LIFE ESTIMATION AND STATIC ANALYSIS OF PISTON USING ANSYS WORKBENCH OF FOUR STROKE ENGINE

Abhishek.P.Inamdar [1], Dr.B N Ravikumar [2], Dr.Prakash.S.Inamdar[3]

[1]P.G student, [2]Professor, [3]H.O.D
[1]Mechanical Engineering,
[1]Bangalore Institution of Technology, Bangalore, INDIA.

Abstract **-** The aim of this project is to use Ansys workbench to conduct a static structural analysis of the designed piston made from Al alloy and CFRP. A piston's function is to transmit energy from the expanding gas within the cylinder to the crankshaft via a rod or connecting rod in an I.C engine. Because material is such a crucial feature of combustion engines, the fabric chosen here is Al alloy and CFRP. After conducting static structural analysis, the weights of the designed piston is taken into account and based on that the better material is decided. Because there's a knowledge gap between Al Alloy and CFRP, we are conducting material optimisation for the Designed piston employing a finite element approach. The analysis will be carried out in Ansys V19.2 and the designing will be done on Catia.

IndexTerms - **Piston, Static Analysis, Fatigue, Ansys, Aluminium alloy, CFRP.**

1.INTRODUCTION

The purpose of a piston in an engine is to transfer power from the expansion of gas in the cylinder to the crankshaft through a piston rod or connecting rod. As a material is a critical aspect of internal combustion engines, the material being used here is Al alloy and CFRP since there is a knowledge gap between Al alloy and CFRP so, we are undertaking analyse static structural analysis utilising finite element approach for designed piston. When fuel is burned in an engine cylinder, a high temperature and pressure are created.
The piston is subjected to high temperatures because of its fast speed and high loads as well as structural stresses if these stresses are more than the designed values, the piston may fail. To avoid piston failure, the strains caused by combustion are taken into account. In order to maintain safe allowed limits, the intensity of thermal and structural stresses should be decreased.
The purpose of this project is to employ CAE tools to find the optimal material for designing a I..C engine piston that creates the least amount of mechanical stress.

1.1 Design and Analysis

The fundamental requirement of the piston is to design a 150 CC piston in Catia, then import the developed piston into Ansys and assign boundary conditions and loads. After material is defined, a statical analysis is performed, and the piston's weight is taken into consideration.

Finite Element Analysis

The numerical system Finite Element Analysis (FEA) is used to solve engineering and mathematics problems. When dealing with challenges such as entangled geometries, loadings, and material qualities for which analytical solutions are unavailable, FEA is quite useful. Engineering analysis, design optimization, and simulation may all be done with FEM. Displacements, stress distribution, natural frequencies and associated modes of vibration, thermal stress distribution, nonlinear effects, fluid-structure interactions, and many other broad objectives arise during the design and development of a product

2. PROBLEM DEFINETION

This research focuses solely on piston weight analysis and material optimization. The current study focuses on engine parts, specifically the piston, which is the primary source of vibration or noise. The data used to investigate these pistons came from a four-stroke single-cylinder Bajaj pulsar 150 cc motorcycle engine. Operating gas pressure, temperature, and piston material qualities are the parameters used in the simulation. The major goal of this research is to investigate the stress concentration zones in the piston, as well as the component's overall deformation and multibody dynamic analysis.
Modeling of pistons is developed using Catia, and static and fatigue analyses are performed utilising material optimization of aluminium alloy and CFRP, according to the industrial dimension.
Finding a weight optimised material, conducting modal analysis to find piston modes and corresponding frequencies, and conducting thermal analysis to find study state thermal behaviour in Piston for applied load conditions, we can conclude that the piston's performance will be improved based on the values obtained from material and weight optimization.

2.1 METHODOLOGY

- CATIA V5 is used to design 3-D piston models.
- ANSYS Workbench 19.2 is used to mesh and analyse the piston.

- Individual structural analyses are used to determine various stresses.
- Different zones with high stress concentrations are found and studied.
- In terms of stresses, deformation, and weight, the two materials are compared.
- Static structural linear analysis of piston
- Fatigue life estimation of piston.
- Total deformation of the piston.

