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THERMAL ANALYSIS ON PISTON OF VARIOUS MATERIALS AND COMPARISON WITH EACH OTHER'S BY USING FINITE ELEMENT ANALYSIS TECHNIQUE

Jatender Datta*[1] & Dr. Sahib Sartaj Singh[2]
*[1&2]Research Scholar, PhD (Mechanical Engg.), Desh Bhagat University, Mandi Gobindgarh (India)
Workshop Suptt. , Punjabi University, Patiala (India)

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ABSTRACT

This paper describes the **Thermal(Steady state)** analysis of cast iron, cast alloy steel and carbon graphite pistons by using finite element Analysis (FEA) .The parameters used for the simulation are operating gas temperature and material properties of pistons. The specifications used for the study of these pistons belong to four stroke 100cc hero bike engine. This paper illustrates the procedure for analytical design of cast iron , cast alloy steel and carbon graphite pistons using specifications of four stroke 100cc hero bike engine. The results predict the minimum and maximum value of GRADN: Resultant Temp Gradient on all of these pistons using FEAwith applied the temperature 100°C on the top of piston. The 3Dmodelling of piston is done inSolidworks (Feature module) and Simulation module was used to mesh the pistons, thermal analysis with temperature applied on the top of piston head

KEYWORDS: Thermal analysis, FEA on piston, temperature applied on piston, resultant temperature gradient.

I. 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 or 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.

II. FINITE ELEMENT ANALYSIS (FEA)

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. It is an advanced engineering tool that is used in design and to augment/replace experimental testing.

III. METHODOLOGY OF PROPOSED WORK

The methodology of this work is based upon information collected and processed the study and research phase.

The technique to be applied for the design of piston are as follows:

- Data gathering of recent development in IC engine piston.
- Reverse engineering this piston, and calculated dimensions were measured and reproduced as a 3-D model in Solidworks software, and analyzed in Solidworks Simulation.
- Selection of Material from software's library
- Meshing of Piston.
- Applying Boundary conditions.
- Result calculation.
- Comparing the results of thermal load analysis study.

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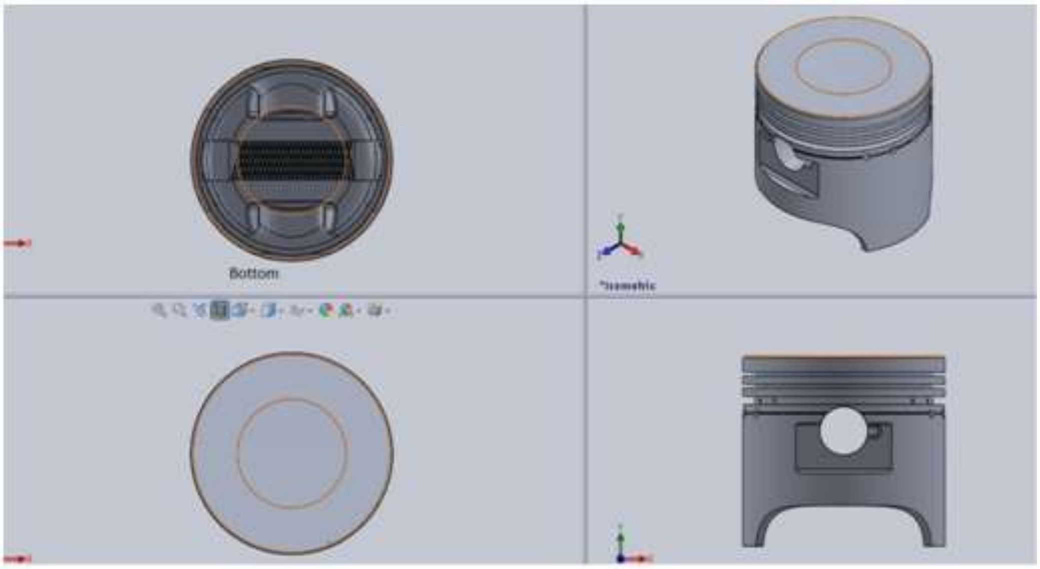
IV. ENGINE SPECIFICATIONS

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

V. 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 Solidworks3D modeling software as below:



VI. BOUNDARY CONDITIONS AND LOADS

a. Maximum Temperature at top surface of the piston 100°C .
b. Piston pin holes are fixed.

