STRUCTURAL ANALYSIS AND GEOMETRY OPTIMIZATION OF PISTON BY MATERIAL REDUCTION FOR VALUE ENGINEERING *USING NX SOFTWARE*

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Abstract: This study is to define value engineering. Value engineering is a systematic method to improve the value of goods or product by using an examination of function. Value as define is the ratio of function to cost. It can therefore be increase by either improving the function or reducing the cost. Piston is called as heart of an engine. Since long, the researchers are studying in this area to improve the engine efficiency. Geometry optimization by reducing the material has been gaining importance in automobile field because by removing the material the weight of the piston decreases which helps to decrease the load on the engine and improve the efficiency.

The piston selected for the study is of Honda shine 124.7cc. Structural analysis is performed to find the stresses generated on the piston in working environment by using software NX. Material used for piston is cast aluminium. The practical trial is performed by modifying the existing piston to measure the change in efficiency.

***IndexTerms* – Structural Analysis, Piston, IC Engines**

I. Introduction

Now a days the trend is to develop IC engine of increased power capacity for that the important studies are being done on piston by reducing the weight of the structure by removing the material under safe design and hence to reduce fuel consumption. Piston transfer the force from expanding gases in the cylinder via connecting rod. By minimizing the inertia force the fuel consumption will reduce which will increase the efficiency.

Objective of the project is to design a piston of Honda shine which will be more efficient as compare to existing one. Factors which affect the functioning of piston

- Piston should have enormous strength and heat properties to withstand gas pressure and inertia forces. They should have minimum weight to minimize the inertia forces.
- The material of the piston should have good and quick dissipation of heat from the crown to the rings and bearing area to the cylinder walls. It should form an effective gas and oil seal.
- Material of the piston must possess better wearing qualities, so that the piston should be able to sustain sufficient surface-hardness in working environment.
- Piston must have rigid construction to withstand thermal, mechanical distortion and sufficient area to prevent under wear.

II. Literature Review

Different researchers have done varieties of work on piston geometry, piston material and its optimization. M. Srinadh et al[1] (August 2015) have designed a piston for 1300cc diesel engine car and taken 3 different profile rings . The structural and thermal analysis was performed in ANSYS software on the piston and piston rings model using Cast iron, aluminium Alloy A360 and Zamak. By comparing the analysis, it was decided which material is better for manufacturing of Piston and piston rings. Kammila V Prudhvi Raj Kiran et al[2] (November 2015) have presented a general study on the performance comparison of composite Piston and Aluminium Alloy Piston. Silumin alloy was used as a material for piston. Using solid works software the analysis was done and it was found that the Max Strain, Displacement, and Max Stress for the SILUMIN Alloy piston are less than that of Al-Alloy Piston. Mallavarapu Nageswari et al [3] (December 1015) studied the static and thermal analysis on piston made of aluminium silicon alloy, zirconium and aluminium MgSi material using Ansys, CAE software. They analysed piston with aluminium alloy material immersed with material namely zirconium and MgSi in place of silicon for better thermal conditions and deformation factors. The main purpose is to find the real behaviour during combustion process. They concluded that by adding zirconium to aluminium alloy one could extend performance of IC engine. In addition, as a replacement for aluminium with zirconium, aluminium with MgSi coating can be used. Anup Kumar Shetty et al [4] (April 2017) describes the structural analysis of four different aluminium alloy pistons, by using finite element method (FEM). The analysis results are used to optimize piston geometry of best aluminum alloy.

III. EXPERIMENTAL METHODOLOGY

The piston selected for the study is of Honda shine 124.7cc. The average of the vehicle is measured before any modification on the piston. Using the existing piston configuration and dimension the structural analysis was performed on NX software and the results were recorded. After studying, the damages normally found on that type of piston some modification were adopted by reducing the dimension of skirt. Now again the structural analysis was performed using NX software and the result of stress and strain compared with the existing piston. The result of stress strain found suitable for practical application so the modified piston assembled in the Honda shine engine and the average is measured.