2.2 Piston Design

Engine: Bajaj 150 CC petrol engine

Table:1 seen below shows the engine specification like bore, stroke length, displacement etc.

Table-1: Engine Specifications

Description	Value's
Engine Type	Four-stroke petrol engine
No of cylinders	Single-cylinder
Bore	57mm
Stroke	56mm
Max power	15.06 KW @ 9000 rpm
Torque	12.5 NM @ 6500 rpm
Displacement volume	150 cc

The dimensions for the piston design that will be designed in Catia are shown below in Fig 1.

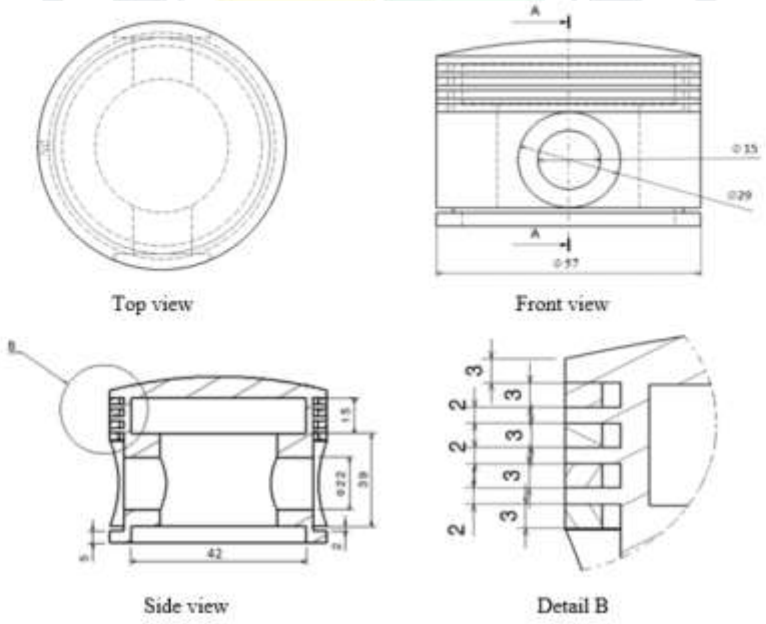

Fig-1: Drafted view of piston

3. Material selection and Material property.

3.1 Aluminum alloy: -

For pistons with higher speeds, aluminium alloys are employed. Low density allows for the construction of lightweight pistons, which reduces the stresses caused by inertia forces, good thermal conductivity results in lowering the temperature of the piston crown, which is critical in spark ignition engines, ease of casting, and good machinability are all advantages of aluminium alloys. The below tables 2 and 3 give the mechanical and physical property of aluminum alloy

Table-2: Mechanical property of Al alloy.

Mechanical Properties	Values
Tensile strength	440 MPa
Yield Strength	420 MPa
Shear Strength	260 MPa
Fatigue Strength	125 MPa
Elastic Modulus	70-80 GPa
Poisson's Ratio	0.33

Table -3: Physical properties of Al alloy

Physical properties	Values
Density (Kg/m^3)	2767.99
Melting point (^{0}C)	510

3.2 CFRP Material: -

A composite material made of carbon fibre reinforced polymer. Carbon fibre is reinforced into the Matrix, which is lightweight with good strength, sandwiched with variable orientations, and corrosion-free, and is used mostly in the aerospace industry and partially in the vehicle industry. Carbon fibres have a number of benefits, including high tensile strength, stiffness, temperature tolerance, chemical resistance, light weight, and minimal thermal expansion. The below tables 4 give the mechanical and physical property of aluminum alloy

Table-4: Material Properties of CFRP

MATERIAL	CFRP
Type	composite
Cost ($ / kg)	110
Density (*r*, *Mg*/ m^3)	1.5
Young's-Modulus (*E* , GPa)	1.5
Shear -Modulus (*G* , GPa)	53
Poisson's-Ratio (*n*)	0.28
Yield Stress ($s_{Y,}$ MPa)	200
UTS ($s_{f, MPa}$)	550
Breaking strain ($e_{f,}$ %)	2
Fracture Toughness (*K c*, *MN* m$^{3/2}$)	38
Thermal Expansion (*a* ,10^{-6}/ °C)	12

4. 3-D Modeling of piston

The Figure 2 shows the isometric view of piston along with the piston rings obtained by designing using Catia V5. This isometric view of piston design will be used for the further analysis carried out in Ansys.