Note: Model, meshing, Units, boundary conditions and loads will be same in all tests.

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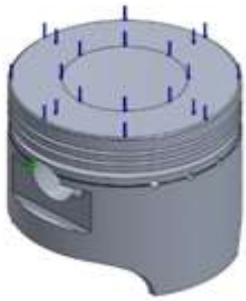
VII. ANALYSIS ON CAST IRON PISTON

Model Information



Model name: Piston 100cc_Hero Splendor
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
LPattern2 	Solid Body	Mass:0.196012 kg Volume:2.7224e-005 m^3 Density:7200 kg/m^3 Weight:1.92092 N	DEFAULT

Model Reference	Properties	Components
	Name: Gray Cast Iron Model type: Linear Elastic Isotropic Default failure criterion: Mohr-Coulomb Stress Tensile strength: 1.51658e+008 N/m^2 Compressive strength: 5.72165e+008 N/m^2 Elastic modulus: 6.61781e+010 N/m^2 Poisson's ratio: 0.27 Mass density: 7200 kg/m^3 Shear modulus: 5e+010 N/m^2 Thermal expansion coefficient: 1.2e-005 /Kelvin	Solid Body 1(LPattern2)(Piston 100cc_Hero Splendor)

Mesh Information – Details

Total Nodes	139938
Total Elements	86193
Maximum Aspect Ratio	167.85
% of elements with Aspect Ratio < 3	90.8
% of elements with Aspect Ratio > 10	0.39
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:42
Computer name:	DEFAULT

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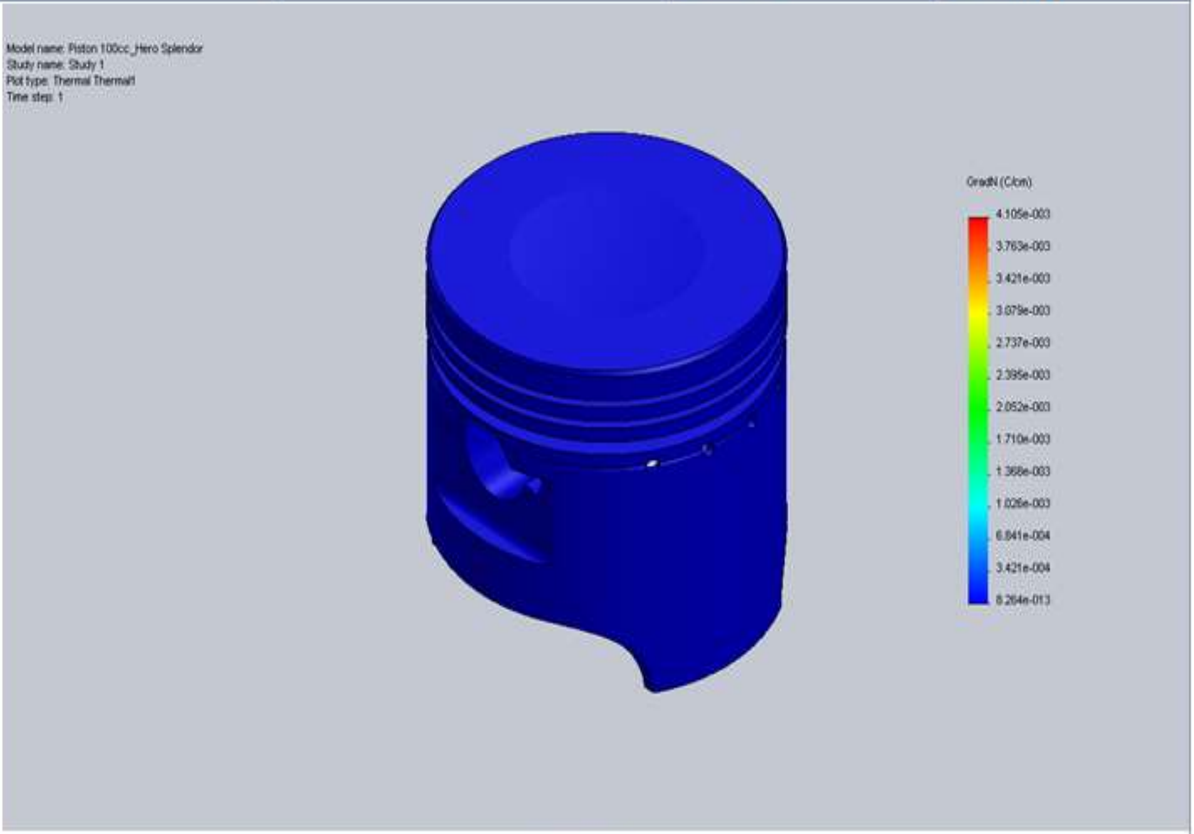
VIII. STUDY RESULTS

