Static Analysis of 2 Wheeler Connecting Rod using Fusion 360

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Abstract -*In the internal combustion engine, the connecting rod connects the piston to the crank or crankshaft. Together with the crank, they form a simple mechanism that converts reciprocating motion into rotating motion of the piston and crankshaft. The material used in the connecting rod should be chosen wisely because during manufacturing process it has to undergo various production processes and subsequent heat treatment process, which is very much important for strength and stiffness. It may be made of carbon steel, aluminium or any other alloy. In this present work, the model is developed, designed and analysed using ANSYS for different materials of connecting rod. The project also analyses factors such as stress, strain, factor of safety, deformation, fatigue analysis and working cycle while taking into consideration the difference in weight and design. The results obtained from performed analysis can be used to modify the design of existing connecting rod, so that better performance i.e. reduced inertia, fatigue life and manufacturability can be obtained under varying static and dynamic conditions.*

Key Words:connecting rod, analysis, fusion 360

1.INTRODUCTION

Connecting rod interconnects the piston and the crank shaft and transmits the gas forces from the piston to the crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin and thus convert the reciprocating motion of the piston into rotary motion of the crank. Generally connecting rods are manufactured using carbon steel and in recent days aluminium alloys are finding its application in connecting rod. In this work connecting rod is replaced by aluminium based composite material. And it also describes the fabricating and testing of connecting rod. It consists of a long shank a small end and big end. The small end of connecting rod is usually made in the form of an eye and is provided with a bush. It is connected to the piston by means of piston pin. Thebig end of connecting rod is connected to the crank by means of damping. Connecting rod has three main zones. The piston pin end, the centre shank and the big end. The piston pin end is the small end, the crank end is the big end and the centre shank is of I cross section. Connecting rod is a pin jointed strut in which more weight is concentrated towards the big end. Connecting rod is acted upon by gas loads and inertia loads during its operation. The forces include gas forces due to combustion and inertia forces due to its own weight. The automobile engine connecting rod is a high volume production, critical component. Every vehicle that uses an internal combustion engine requires at least one connecting rod depending upon the number of cylinders in the engine.

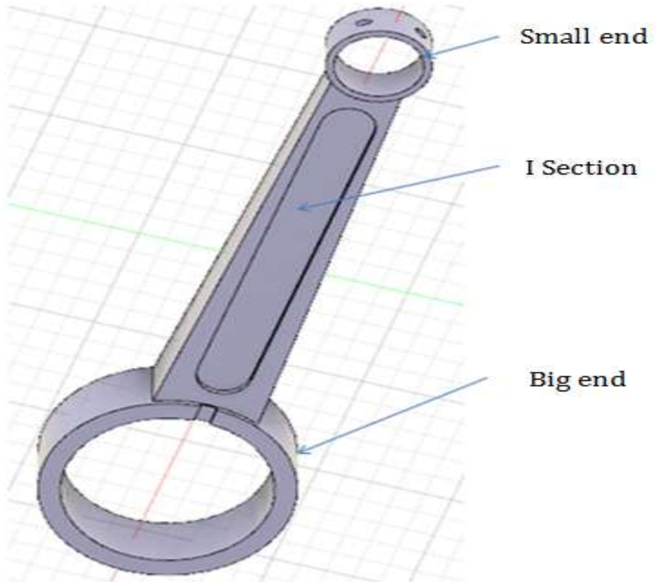


Fig -1: Connecting rod

1.1 Piston-connecting rod assembly

A Connecting rod is a member which connecting between piston and crank shaft. Material, such as structural steel, aluminium alloy, titanium, and cast iron are used. The connecting rod package has to be custom tailored to the engine and the customer's needs, says Kerry Novak of Crower. The Small end of the connecting rod is connected to the piston end using a gudgeon pin, wrist pin by press fit. Big end is connected to the crank shaft using fasteners. Stresses on the connecting rod are always high due to the combustion chamber pressure, inertia forces, which induces high value of stresses. According to Vegi[1] failure of a connecting rod, usually called "throwing a rod" is one of the most common causes for catastrophic engine failure in cars. However, failure of the connecting rod is not common since the big automobile companies try to keep very highfactor of safety of 2 or 3 above. To provide warranty, automobile companies should have the robust design and manufacture capability. By having all this factors in consideration, a lot of engines fail or cease due to failure of connecting rod assembly, which leaves the companies to consider that the connecting rod as a very high risk component. For example connecting rod failed for GM 2014 Chevy Malibu's, 2014 Buick Regal GS , 2014 Chevy Impala, 2014Cadillac ATS and 2015 Porsche 911 GT3, which caused millions of dollars to be spent on recall to replace the whole engine and redesign the connecting rod. While designing the connecting rod, Vegi[1] suggested that measures have to be taken to reduce the stresses in the connecting rod. Methods, like grinding the edges to give smooth surface and radius to prevent crack initiation, shot peening methods are used which induces compressive surface stress to balance the weight of the connecting rod and piston assembly to reduce the bending stress due to centrifugal action. He suggest us to use high end equipment which zooms in the connecting rod to give minute invisible cracks, which lead to brittle fracture in the ductile material.

