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Static analysis and comparison between carbon graphite, aluminum alloy 2618 and aluminum alloy 4032 pistons of IC engine with pressure applied on the top of piston head.

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Abstract: This paper describes the stress distribution; displacement and Strain of aluminum alloy 2618, Aluminum Alloy 4032 and carbon graphite pistons by using finite element Analysis (FEA) .The parameters used for the simulation are operating gas pressure, 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 aluminum alloy 4032, aluminum alloy 2618 and carbon graphite pistons using specifications of four stroke 100cc hero bike engine. The results predict the maximum stress and critical region on all of these pistons using FEA. It is important to locate the critical area of concentrated stress for appropriate modifications. The CAD model of the pistons was drawn by using Solidworks (Feature module) and Simulation module was used to mesh the pistons, Static analysis with pressure applied on the top of piston head.
Keywords: aluminum alloy 2618 piston,IC engine piston, carbon graphite piston analysis, stress analysis on piston, strain, displacement, analysis on aluminum alloy 4032 piston.

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. FEM (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.

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

A. Data gathering of recent development in IC engine piston.
B. Reverse engineering this piston, and calculated dimensions were measured and reproduced as a 3-D model in Solidworks software, and analyzed in Solidworks Simulation.
C. Selection of Material from software's library
D. Meshing of Piston.

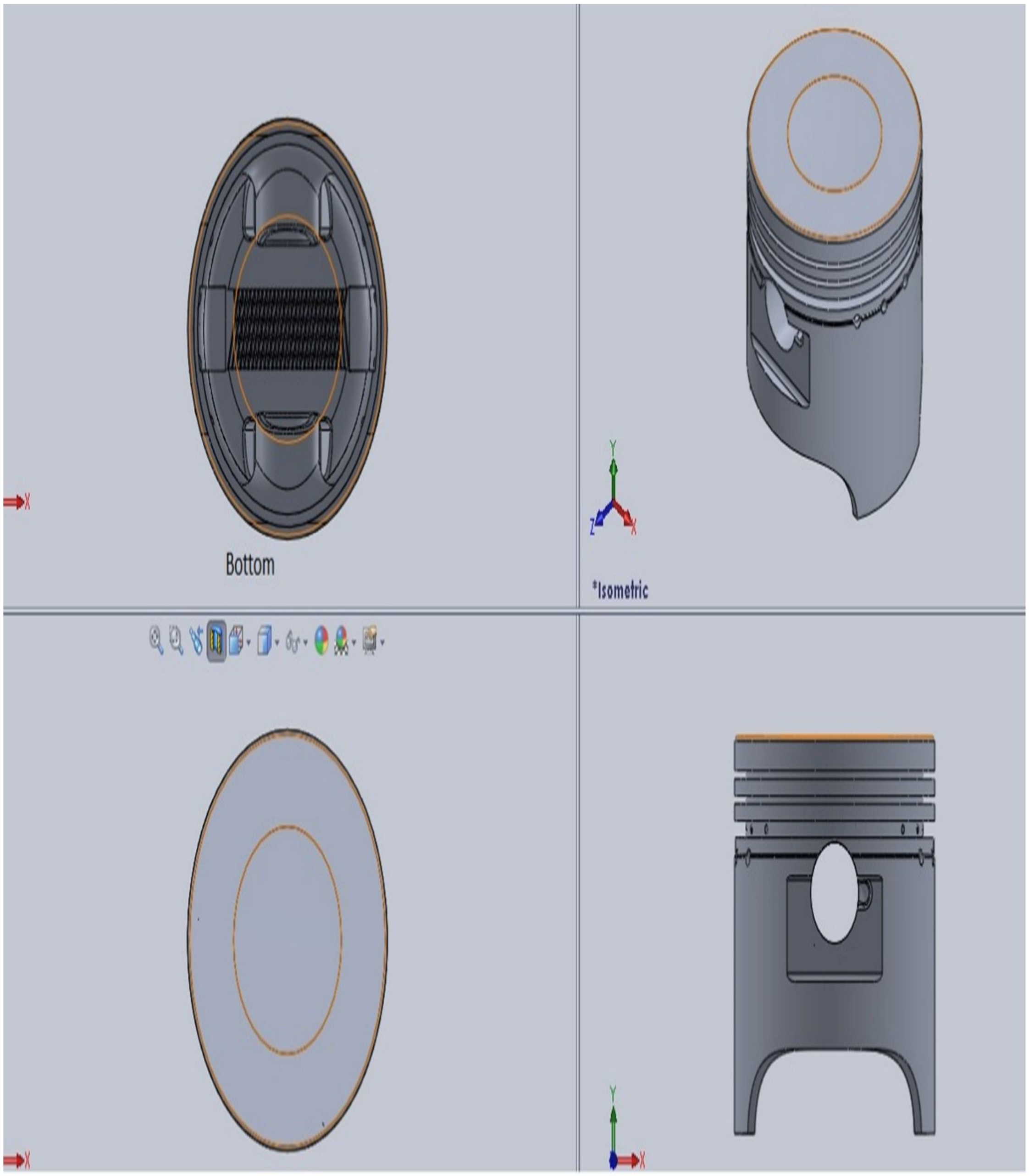
E. Applying Boundary conditions.
F. Result calculation.
G. Comparing Total deformation and Max. Von misses stress in Static analysis.