Name	Type	Min	Max
Thermal1	GRADN: Resultant Temp Gradient	8.2639e-013 C/cm Node: 80838	0.0041049 C/cm Node: 101644



Study (I)

IX. ANALYSIS ON CAST ALLOY STEEL PISTON

Volumetric Properties

LPattern2 	Solid Body	Mass:0.198735 kg Volume:2.7224e-005 m^3 Density:7300 kg/m^3 Weight:1.9476 N	DEFAULT

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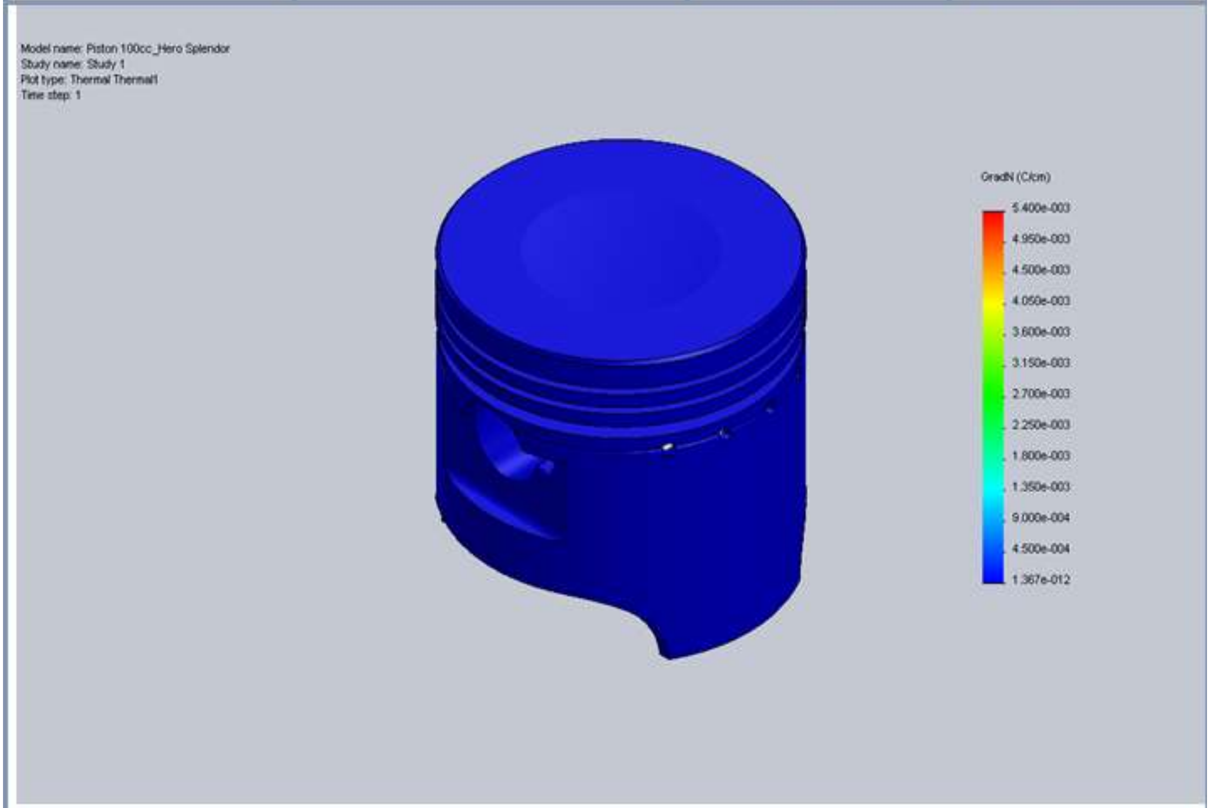
Material Properties