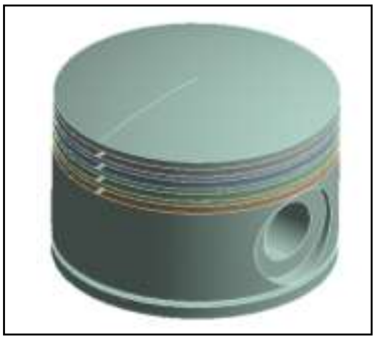

Fig-2: Isometric view of piston

4.1 Meshing of piston

The following properties of the final mesh are constructed in this work: tetra elements are utilised with a general element size of 10 for the model, patch confirming, edge sizing, body sizing, and face sizing methods are employed. Because the discontinuities are where the tension is concentrated, fine meshing is done there. Other places handle coarse meshing.
There will be a total of 66803 nodes and 37840 elements in this diagram. Figure.3 shows a finite element mesh piston model.

Fig -3: Meshing of piston model.

Table-5: Shows total number of nodes and elements of meshed piston model

STASTICS	
NODES	66803
ELEMENTS	37840

4.2 Applying boundary conditions

Finite element model of piston with the applied boundary conditions is shown in the below Figure 4.
The finite element model of piston is loaded with a combustion gas pressure of 16Mpa on the piston head, and fixed support is given at the piston pin bore as shown in the below Figure 4. With these boundary conditions different analysis over the piston is carried out.

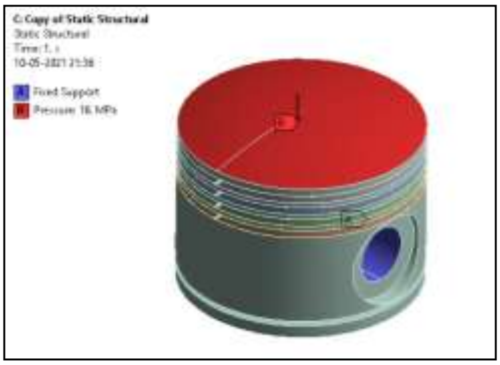

Fig -4: FE Model with boundary conditions

5. Linear static analysis of piston

The below figures show the stress tensor obtained for the piston when static analysis is performed by applying the boundary conditions.

5.1 Case 1: Static analysis for Aluminum alloy.

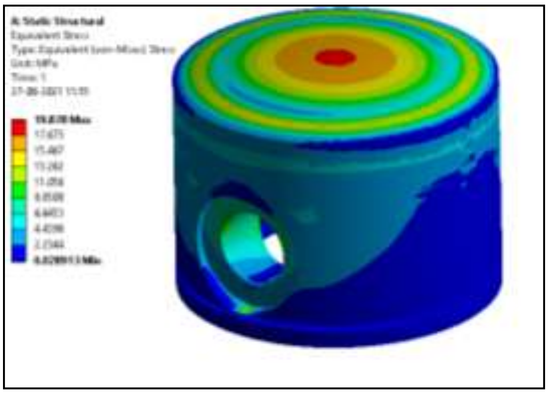

Fig-5: Max Equivalent stress is 19.87 MPa for the applied load condition.

Figure 5 Shows FEA findings for equivalent stresses of piston for the given load and its boundary constraints, the Von-misses stress is found to be max at the centre of Crown at 19.878 MPa for the Piston design.

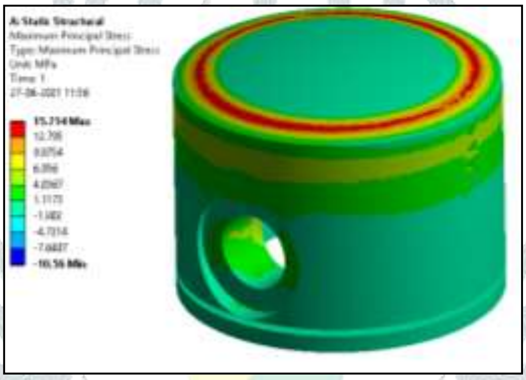

Fig-6: Max principal stresses is 15.714 MPa for the applied load condition.