IV. MATERIAL

Material used for the Honda shine piston is cast aluminium. Properties of the material is tabled below[5].

Table 1: Material Properties

Material	**Cast Aluminum**
Young's modulus (E)	69 GPa
Poisson's ratio (μ)	0.32
Thermal conductivity (K)	2.05 W/M°C
Density	2712 Kg/M^3
Specific heat	0.900 J/kgK

The other most commonly used material for pistons of IC engines are cast iron, cast aluminium, forged aluminium, cast steel and forged steel.

V. MODELING OF EXISTING PISTON

- **Technical specification [2]**

Table 2: Technical specification

Vehicle	HONDA SHINE
Engine type	Air-cooled, 4-stroke
Displacement	124.7 cc
Max Power	10.30 BHP @ 7500 r.p.m(7.68 KW)
Max Torque	9.78 Nm @ 5500 r.p.m
Compression ratio	9.2:1
Starting	Kick & Self start
Bore	52.4 mm
Stroke	57.8 mm

- **Theoretical calculation**

1) Torque

$$P = \frac{2\pi N\ T}{60}$$

$$T = \frac{P*60}{2\ \pi\ N}$$

$$T = \frac{7.68*10^3*60}{2*\pi*\ 7500}$$

T = 9.78 N-m

2) Diameter of piston

$$cc = \pi r^2 h$$

Where h = stroke length in mm.

Cylinder area = displacement

We know that displacement so to find diameter of piston

$$124.7 = \pi r^2 0.0578$$

$$r^2 = 687.08 \text{ m}$$

$$r = 26.21 \text{ mm}$$

D = 52.42 mm

3) Cylinder inside pressure

Pressure = force/area (F/A)

Force =power/velocity (P/V)

We know that power

Velocity =2LN/60

= 2 * 0.0578*5000/60

= 9.63 M/S

$$\text{Force} = \frac{power}{velocity}$$

Area = πr^2

= 3.14 *687.08

=2.12 *10^{-3} m^2

Pressure = force / area

=797.085/2.12 *10^{-3}

= 0.375983 Mpa

Maximum Pressure = 15 * P min

= 15 * 0.375983

= 5.63 Mpa

$$\text{Force} = \frac{7.68*10^3}{9.63}$$
$$= 797.085 \text{ N}$$

Table 3: Dimensions [5,6]

PARAMETERS	CALCULATED & MEASURED VALUES
Piston length	37.5 mm
Piston diameter	52.42 mm
Piston pin external diameter	13 mm
Piston pin internal diameter	9 mm
Piston ring axial thickness	1.50 mm
Piston ring radial thickness	1.50 mm
Depth of ring groove	2.20 mm
Gap between the rings	2.30 mm