Model Reference	Properties	Components
	**Name:** Cast Alloy Steel **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Yield strength:** 2.41275e+008 N/m^2 **Tensile strength:** 4.48082e+008 N/m^2 **Elastic modulus:** 1.9e+011 N/m^2 **Poisson's ratio:** 0.26 **Mass density:** 7300 kg/m^3 **Shear modulus:** 7.8e+010 N/m^2 **Thermal expansion coefficient:** 1.5e-005 /Kelvin	Solid Body 1(LPattern2)(Piston 100cc_Hero Splendor)
Curve Data:N/A		

X. STUDY RESULTS

Name	Type	Min	Max
Thermal1	GRADN: Resultant Temp Gradient	1.36703e-012 C/cm Node: 76816	0.00540006 C/cm Node: 101644



STUDY II

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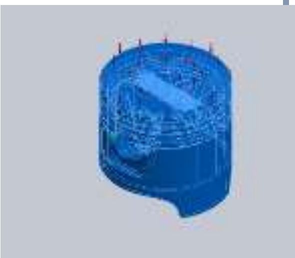
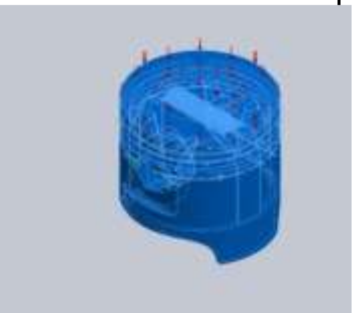
XI. ANALYSIS ON CARBON GRAPHITE PISTON

Volumetric Properties

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
LPattern2 	Solid Body	Mass:0.0609817 kg Volume:2.7224e-005 m^3 Density:2240 kg/m^3 Weight:0.59762 N	DEFAULT

Material Properties

Model Reference	Properties		Components
	Name:	**C (Graphite)**	**SolidBody 1(LPattern2)(Piston 100cc_Hero Splendor)**
	Model type:	**Linear Elastic Isotropic**	
	Default failure criterion:	**Unknown**	
	Yield strength:	**1.20594e+008 N/m^2**	
	Tensile strength:	**1.00826e+008 N/m^2**	
	Elastic modulus:	**2.1e+011 N/m^2**	
	Poisson's ratio:	**0.28**	
	Mass density:	**2240 kg/m^3**	
	Thermal expansion coefficient:	**1.3e-005 /Kelvin**	
Curve Data:N/A			