2. MATERIAL SELECTION

Aluminium alloys are used mainly in the Aerospace Industry because of their low densityand high strength, toughness and resistance to corrosion. To improve the Strength of Aluminium and its alloys without a loss in ductility, ceramic particles can be added forming a composite material.Aluminium alloy with zinc has the primary alloying element. It is strong with a strength comparable to many steels and good fatigue strength and average machinability, but has less resistance to corrosion then many other aluminium alloys.7075 aluminium alloy is an aluminium alloy, with zinc as the primary alloying element. 6061 Aluminium plate is a precipitation-hardened aluminium alloy containing magnesium and silicon as its major alloying elements. 6061 aluminium plate is one of the most versatile of the heat-treatable alloys. 6061 is popular for its medium to high strength requirements, good toughness and excellent corrosion resistance.

Table-1: Physical properties of Al7075 and Al6061

Properties	Al7075	Al6061
Elastic modulus(GPA)	71.7	68.9
Density(g/cc)	2.81	2.7
Poisson Ratio	0.33	0.33
Hardness	60	30
Yield strength	145	275

3. MODELING AND ANALYSIS

3.1 Modeling

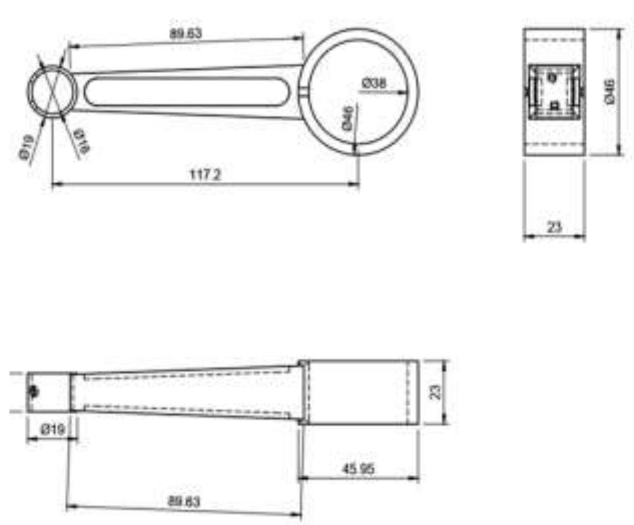


Fig - 2 General dimension of connecting rod

Being one of the most integral parts in an internal combustion engines design, the connecting rod must be able to withstand tremendous loads and transmit a great deal of power. It is no surprise that a failure in a connecting rod can be one of the most costly and damaging failures in an engine. The maximum compressive load on the connecting rod will be algebraic sum of the gas load and the inertia load due to the reciprocating masses and the effect of the inertia load is to decrease the maximum compressive gas load. This load is further reduced slightly by the piston rings and piston friction. As the gas pressure is maximum near the dead centre, it is not necessary to resolve the piston load along the connecting rod since the angularity of the rod will be very small. Also the total stress in the rod is the sum of direct compressive stress due to net piston load and the transverse bending stress also known as whipping stress. Maximum direct compressive stress and the maximum whipping stress do not occur at one crank angle. Direct compressive stress is maximum at the top dead centre and whipping stress is maximum at about 65° to 68° from top dead centre. The maximum stress due to the combined effect usually occurs when $\theta=90^{o}$ and its value is low when compared to the direct stress due to maximum gas load. Therefore, to find the section of the connecting rod, use maximum gas load instead of net piston load with a suitable factor of safety. Hence a robust section will be obtained which can able to withstand the maximum whipping stress and the bending stress. The connecting rod will besubjected to altering direct compressive and tensile stresses. Therefore, the connecting rod is designed as a strut. As with respect to rod length, the radius of gyration of I-section or diameter in the case of circular cross section is large, Rankline Gordon formula is used to find the cross section of the connecting rod.