- **Modeling of piston in NX**

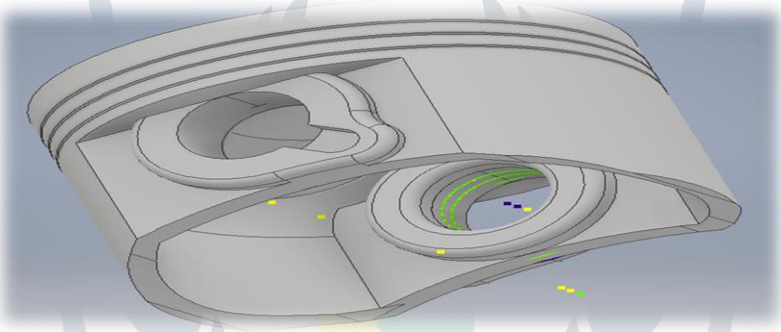

Figure 1: Modeling of piston of Honda shine

VI. STRUCTURAL ANALYSIS AND GEOMETRY OPTIMIZATION OF EXISTING PISTON

- **Stress Elemental (Von Mises) and stress elemental nodal**

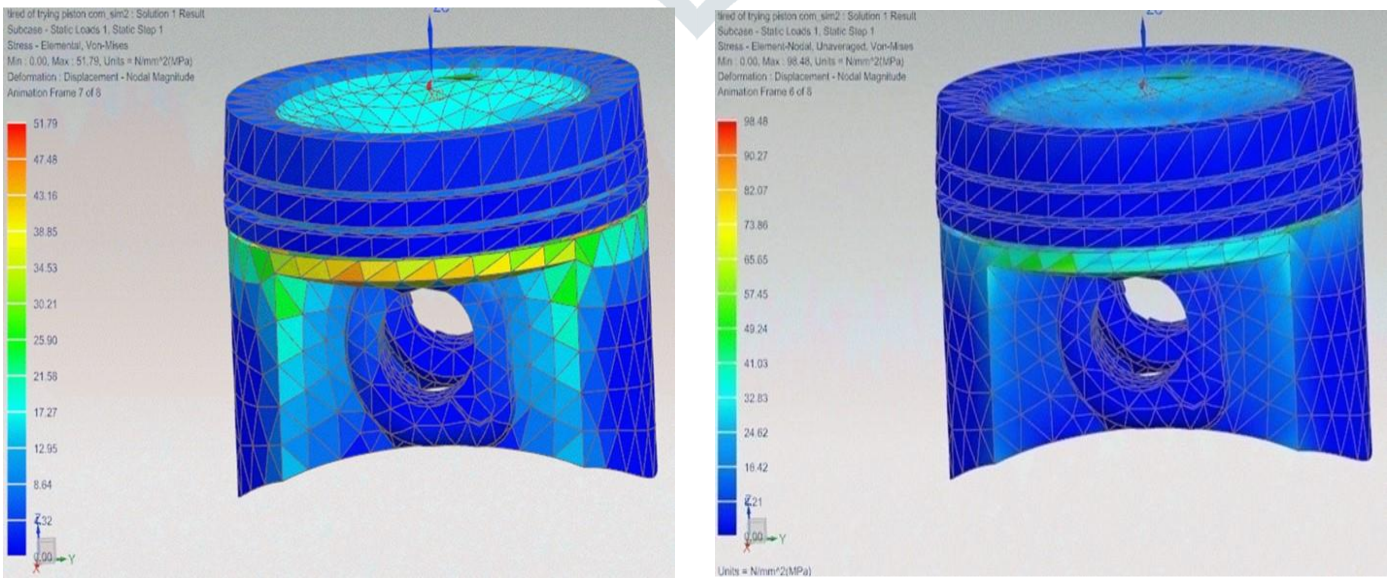

Figure 2: (a) Stress Elemental (Von Mises) (b) Stress elemental nodal

The Von Mises Stress distribution on the piston is visualized in above figure 2 (a) along with color palette. The color shows the flow of forces . Red zone shows the maximum stress intensity & blue zone shows the minimum stress intensity. The maximum stress value found is 51.79 Mpa which is under safe design value. The stress elemental nodal in Fig. 2 (b) shows the stress at each nodes whose maximum value is 98.48 Mpa.

