

Assembly Analysis of Piston, Connecting Rod & Crankshaft

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Abstract: *The main function of the piston of an IC engine is to receive the impulse from the expanding gas and to transmit the energy to the crankshaft through the connecting rod. The piston must also disperse a large amount of heat from the combustion chamber to the cylinder walls. The aim of this Project is to Model & Assemble the Piston, Connecting Rod & Crankshaft for a 4-stroke air-cooled 150cc Engine by theoretical calculations & also to Compare the Structural Analysis & Modal Analysis on two different materials such as (Aluminum Alloy – Cast iron) for Piston, (Aluminum Alloy – Manganese steel) for Connecting Rod & (Nickel Chromium steel – High carbon steel) for Crankshaft. Modeling, Assembly of Piston, Connecting rod and Crankshaft is done in Pro/Engineering software & Analysis is done in ANSYS. Structural analysis is used to determine displacements & stresses under static & buckling loads. Modal Analysis is used to determine the Vibration characteristics (natural frequencies & mode shapes) of the three components. By comparing the displacement & stress results, using Cast Iron for Piston, Manganese Steel for Connecting rod and High Carbon Steel for crankshaft is best combination for assembly.*

Keywords: Piston, Connecting Rod, Crankshaft, Pro/E, ANSYS, Structural Analysis & Modal Analysis.

1. Introduction

Internal combustion engines are seen every day in automobiles, trucks, and buses. The name internal combustion refers also to gas turbines except that the name is usually applied to reciprocating internal combustion (I.C.) engines like the ones found in everyday automobiles. Spark ignition engines take a mixture of fuel and air, compress it, and ignite it using a spark plug. The name 'reciprocating' is given because of the motion that the crank mechanism goes through. The piston cylinder engine is basically a crank-slider mechanism, where the slider is the piston in this case. The piston is moved up and down by the rotary motion of the two arms or links. The crankshaft rotates which makes the two links rotate. The piston is encapsulated within a combustion chamber. The bore is the diameter of the chamber. The valves on top represent induction and exhaust valves necessary for the intake of an air-fuel mixture and exhaust of chamber residuals. In a spark ignition engine a spark plug is required to transfer an electrical discharge to ignite the mixture.

1.1 Piston

In every engine, piston plays an important role in working and producing results. Piston forms a guide and bearing for the small end of connecting rod and also transmits the force of explosion in the cylinder, to the crank shaft through connecting rod. The piston is the single, most active and very critical component of the automotive engine.

1.2 Connecting Rod

In a reciprocating piston engine, the connecting rod connects the piston to the crank or crankshaft. The small end attaches to the piston pin, gudgeon pin or wrist pin & big end connects to the bearing journal on the crank throw, running on replaceable bearing shells accessible via the connecting

rod bolts which hold the bearing "cap" onto the big end; typically there is a pinhole bored through the bearing and the big end of the con rod so that pressurized lubricating motor oil squirts out onto the thrust side of the cylinder wall to lubricate the travel of the pistons and piston rings.

1.3 Crankshaft

The crankshaft, sometimes casually abbreviated to crank, is the part of an engine which translates reciprocating linear piston motion into rotation. To convert the reciprocating motion into rotation, the crankshaft has "crank throws" or "crankpins", additional bearing surfaces whose axis is offset from that of the crank, to which the "big ends" of the connecting rods from each cylinder attach. It typically connects to a flywheel, to reduce the pulsation characteristic of the four-stroke cycle, and sometimes a torsional or vibrational damper at the opposite end, to reduce the torsion vibrations often caused along the length of the crankshaft by the cylinders farthest from the output end acting on the torsional elasticity of the metal.

2. Experimental Calculations

2.1. Engine Specifications

Suzuki GS150R is a 150cc, 4-stroke air-cooled engine is used for the study on Piston, Connecting Rod & Crank Shaft. This delivers robust acceleration performance in the low to mid range. The engine is specially designed to fulfill the conflicting demands of acceleration and fuel efficiency.