3.1.1 Pressure calculation of connecting rod

Pressure calculation
Consider a 150cc engine
Engine type air cooled 4-stroke
Bore × Stroke (mm) = 57×58.6
Displacement = 149.5cc
Maximum Power = 13.8bhp at 8500rpm
Maximum Torque = 13.4Nm at 6000rpm
Compression Ratio = 9.35/1

- Density of petrol at 288.855 K, = 737.22×10^{-9} kg/mm^3
- Molecular weight, M = 114.228 g/mole
- Ideal gas constant, R = 8.3143 J/mol. k

From gas equation,
$PV = m.\, R_{specific}.\, T$
Where,
P = Pressure, Pascal
V = Volume, mm^3
m = Mass, kg
$R_{specific}$ = Specific gas constant
T = Temperature, Degree
But,
Mass = density × volume
$m = 737.22\times10^{-9} \times150 \times 10^3$
m = 0.11kg
Rspecific = R/M
$R_{specific}$=8.3143/0.110543
Rspecific = 75.186
$P = m.\, R_{specific}.\, T/V$
$P = 0.11\times75.186 \times(288.85/150\times10^3)$
P = 16.010MPa
P = 16MPa

3.2 Analysis

The material chose for manufacturing the connecting rod are Aluminium 7075 and Aluminium 6061. The materials were analysed using Auto desk fusion 360 software for safety factor, displacement, stress and other forces acting on the connecting rod.

In this work we are analysing the connecting rod for different materials for static structural condition in Auto desk software.

The steps needed to perform an analysis depend on the study type. Analysis is done by performing the following steps,

- A model is created, defining its analysis type and options.
- Defining the parameters of the study. A parameter can be a model dimension, material property, force value, or any other input.
- Defining the material properties.
- Constraints and loads are specified.
- The program automatically creates a mixed mesh when different geometries (solid, shell, structural members etc.) exist in the model.
- Meshing the model to divide the model into many small pieces called elements. Fatigue and optimization studies use the meshes in referenced studies.
- Run the study
- Review results

Fig -3: Model of connecting rod

3.2.1 Load & fixed support

Fixed support

Fig -4: Fixed support of connecting rod

Load

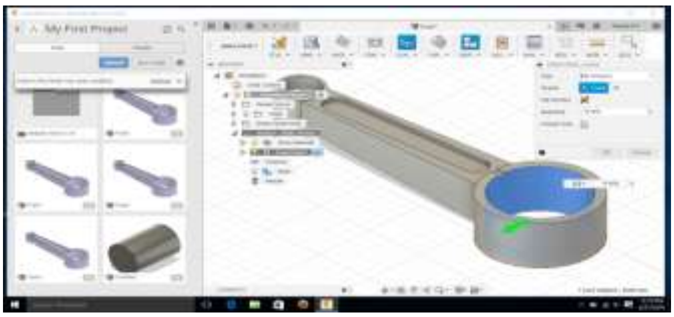


Fig - 5: Load on connecting rod

3.2.2 Meshing

Meshing is probably the most important part in any of the computer simulations, because it can show drastic changes in results you get. Meshing means you create a mesh of some grid-points called 'nodes'. It's done with a variety of tools & options available in the software. The results are calculated by solving the relevant governing equations numerically at each of the nodes of the mesh. The governing equations are almost always partial differential equations, and Finite element method is used to find solutions to such equations. The pattern and relative positioning of the nodes also affect the solution, the computational efficiency & time.