- **Strain elemental and strain elemental nodal**

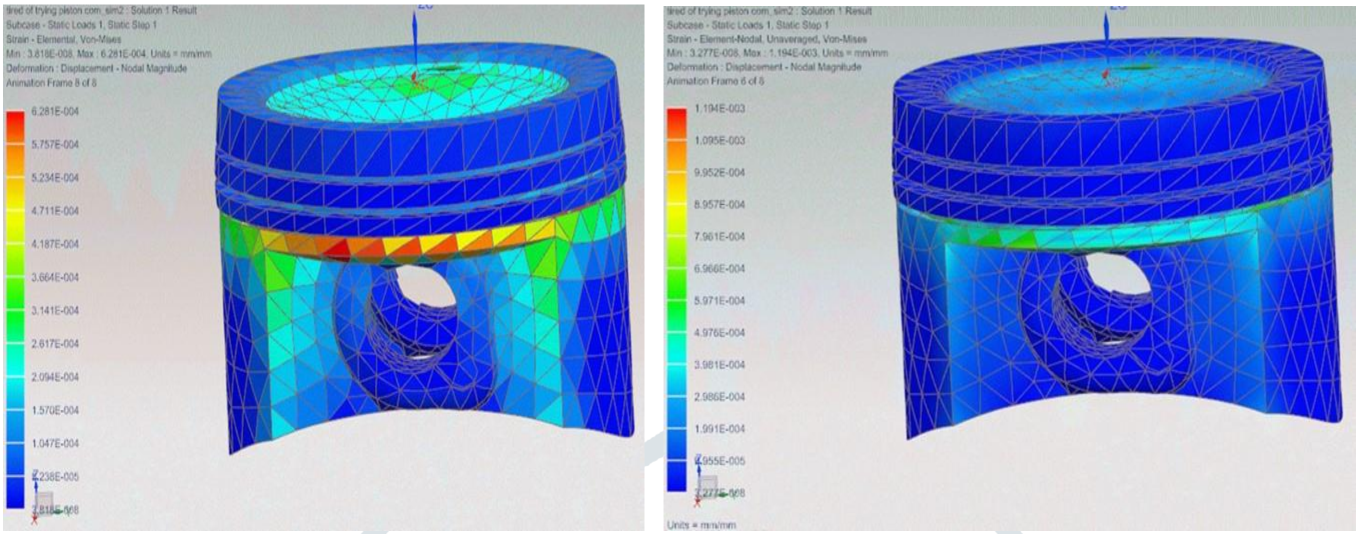

Figure 3: (a) Strain elemental and (b) Strain elemental nodal

Strain elemental is maximum on the rib of the piston which is colored red in the Fig.3 (a). The maximum strain is 6.489e-004mm/mm. Strain elemental nodal shows the strain at each node which is in the range of 1.253e-003mm/mm to 2.975e-008mm/mm in Fig 3 (b).

- **Deformation**

Figure 4 shows the deformation, the distance till the piston can deform under operating pressure.