- Type Air-cooled, 4-Stroke,
- Bore x Stroke (mm) = 57.0 x 58.6
- Displacement (cm³)= 149.5
- Max Power=13.8bhp @ 8,500rpm
- Max Torque=13.4Nm @ 6,000rpm
- Compression Ratio = 9.35:1
- Carburetor=BS26 with TPS

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- Ignition=CDI
- Starting=Electric & Kick
- Transmission=5-speed
- Maximum gas pressure ,
- $P = 15.454\text{N/mm}^2$
- Indicated power IP =11217.05kw
- Brake power BP = 8415.2kw
- Mechanical efficiency=75%

- l_c = length of crankpin = 34.38 mm
- b = distance between the bearings 1 & 2 is equal to twice the piston diameter
- $= 2D = 2 \times 57 = 114$ mm, i.e. $b_1 = b_2 = b/2 = 57$ mm

2.2. PISTON

- Temperature at the center of piston head $T_c = 260^\circ\text{C}$ to 290°C
- Temperature at the edge of piston head $T_e = 185^\circ\text{C}$ to 215°C
- Maximum gas pressure $p = 15.454\text{N/mm}^2$
- Bore or outside diameter of piston $D = 57\text{mm}$

• Thickness of piston head $t_h = \sqrt{\frac{3pD^2}{16\sigma_t}} = 5.45\text{mm}$

Piston rings

- p_w = pressure of the gas on the cylinder wall = 0.042N/mm^2
- σ_t = allowable bending(tensile stress) for cast iron rings = 110Mpa

• Radial thickness $t_1 = D \sqrt{\frac{3p_w}{\sigma_t}} = 1.93\text{mm}$

- Axial thickness $t_2 = D/10n_r = 1.9\text{mm}$
- n_r = no of rings = 3
- width of the top land $b_1=6.54\text{mm}$
- distance between ring grooves,
- $b_2 = t_2 = 1.9\text{mm}$
- Total length of the piston
- L = length of the skirt \times length of ring section + top land
- Length of ring section = $5 \times b_2$ or $t_2 = 9.5\text{mm}$
- $L = 45.6 + 9.5 + 6.54 = 61.64\text{mm}$

2.3 Connecting Rod

- Length of connecting rod = 2times the stroke $L = 2 \times 58.6 = 117.2\text{mm}$
- Buckling load , $W_b = (\sigma_c \cdot A)/1+a[1/k_{xx}]^2$
- Thickness of flange and web of the section $t = 3.21\text{mm}$
- Width of section $B=4t=12.84\text{mm}$
- Height of section $H=5t=16.05=16\text{mm}$
- Area $A=11t^2=113.3\text{mm}^2$
- Height of the big end (crank end)= $H_2=1.1H$ to $1.25H$
- $H_2=20\text{mm}$
- Height at the small end (piston end)= $0.9H$
- $H_1=14.4\text{mm}$

2.4 Crankshaft

- D = piston diameter or cylinder bore = 57 mm
- P = maximum intensity of pressure on the piston = 15.454 N/mm^2
- d_c = Diameter of crankpin = 22.92mm

