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Temperature Distribution Analysis on Piston Made of Carbon Graphite and Cast Alloy Steel As Well As Comparison Using Finite Element Method

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Abstract – This paper describes the analysis and comparison between the pistons made of cast alloy steel and carbon graphite using finite element analysis. In this paper, reverse engineering the piston of 100cc hero bike engine was done using Solidworks software and the thermal load test analysis was done by solidworks simulation software. In the analysis part, temperature of 473 degree kelvin applied on the top of the piston and the result of Total heat flux and temperature distribution was found and analyzed the more suitable material of piston for an IC engine. The comparison was done between cast alloy steel and carbon graphite as piston materials. The model was meshed in solidworks simulation software to perform the analysis.

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

1. INTRODUCTION

Piston plays an important role in an IC engine. A piston is a part of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. 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. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall.

2. FINITE ELEMENT METHOD

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). Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The analytical solution of these problems generally require the solution to boundary value problems for partial differential equations. The finite element method formulation of the problem results in a system of algebraic equations. The method yields approximate values of the unknowns at discrete number of points over the domain.To solve the problem, it subdivides a large problem into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

3. VOLUMETRIC AND MECHANICAL PROPERTIES OF MATERIAL

Table 1: Cast Alloy Steel

S NO	PROPERTIES	VALUE
1	MASS	0.198 kg
2	VOLUME	2.72e-005m^3
3	DENSITY	7300kg/m^3
4	WEIGHT	1.94 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: Cast Alloy Steel

S NO	PROPERTIES	VALUE
1	POISSONS RATIO	0.26
2	THERMAL EXPANSION COEFFICIENT	1.5e-005/K
3	DENSITY	7300 kg/m^3
4	THERMAL CONDUCTIVITY	38 W/(m-K)
5	SPECIFIC HEAT	440 J (kg-K)

Table 4: 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)

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:

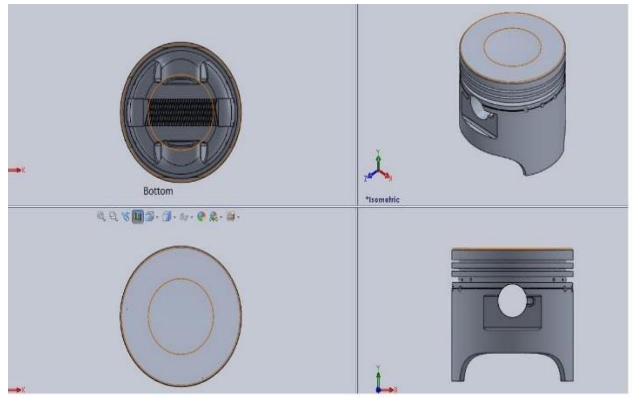

Figure 1. Model of Piston

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

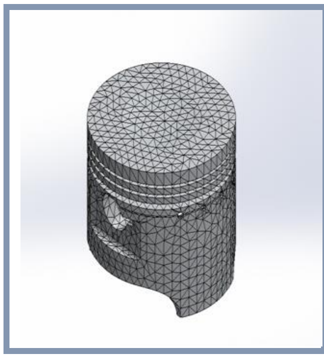

Figure 2: Meshed Model

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	SolidWorks document (C:\Users\JATENDER DATTA\Desktop\desk new)