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 Solidworks 3D modeling software as below



VI. BOUNDARY CONDITIONS AND LOADS

A. Maximum gas pressure at top surface of the piston 72.5 psi (5 Bar)
B. Piston pin holes are fixed.

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

VII. ANALYSIS ON ALUMINUM ALLOY 4032 PISTON

Model Information

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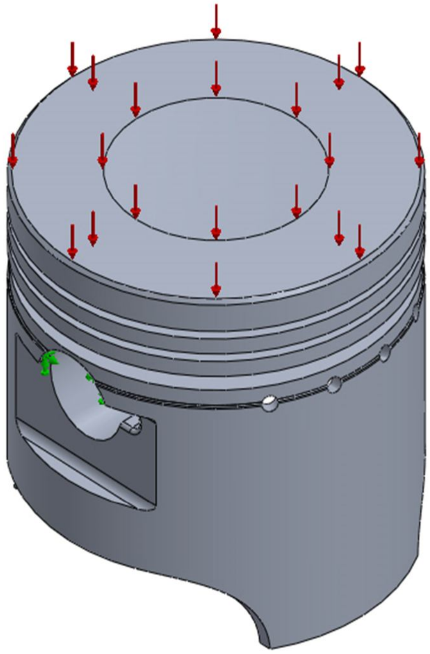
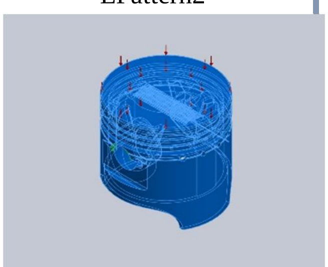


Model name: Piston 100cc_Hero Splendor
Current Configuration: Default

Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
LPattern2 	Solid Body	Mass:0.0729602 kg Volume:2.7224e-005 m^3 Density:2680 kg/m^3 Weight:0.71501 N	Default

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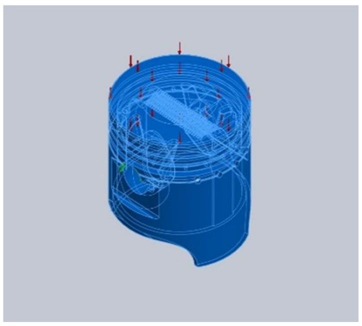
Units

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

Material Properties

Model Reference	Properties	Components
	Name: 4032-T6 Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 3.15e+008 N/m^2 Tensile strength: 3.8e+008 N/m^2 Elastic modulus: 7.9e+010 N/m^2 Poisson's ratio: 0.34 Mass density: 2680 kg/m^3 Shear modulus: 2.6e+010 N/m^2 Thermal expansion coefficient: 1.94e-005 /Kelvin	SolidBody 1(LPattern2)(Piston 100cc_Hero Splendor)
Curve Data:N/A		

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):	00:00:37
Computer name:	DEFAULT