3. 2D Drawings

3.1 PISTON

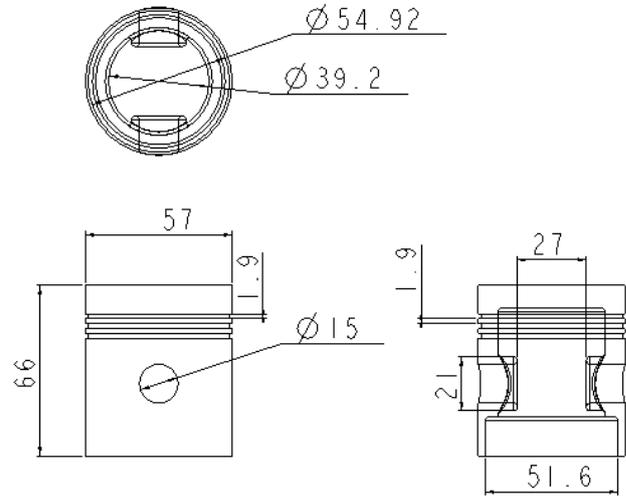


Figure 1.1: Piston 2D drawing

3.2 Connecting Rod

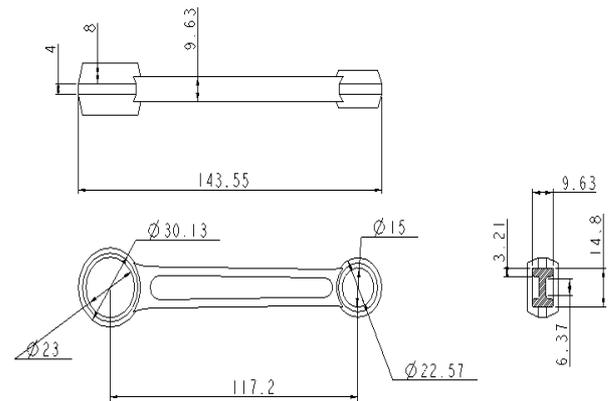


Figure 1.2: Connecting rod 2D drawing

3.3 Crankshaft

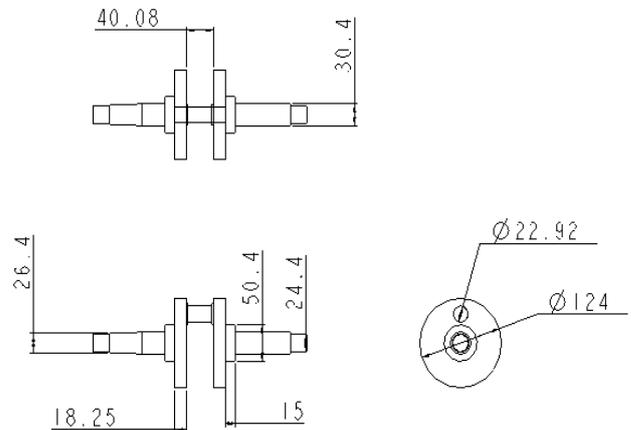


Figure 1.3: Crankshaft 2D drawing

3.4 Assembly

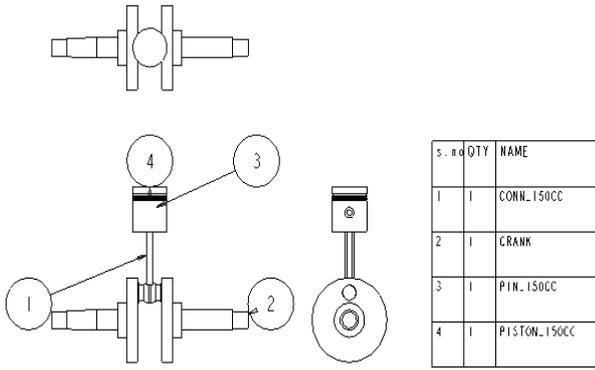


Figure 1.4: Assembly 2D drawing

4. Designing the Models by using PRO/Engineer software

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

4.1 Piston

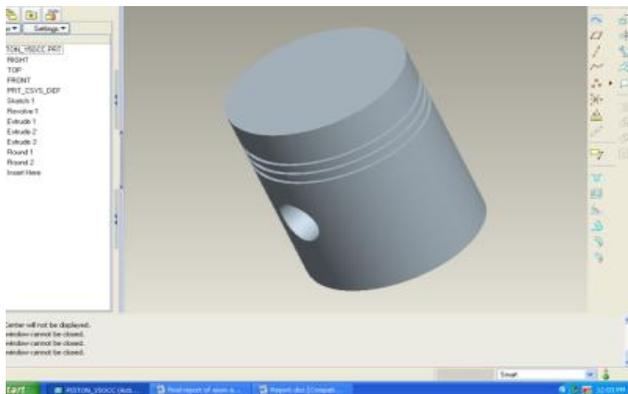


Figure 2.1: Piston 3D model

4.2 Piston Pin

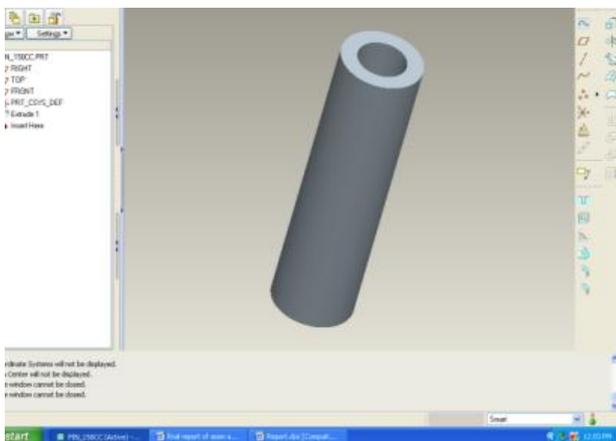


Figure 2.2: Piston pin 3D model

4.3 Connecting Rod

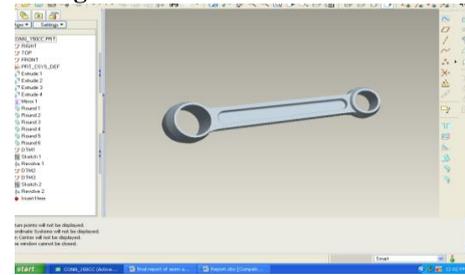


Figure 2.3: Connecting rod 3D model

4.4 Crankshaft

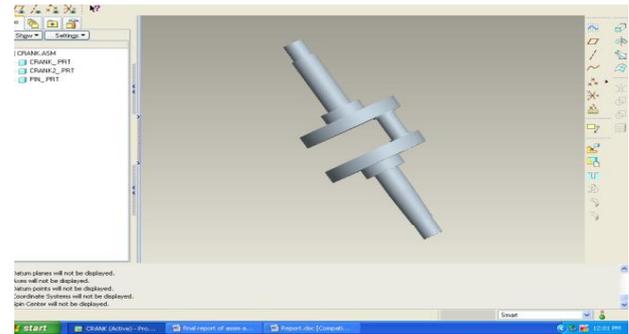


Figure 2.4: Crankshaft 3D model

4.5 Assembly

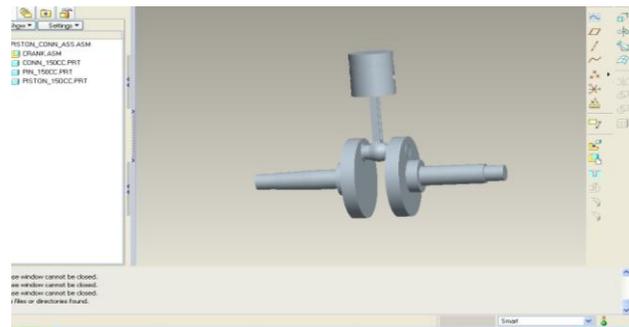


Figure 2.5: Assembly 3D model

5. Results & Discussions

Structural analysis is Used to determine displacements, stresses, etc. under static loading conditions. ANSYS can compute both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep. Buckling Analysis is Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigen value) buckling and nonlinear buckling analyses are possible.