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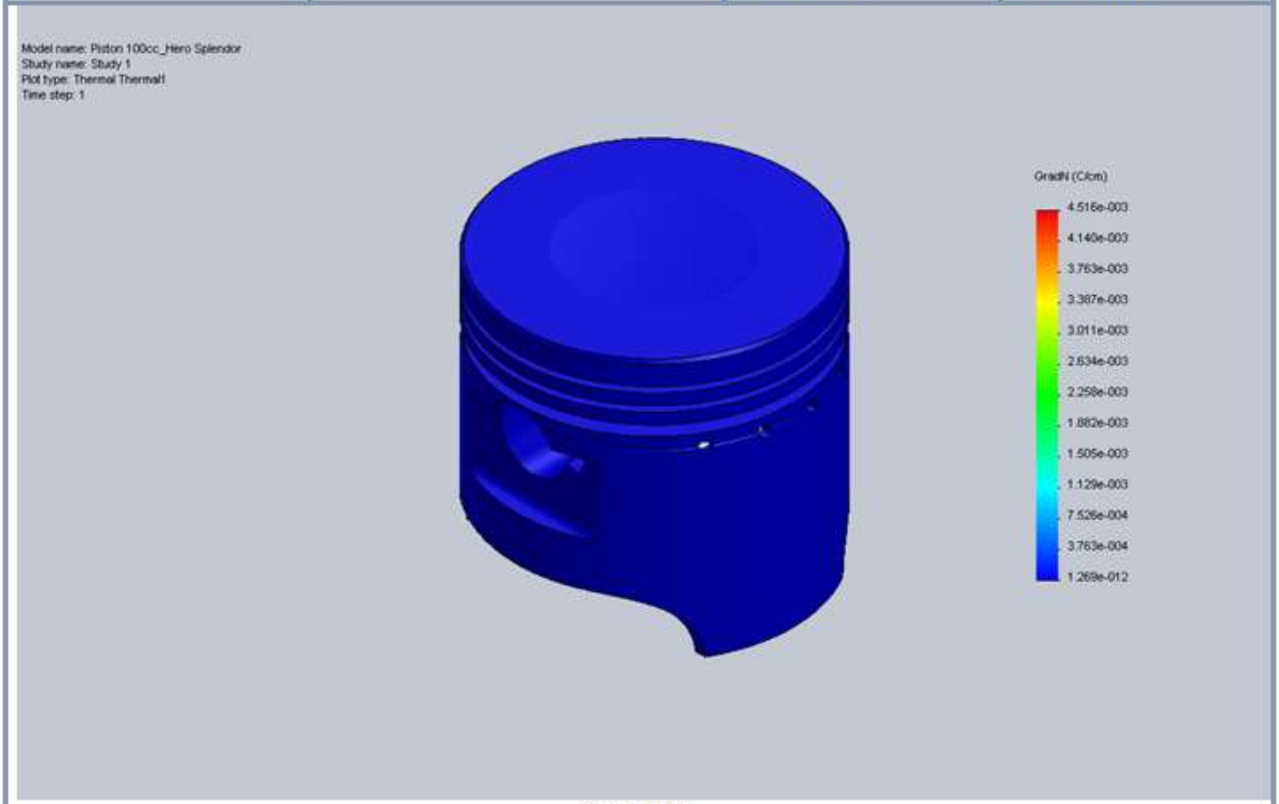
XII. STUDY RESULTS

Name	Type	Min	Max
Thermal1	GRADN: Resultant Temp Gradient	1.26861e-012 C/cm Node: 76555	0.0045159 C/cm Node: 101644



Study (III)

XIII. CONCLUSION

In the conclusion, according to above results of thermal analysis on various materials of piston applied temperature of 100°C on the top of piston, the maximum GRADN value found of cast alloy steel is more as compared to cast iron and carbon graphite. In fact there is a least difference of maximum value of result found between cast iron and graphite.

Moreover, cast iron is lighter in weight in the comparison of cast alloy steel. But according to volumetric properties, Carbon Graphite material is much lighter than cast iron and cast alloy steel.

Furthermore, according to material properties cast iron has low **Thermal expansion coefficient**as compared to carbon graphite and cast alloy steel but according to properties, there is slightly difference between c-graphite and cast iron.

On the other hand, cast iron has good thermal conductivity as compared to cast alloy steel. But the carbon graphite has excellent thermal conductivity as compared to cast iron and cast alloy steel. There is so much difference.

At last, according to the above study, Carbon Graphite piston is much better as compared to cast iron and cast alloy steel for IC engine especially due to light weight and excellent thermal conductivity, in fact carbon shows an excellent resistance to thermal shocks

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