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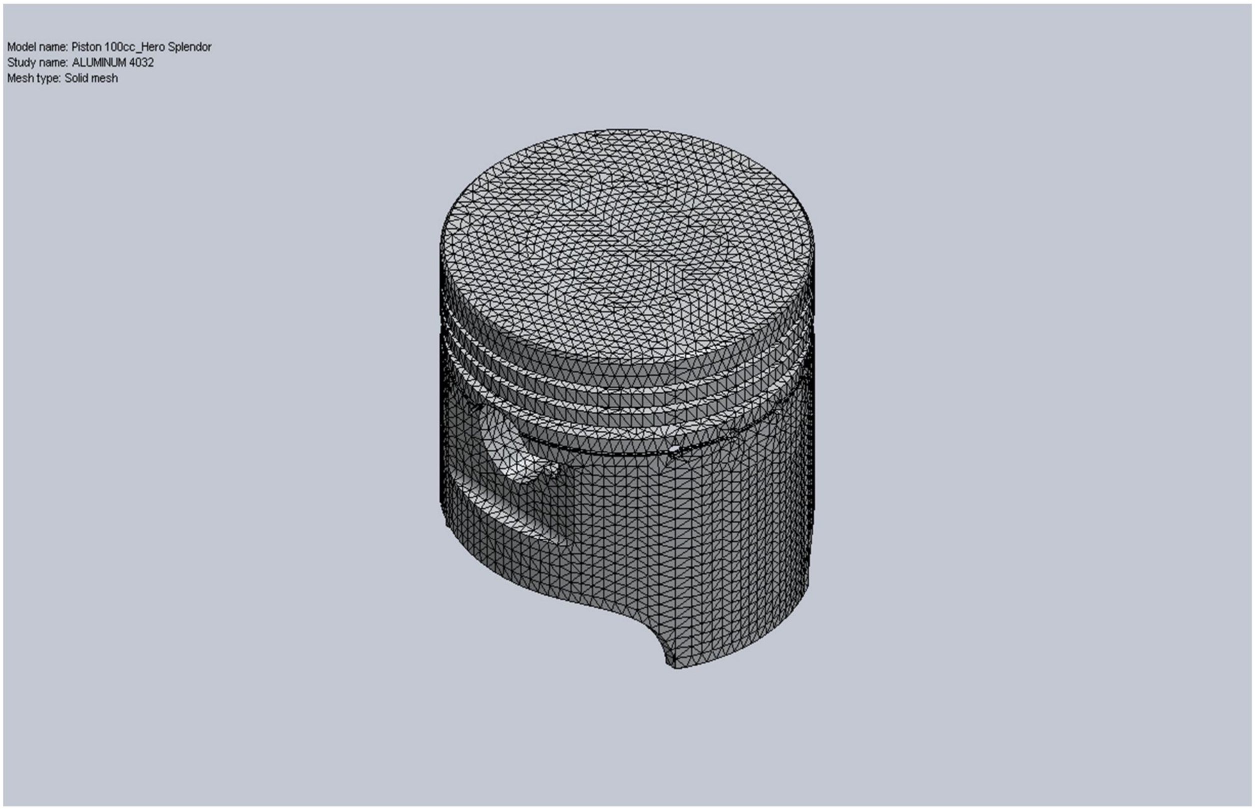
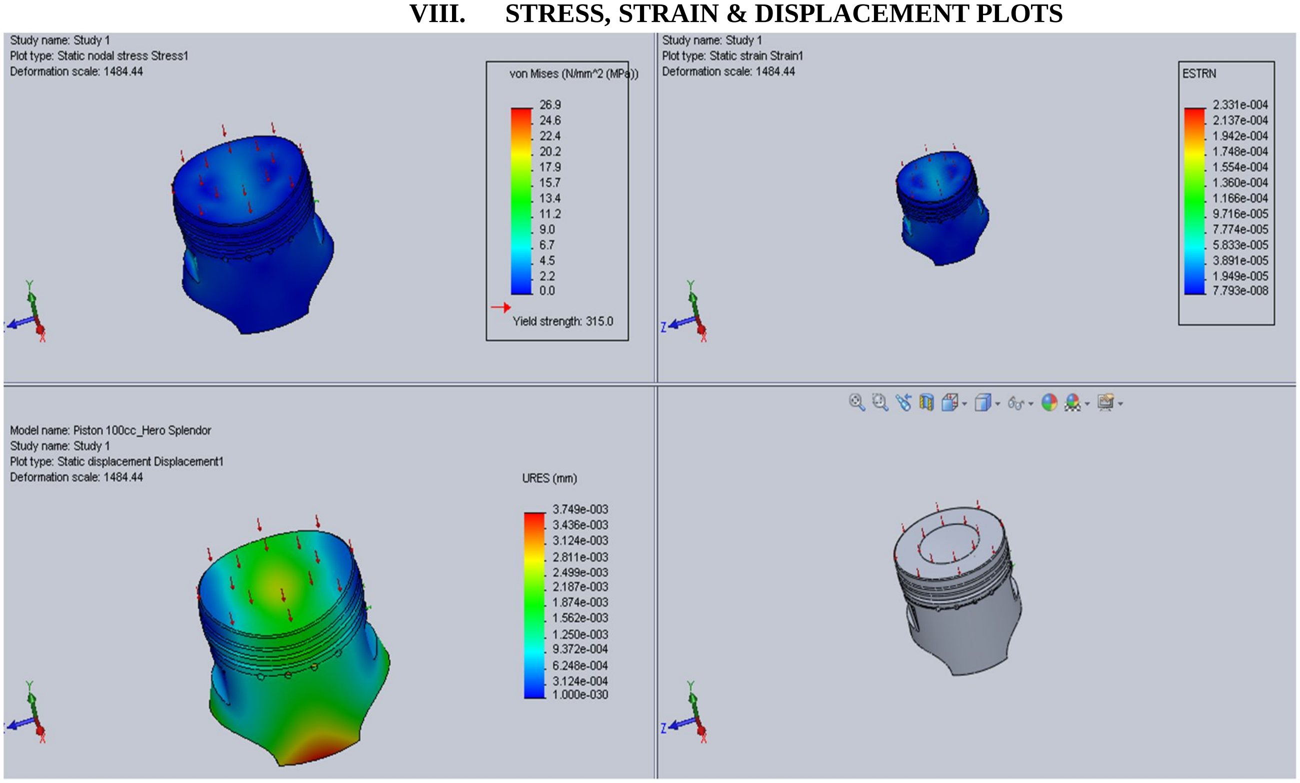