5.1 Structural Analysis for Materials

	Material	'E'	'μ'	Density
Piston	Aluminum Alloy	70000 N/mm ²	0.33	0.0000026 Kg/Mm ³
Connecting Rod	Aluminum Alloy	70000 N/mm ²	0.33	0.0000026 Kg/Mm ³
Crank shaft	Nickel Chromium Steel	210000 N/mm ²	0.27	0.0000077 Kg/Mm ³

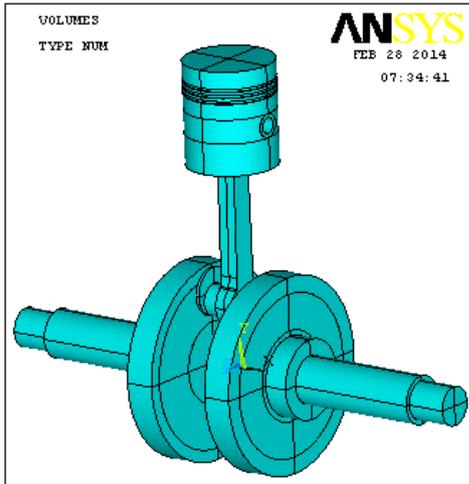


Figure 3.1: Imported Model from Pro/Engineer

Applying Pressure – 15.454N/mm²

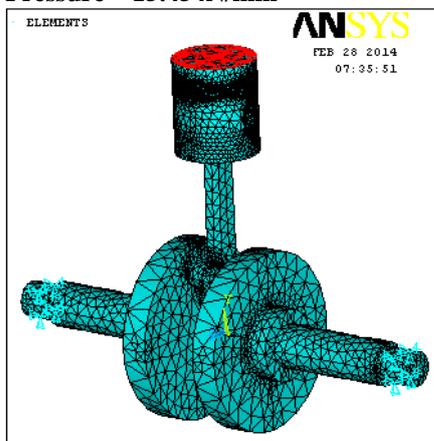


Figure 3.2: Applying the Loads

Von Mises Stress

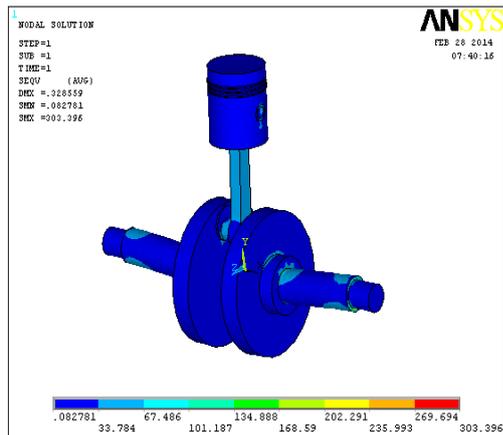


Figure 3.3: Nodal Solution

5.2 Modal Analysis

Modal analysis is typically used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a harmonic response or full transient dynamic analysis. Modal analyses, while being one of the most basic dynamic analysis types available in ANSYS, can also be more computationally time consuming

than a typical static analysis. A reduced solver, utilizing automatically or manually selected master degrees of freedom is used to drastically reduce the problem size and solution time.