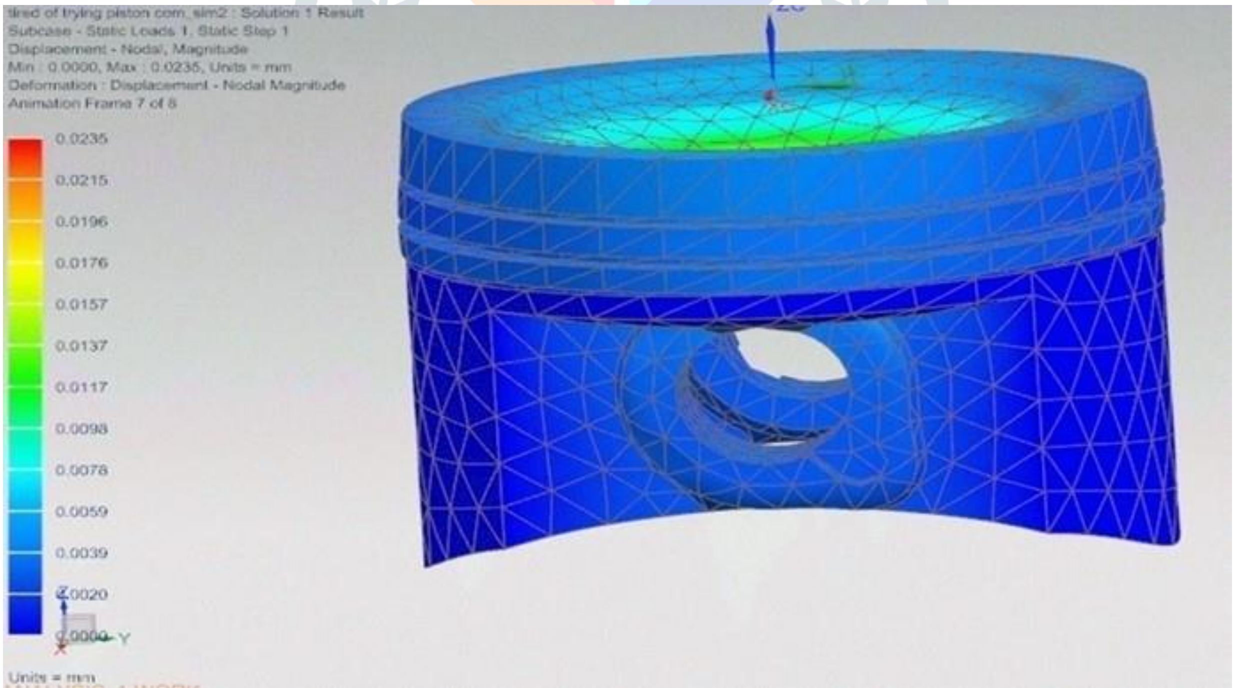

Figure 4: Deformation

VII. STRUCTURAL ANALYSIS AND GEOMETRY OPTIMIZATION OF MODIFIED PISTON

- **Modification of piston**

The actual weight of the piston is measured 84 grams . The modification is done on the basis of weight reduction. By observing other pistons, which portion of the piston can be reduce so that it can perform same as it perform in the operating environment was decided. The skirt of the piston is filed by using filer and the shape is made curvature to protect the piston damage from running unmixed fuel. It has reduced the weight of the piston by 2 grams. Then after the holes are created on skirt wall(both side) of 2mm. It has reduced the weight of piston by 6 grams. The overall reduction in the weight is by 8 grams. Figure 5 shows the real & modified pistons.

Figure 5: Actual & modified piston

- **Stress Elemental (Von Mises) and stress elemental nodal**

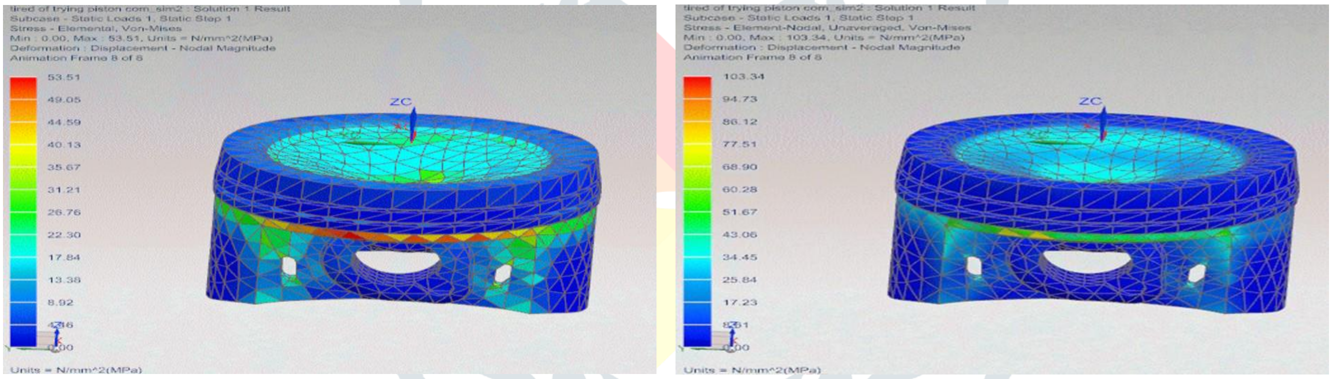

Figure 6: (a) Stress Elemental (Von Mises) and (b) stress elemental nodal

In real piston the stress found is 51.79 Mpa & the stress found in modified piston is 53.51 Mpa in Fig. 6 (a) so the stress increased is near about 2 Mpa which is under safe design because the ultimate tensile strength of the material is 700 Mpa. In addition, the maximum stress elemental nodal is 103.34 Mpa in 6 (b).