VIII. STRESS, STRAIN & DISPLACEMENT PLOTS



Study (i)

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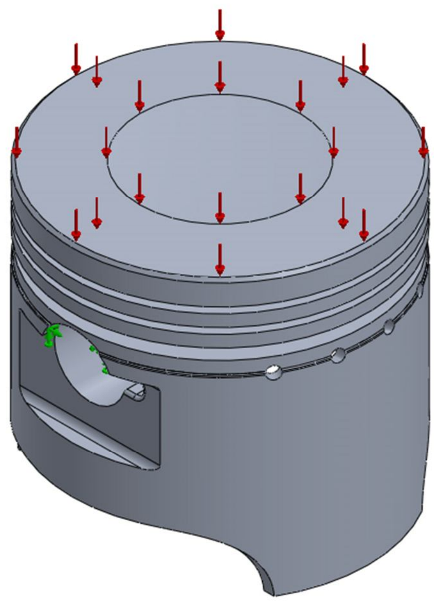
IX. ANALYSIS ON ALUMINUM ALLOY 2618 PISTON

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:0.0751381 kg Volume:2.7224e-005 m^3 Density:2760 kg/m^3 Weight:0.736354 N	DEFAULT

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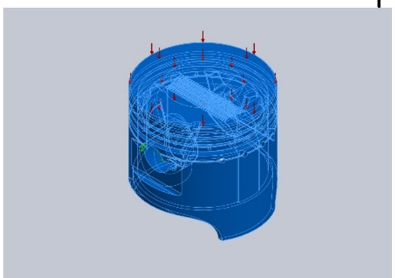
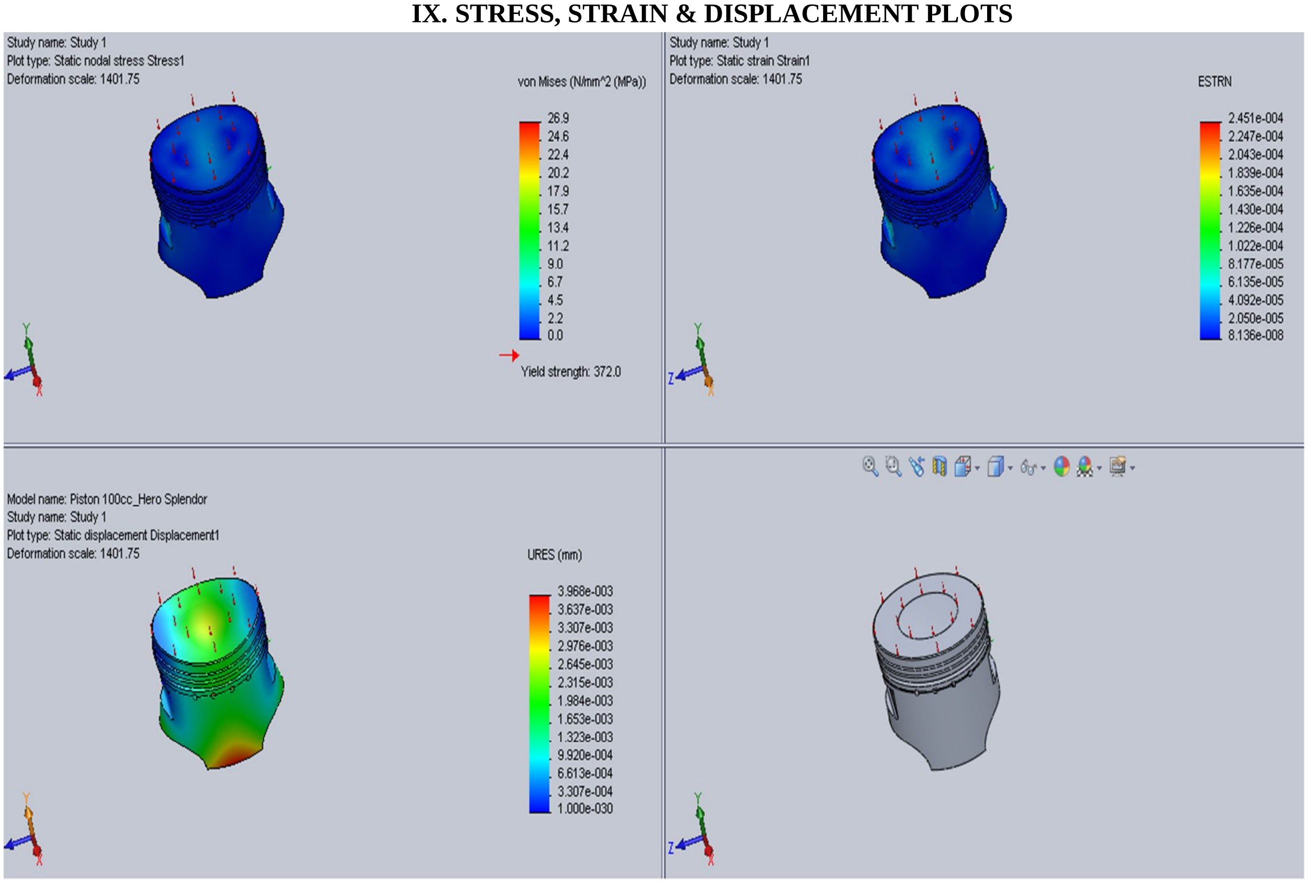
Material Properties

Model Reference	Properties	Components