Displacement

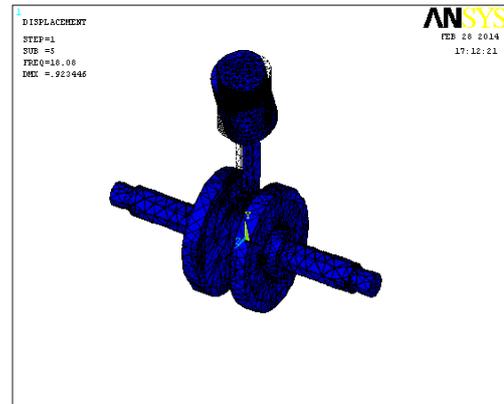


Figure 3.4: Displacement

As per the analysis images

For Material	Displacement (mm)	Von Mises Stress (N/mm ²)
Piston – Cast Iron	0.328559	303.396
Connecting rod – Aluminum Alloy A360		
Crankshaft – Nickel Chromium Alloy Steel		

5.3 Structural Analysis for Materials:

	Material	'E'	'μ'	Density
Piston	Cast Iron	75000 N/mm ²	0.211	0.000007kg/mm ³
Connecting Rod	Manganese Steel	210000 N/mm ²	0.29	0.000008 kg/mm ³
Crank shaft	High Carbon steel	200000 N/mm ²	0.295	0.000007872 kg/mm ³

Pressure – 15.454N/mm²

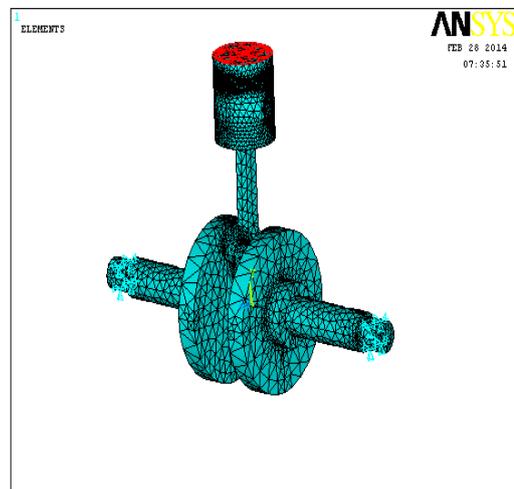


Figure 3.5: Applying the Loads

Von Mises Stress

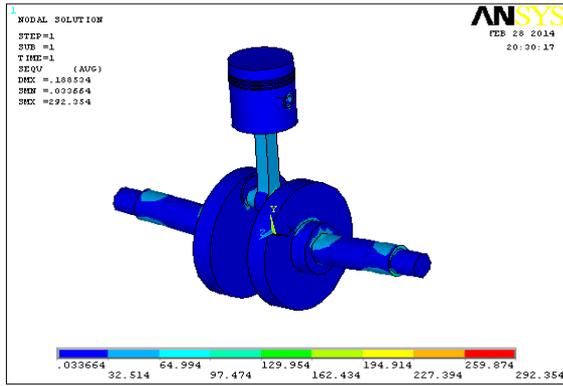


Figure 3.6: Nodal Solution

5.4 Modal Analysis

Displacement

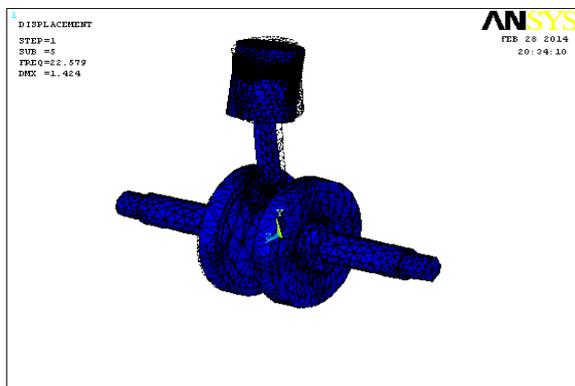


Figure 3.7: Displacement

As per the analysis images

Material	Displacement (mm)	Von Mises Stress (N/mm ²)
Piston – Cast Iron		
Connecting rod – Manganese Steel	0.188534	292.354
Crankshaft – High Carbon Steel		

6. Conclusion

In this project piston, connecting rod and crankshaft are designed & assembled the three parts. Modeling and assembly is done in Pro/Engineer. Structural, Modal analysis are done on the assembly. Analysis is done in ANSYS.

By performing structural analysis, we get displacement and stress. The stress is within the range of permissible stress values. By performing the modal analysis, we can observe different mode shapes of the assembly. By observing the stress value, we conclude that our design is safe for working condition. By comparing the stress results, using (Cast Iron for Piston, Manganese Steel for Connecting rod and High Carbon Steel for crankshaft) is the best combination for assembly.

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