iron

Figure 5. The maximum temperature absorbed on the top of the piston head and edges and distributed properly till the 1st groove of piston ring because of gases in the block.

Figure 6. The maximum temperature occur on the top of the piston head and transferred till the 2^{nd} groove of the piston ring due to the heat generated by the gases in the chamer.

12. CONCLUSION

As per result received from thermal load analysis, the maximum temperature distribution and heat transfer occur in the piston made of Carbon Graphite as compared to Cast Iron due to higher thermal conductivity and the lower specific heat capacity as material properties.

Other advantages of Carbon Graphite is that it is the self – lubricant and reduce the consumption of oil and much lighter in weight as compared to Cast Iron. And carbon has low coefficient of thermal expansion as well as increase the engine performance

In the end, Carbon Graphite occur the more suitable material for piston of IC engine of Automobile.

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