	Name: 2618-T61 (SS) Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 3.72e+008 N/m^2 Tensile strength: 4.41e+008 N/m^2 Elastic modulus: 7.45e+010 N/m^2 Poisson's ratio: 0.33 Mass density: 2760 kg/m^3 Shear modulus: 2.7e+010 N/m^2 Thermal expansion coefficient: 2.2e-005 /Kelvin	SolidBody 1(LPattern2)(Piston 100cc_Hero Splendor)
Curve Data:N/A		

IX. STRESS, STRAIN & DISPLACEMENT PLOTS



Study (ii)

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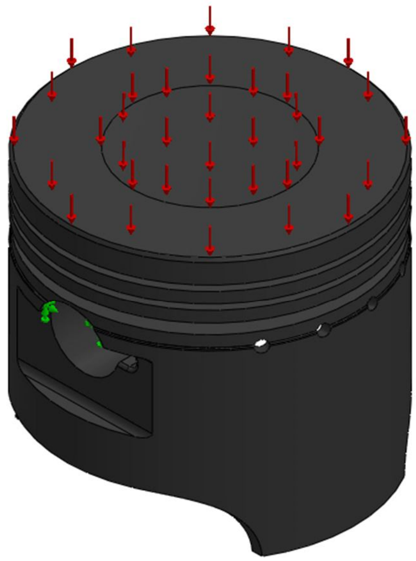
X. ANALYSIS ON CARBON GRAPHITE PISTON