10. UNITS

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

11. RESULTS AND DISCUSSIONS

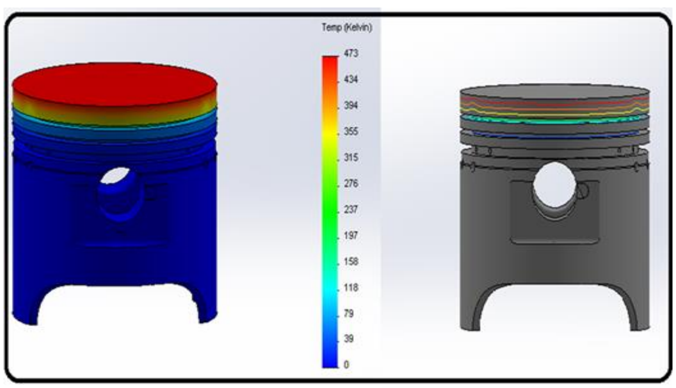

Figure 3: Result of Temperature Distribution in Cast Alloy Steel Piston

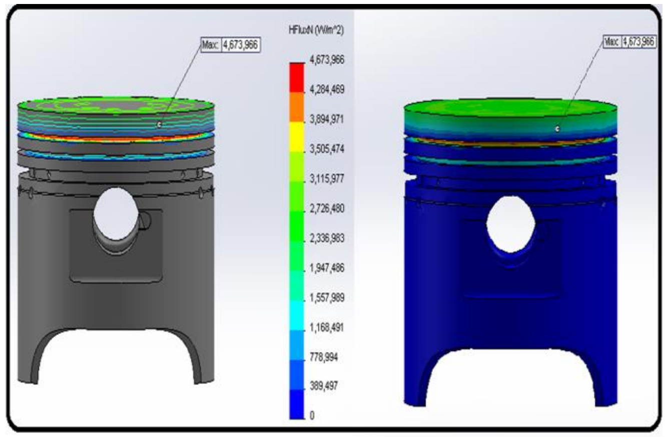

Figure 4: Result of Total Heat Flux in Cast Alloy Piston

Figure (3): Maximum temperature shows on the top of the piston and distribute of temperature shows on the top of the piston due to heat of gases in combustion chamber. Figure (4): Maximum Value of Heat Flux shows on the side portion of piston head just above the first piston ring groove and heat flows till the 2nd groove as shown the behavior in the image.

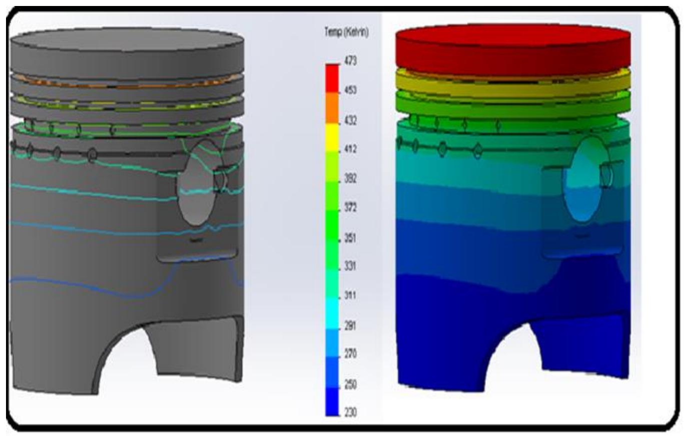

Figure 5: Result of Temperature Distribution in Carbon Graphite Piston

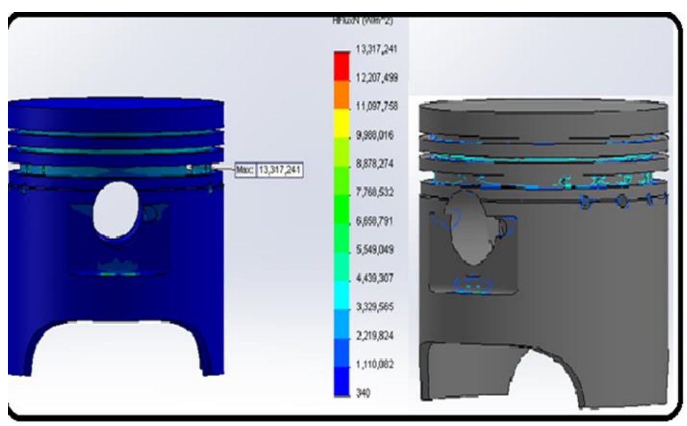

Figure 6: Result of Total Heat Flux in Carbon Graphite Piston

Figure (5): It shows the maximum temperature on the top of the piston head and on the side portion of pison head due to heat of gases in chamber.

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

12. CONCLUSION

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

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 low thermal expansion coefficient as compared to cast alloy steel which plays an important role. On the other hand, Carbon Graphite Piston reduces hydrocarbons emission and it is the sign of good fuel ignition.

At last, According to results, Carbon Graphite is preferable as piston material in IC Engine.

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