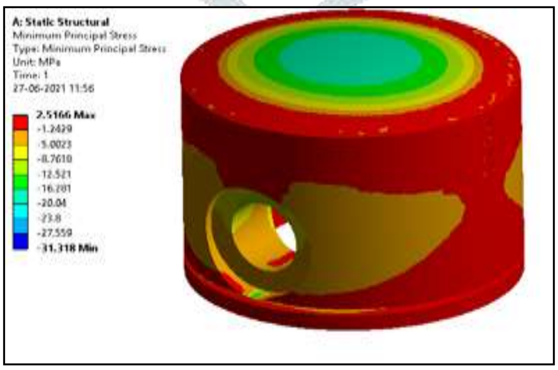

Fig-7: Min principal stresses is 2.5166 MPa for the applied loading state.

Figure 6 and 7 shows max principal and min principal stress for FEA results of Piston. Due to the load and its boundary conditions, the max principal stress is 15.714 MPa and min principal stress is 2.5166 MPa were obtained for the Piston design.

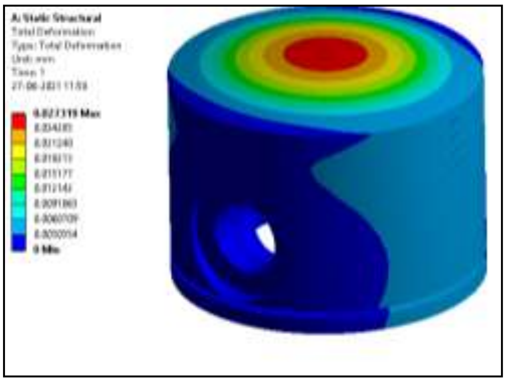

Fig-8: Max total deformations 0.027 mm for the applied load condition.

Figure 8 Shows complete deformation for the effects of the FEA on piston design. In view of its load and boundary conditions, the overall deformation was 0.027 mm.

5.2 Case 2: Static analysis for CFRP.

The below Figure 9 shows the stress tensor obtained for the piston when static analysis is performed by applying the boundary conditions for CFRP composite material.

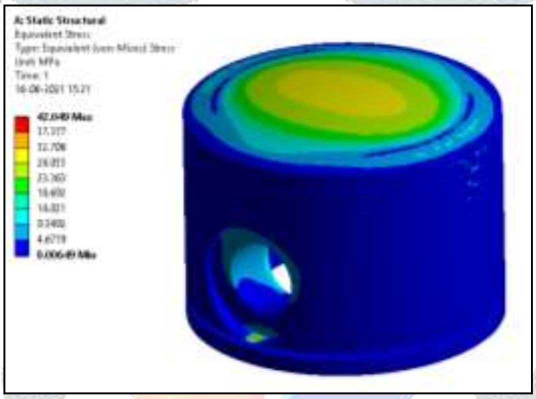

Fig-9: Max equivalent stress 42.049 MPa for the applied load condition.

Figure 9 Shows FEA findings for equivalent stresses of piston for the given load and its boundary constraints, the Von-misses stress is found to be max at the centre of Crown at 42.049 MPa for the Piston.

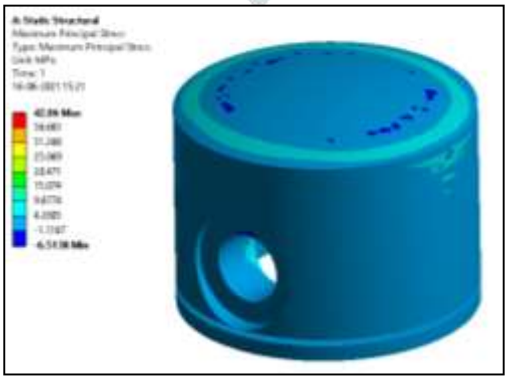

Fig-10: Max principal stress 42.06 MPa for the applied loading state.