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:0.0609817 kg Volume:2.7224e-005 m^3 Density:2240 kg/m^3 Weight:0.59762 N	DEFAULT

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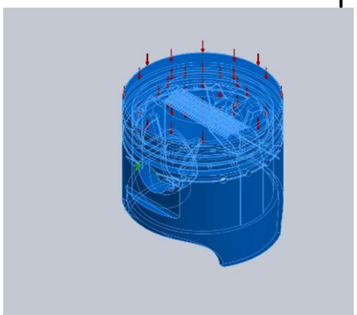
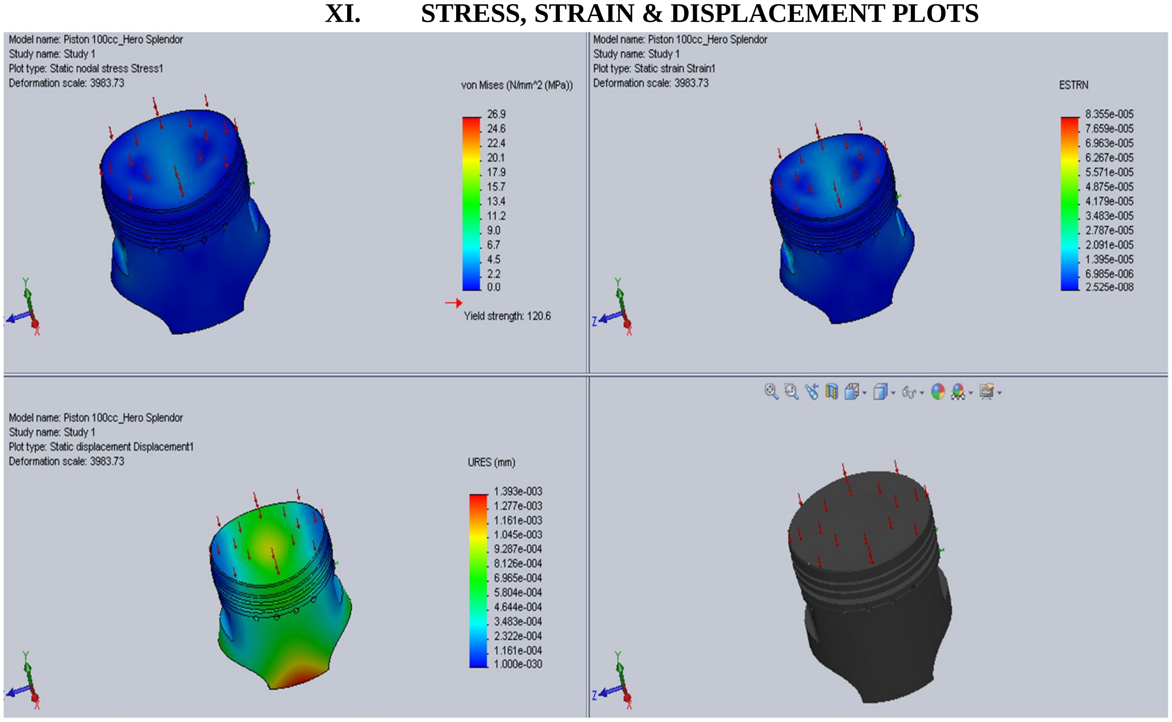
Material Properties

Model Reference	Properties	Components
	Name: C (Graphite) 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	Solid Body 1(LPattern2)(Piston 100cc_Hero Splendor)
Curve Data:N/A		

XI. STRESS, STRAIN & DISPLACEMENT PLOTS



Study(iii)

XII. CONCLUSION

In the conclusion, according to above static analysis results on aluminum alloy 4032 piston (Study I) aluminum alloy 2618 (Study ii) and c-graphite piston (Study iii), we found the maximum stress value of all materials is approximately equal. But the yield strength of aluminum 2618 is more than carbon graphite and aluminum 4032. Furthermore, deformation scale of carbon graphite is higher than aluminum 4032 & 2618.

Moreover, aluminum alloy 4032 is light in weight in the comparison of aluminum alloy 2618. But according to volumetric properties Carbon Graphite material is much lighter than aluminum 4032 and aluminum 2618.