- **Strain elemental and strain elemental nodal**

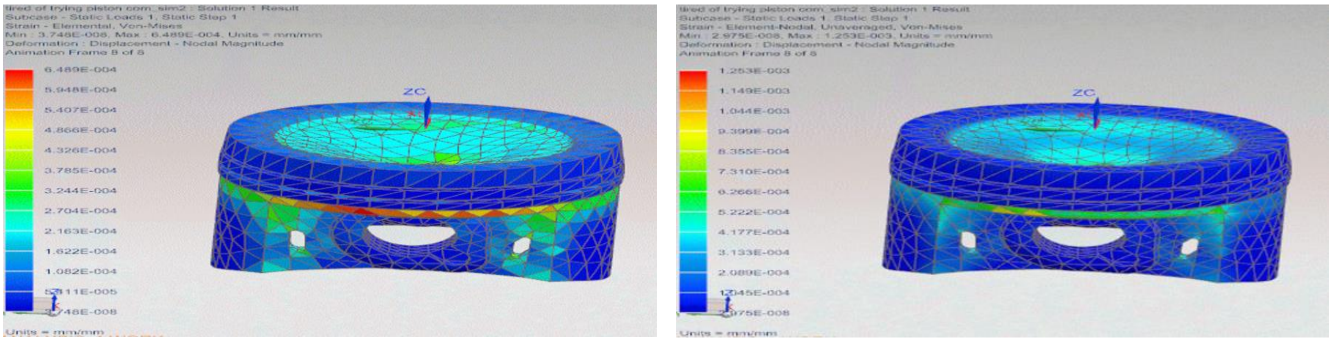

Figure 7: (a) Strain Elemental (Von Mises) and (b) strain elemental nodal

The maximum elemental von-mises strain found is 6.489e-004 mm/mm in modified piston in Fig. 7 (a) while it is found 6.281e-004 mm/mm in unmodified piston which is showing minor difference . So it is safe in the working environment. The maximum nodal strain in the modified piston is 1.253e-003 mm/mm in Fig. 7 (b) while it is 1.194e-003 mm/mm in real piston which is almost same.

- **Deformation**

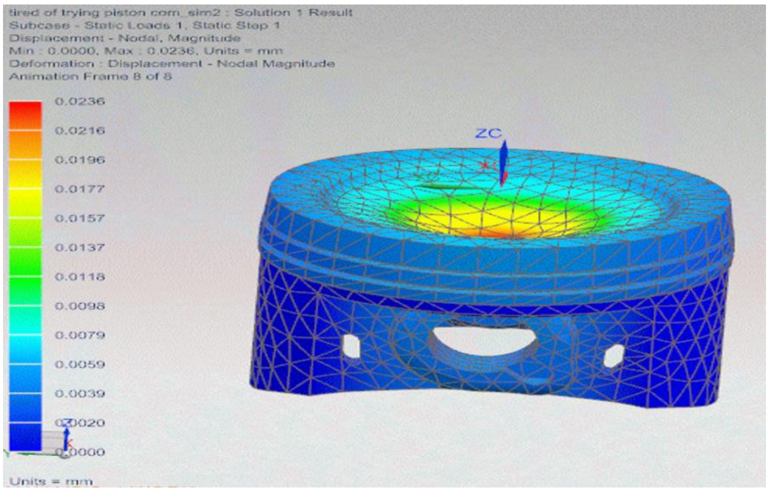

Figure 8: Deformation

The deformation in the real piston is 0.0235mm while it found 0.0236mm in modified piston (Fig.8), which is almost similar so we can say that our design is safe.