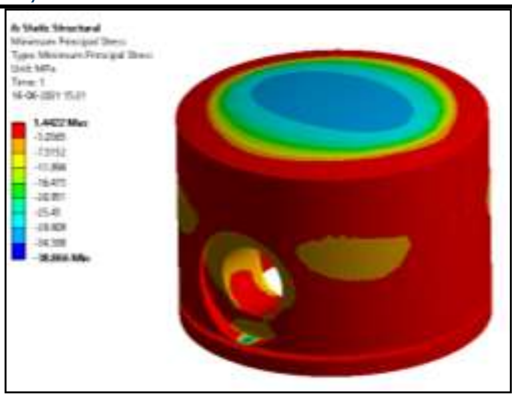

Fig -11: Min principal stresses 1.44 MPa for the applied loading state.

Figure 10 and 11 shows max principal and min principal stress for FEA results of Piston. From the applied load and its boundary conditions, the max principal stress is 42.06 MPa and min principal stress is 1.44 MPa were obtained for the Piston design.

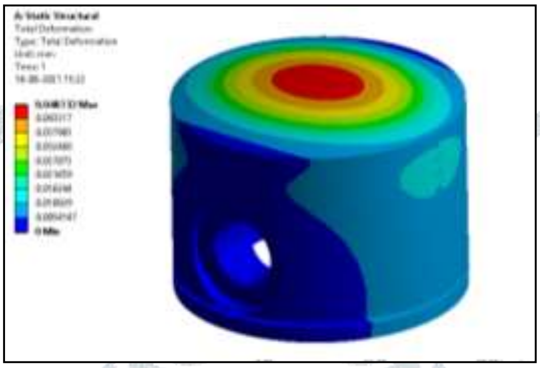

Fig-12: Total deformation 0.0487 mm for the applied load condition.

Figure 12 Shows complete deformation for the effects of the FEA on piston design. In view of applied load and boundary conditions, the overall deformation was 0.0487 mm.

5.3 Fatigue Analysis

The Figure 13 shows that the piston's fatigue life was found by performing fatigue analysis in ANSYS. The estimated fatigue life of the Piston obtained is $1e^{6}$ cycles.

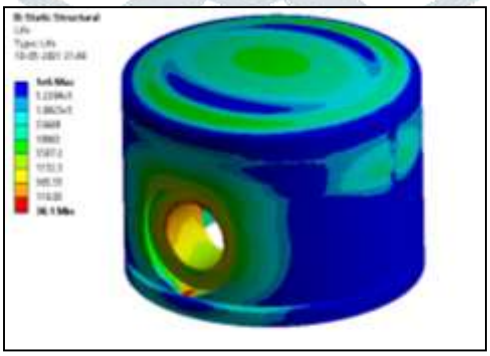

Fig-13: Fatigue life of piston

Because the piston is subjected to high cyclic loads during the blasting phase, fatigue occurs. As shown in Figure 13 the piston can survive $1e^{6}$ cycles before failing or reaching the end of its useful life.

6. RESULTS AND DISCUSSIONS

6.1 Static structural analysis of Piston.

Based on the Analysis results obtained by performing piston analysis, the following discussions are written for materials Aluminium alloy and CFRP.

Table-6: Von-misses Stress, max and min principal stresses, deformation, comparison of different materials.

Material	**Von-misses stress (MPa)**	**Max principal stress (MPa)**	**Minimum principal stress (MPa)**	**Total Deformation (mm)**
	16 MPa	16 MPa	16 MPa	16 MPa
Al alloy	19.878	15.714	2.516	0.0273
CFRP	42.049	42.06	1.442	0.0487

The outcomes of the finite element analysis are shown in a above Table-6 presents the values obtained for equivalent Von Mises stress for Aluminium Alloy and CFRP. The maximum deformation and maximum and minimum principal stresses for piston.

6.2 Weights of both the Piston materials.

Figures below 14 and 15 show the weights of materials that is obtained for the designed piston in Ansys for either material. From the analysis it was seen that CFRP was weighing less than aluminum so, CFRP was chosen over Al.