Furthermore, according to material properties aluminum alloy 4032 has low Thermal expansion coefficient as compare to aluminum alloy 2618. On the other hand, carbon graphite has low thermal coefficient as compared to both of material (aluminum 4032 and aluminum 2618)

Moreover, aluminum alloy 2618 has good thermal conductivity as compared to aluminum alloy 4032. But the carbon graphite has excellent thermal conductivity as compared to aluminum alloy 4032 and aluminum alloy 2618.

At last, according to the above study, Carbon Graphite piston is much better as compared to aluminum alloy 4032 and aluminum alloy 2618 for IC engine.

Carbon exhibits self-lubricant properties which increase the operational reliability of the engine and result in reduced oil consumption.

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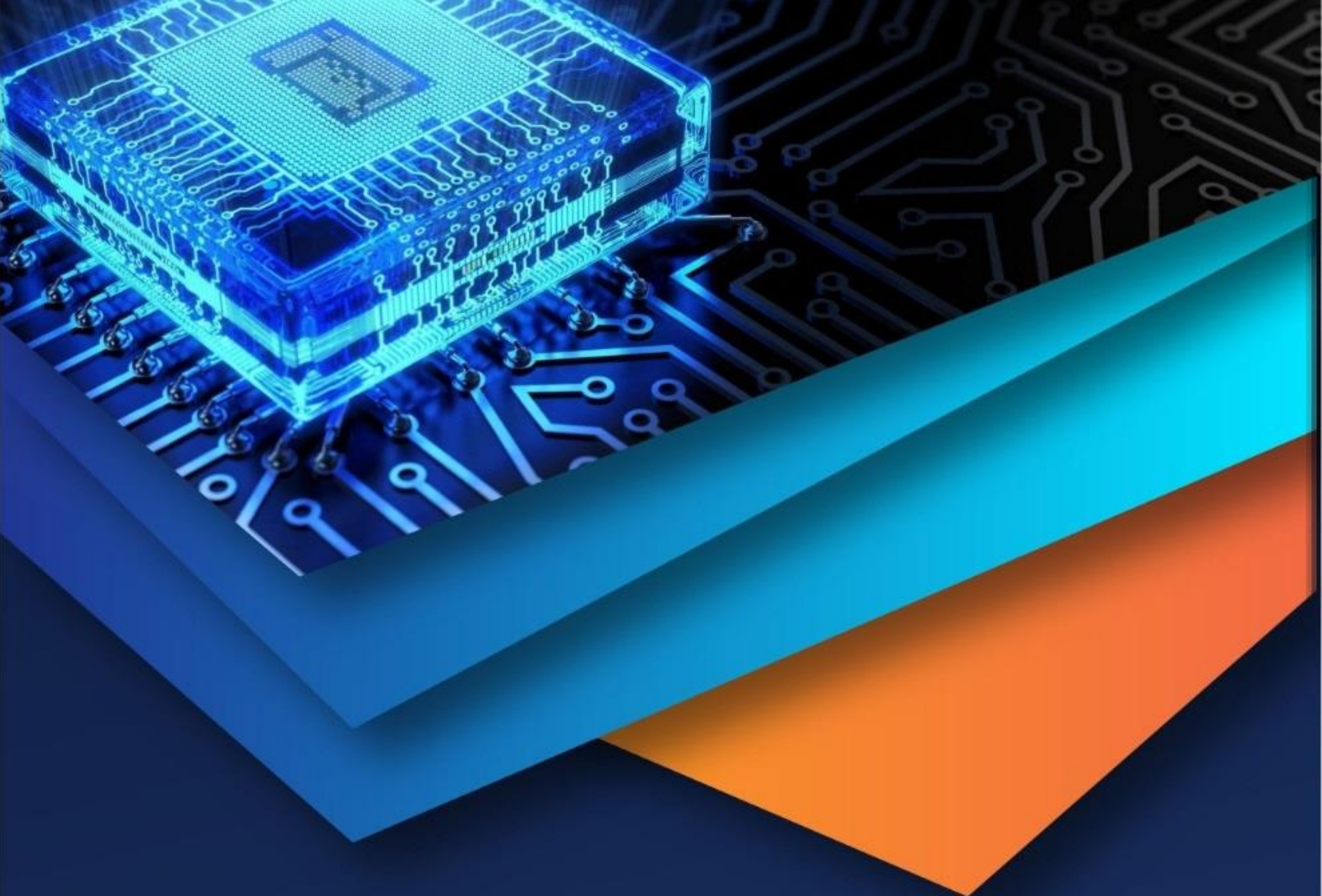

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