VIII. EXPERIMENTAL SETUP

After the piston is being modified, it is assembled in the cylinder of Honda shine. Figure 9 (a) shows the disassembly of actual piston and Fig- 10 shows assembly of modified piston and practical is performed to measure the change in mileage.

Figure 9: (a) Disassembly of engine of Honda (b) Actual piston

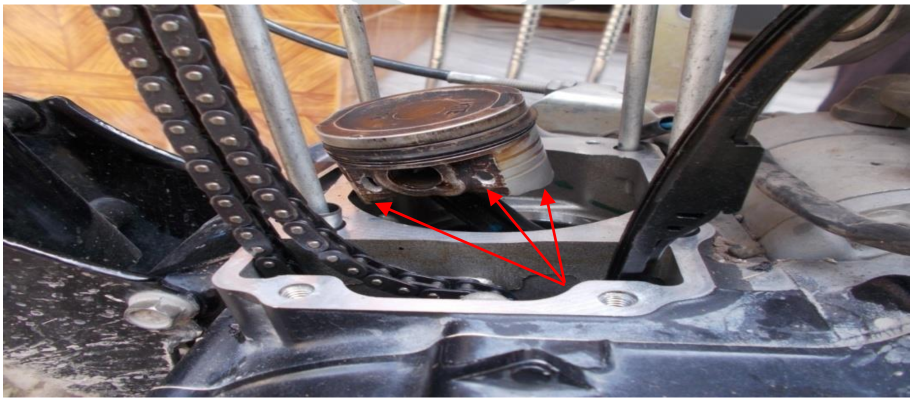

Figure 10: Assembly of Modified Piston

IX. RESULTS

The ultimate tensile strength of cast aluminium is 700 Mpa, while taking factor of safety 3.8 the maximum stress the material can sustain is 180 Mpa. The found stresses are in the limit so the design is safe in operating environment.

Table 4: Result of Structural Analysis

	Before Modification	After Modification
Stress Elemental (Von mises)	Maximum = 51.79 Mpa	Maximum = 53.51 Mpa
Stress Elemental Nodal	Maximum = 98.48 Mpa	Maximum = 103.34 Mpa
Strain Elemental (Von mises)	Maximum = 6.281e-004 mm/mm Minimum = 3.818e-008 mm/mm	Maximum = 6.489e-004 mm/mm Minimum = 3.748e-008 mm/mm
Strain Elemental Nodal	Maximum = 1.194e-003 mm/mm Minimum = 3.277e-008 mm/mm	Maximum = 1.253e-003 mm/mm Minimum = 2.975e-008 mm/mm
Deformation	Maximum = 0.0235 mm	Maximum = 0.0236 mm

Table 5: Results of change in performance after modification

Trial	1	2	3
Fuel Consume	1 liter	1 liter	1 liter
Increase in mileage	0.8 km	0.5 km	0.6 km

Table 6: Results of geometry optimization

	Weight reduced	Increase in Stress	Mileage increased
After Optimization	9.52%	3.32%	1.08%

X. CONCLUSION

- The fundamental concepts and design methods concerned with single cylinders petrol engine have been studied in this article.
- In this project, a piston of Honda shine is modelled in 3D modeling software INVENTOR and analysis is done on NX software.
- Static Structural analysis is performed on the piston by applying the pressure to verify the strength of the piston
- For the value engineering geometry of the piston is optimized by reducing the weight of the structure. By optimizing the geometry with minimizing the weight, the cost of the product will decrease and efficiency increases.
- The Max Strain, Displacement, and Max Stress for the Cast Aluminium piston are analyzed for both actual and modified piston and compared. The values are under safe design condition.
- It was found that the maximum stress after modification is 53.51 MPa, which is less than the maximum tensile stress (700 MPa) of the material.
- Weight of the piston is reduced by 9.52%. While operating the modified piston in actual condition of engine efficiency is increased by 1.08%. It was found that the design parameter of the piston with modification gives the sufficient improvement in the existing results.

XI. ACKNOWLEDGMENT

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