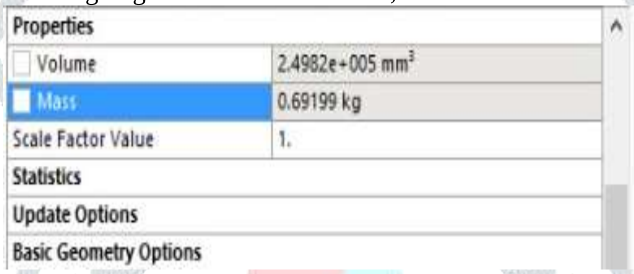

Fig-14: Piston Weight of aluminum.

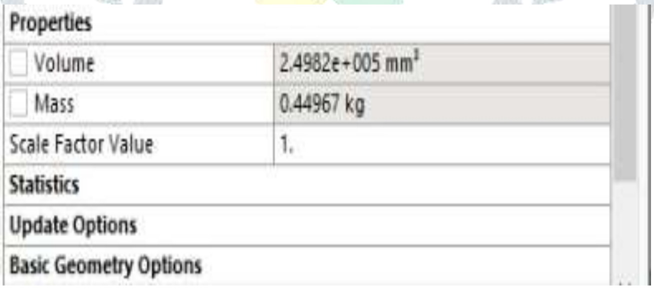

Fig-15: Piston Weight of CFRP.

The below Table 7 depicts the key aspects of the analysis like weight, stress and deformation.

Table-7: Comparison of analyzed values.

Material	**Weight Kg**	**Equivalent Stress MPa**	**Total Deformation mm**
Aluminum	0.69199	19.87	0.0273
CFRP	0.44967	42.049	0.0487

The analysis is carried out using materials aluminum alloy and CFRP based on static analysis carried out, CFRP is preferred materials for the analysis, so further analysis is carried out on CFRP material for fatigue life estimation.

- Aluminum and CFRP static structural analysis are done the equivalent stress obtained for aluminum is 19.878 MPa and CFRP is 42.049 MPa.

- Weights of the piston obtained are 0.69199 Kg for aluminium and 0.44967 for CFRP.

- The fatigue life analysis is carried out and the value is 10^6 cycles.

7. CONCLUSION

The Analysis carried out has been discussed in the last section, here in this section final conclusion of overall study is mentioned.

- The Piston is analyzed by using Ansys 19.2 for various materials like Aluminum alloy and CFRP.
- Static analysis is completed on piston and style of baseline model of piston is obtained results well within the permissible values.
- Based on results obtained on conducting static analysis for both materials it was CFRP material that was selected for further analysis.
- Since the weight of CFRP is lower than aluminum the preferred material will be CFRP.
- With the prediction of high cycle fatigue life, the lifetime of piston is evaluated and obtained a satisfactory result of 1e6 cycles.

REFERENCES

[1] Ch.Venkata Rajam, P.V.K.Murthy, M.V.S.Murali Krishna G.M.Prasada Rao"Design analysis and optimization of piston using CATIA and ANSYS" International Journal of Innovative Research in Engineering & Science, ISSN 2319-5665 volume 1, issue 2 January 2013.

[2] Jaume Anguera Llort "Designing and modeling of piston in combustion engines" Cracow University of Technology, Central Kraków Poland 2013-14.

[3] Beda jangamsagar Kishor, N. P. Jadhav, "Optimization of Geometrical Parameters of Four Stroke Engine Piston", International Journal of Engineering Research and Applications ISSN: 2248-9622, Vol. 4, Issue 2, February 2014.

[4] Ajay Raj Singh, Dr.Pushpendra Kumar Sharma, "Design, Analysis and Optimization of Three Aluminium Piston Alloys Using FEA" International Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 4, Issue 1 Version 3, January 2014.

[5] S N Kurbet, Vinay V Kuppast and Vijaykumar N Chalwa "Finite element and Multi Body Dynamics analysis of piston to predict the engine noise" International Journal of Mechanical Engineering and Robotics Research. ISSN 2278 – 0149 Vol. 2, January 2013.