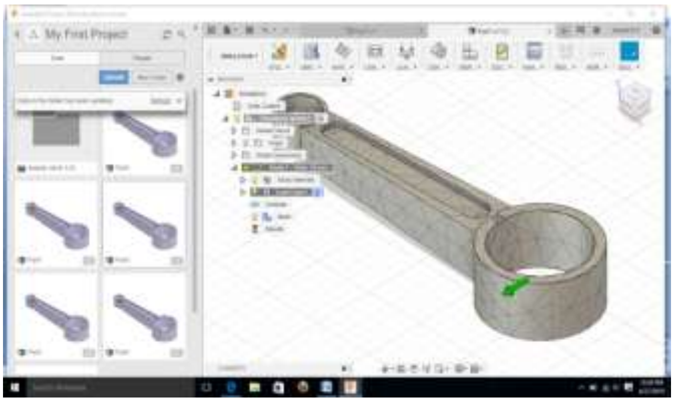


Fig-6: Meshed view of connecting rod

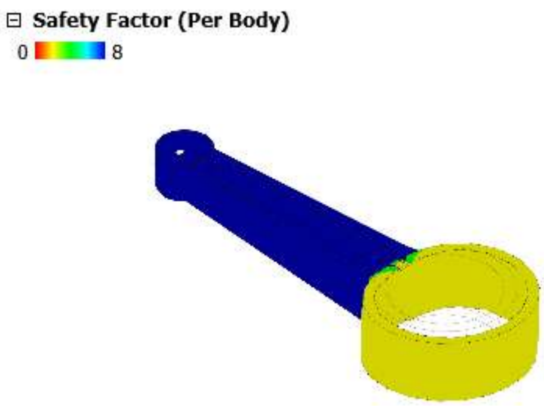
Mesh Type: Tetrahedral
No. of nodes: 3249
No. of elements: 1653

4. RESULT AND DISCUSSION

After the Analysis of connecting rod comparative study should be made between Al7075 and Al6061.

4.1 Safety Factor

Al7075



Al6061

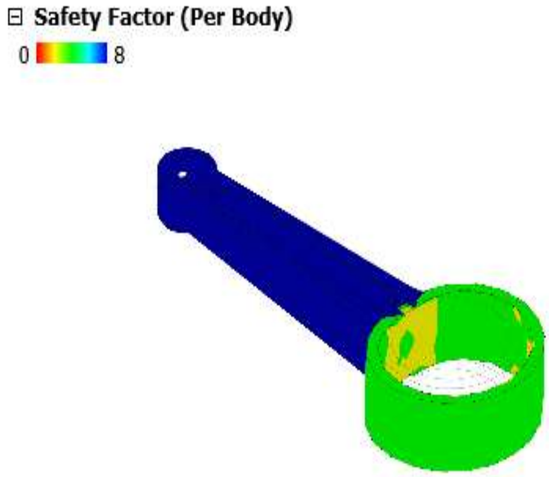
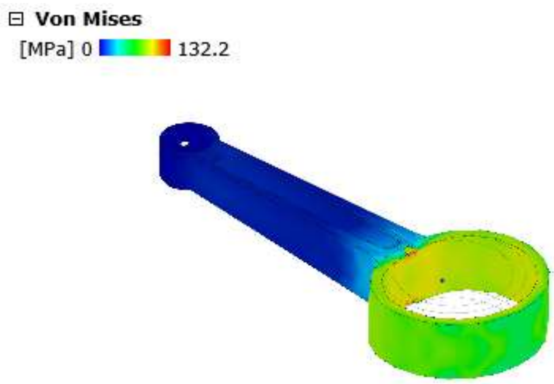


Fig -7: Safety factor of Al7075 and Al6061

Since working stress is same on both Al7075 and Al6061, from analysis safety factor of Al7075 and Al6061 is 8.

4.2 Stress

Al7075



Al6061

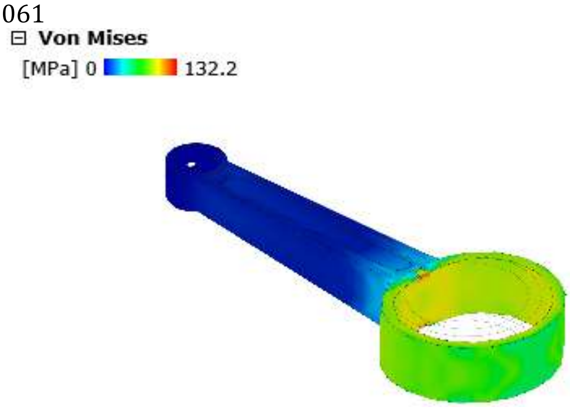
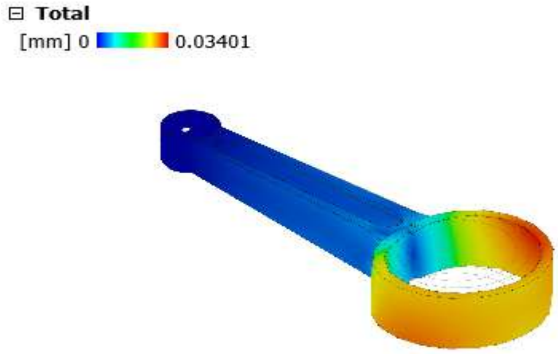


Fig -8: Stress acting on Al7075 and Al6061

Since volume, geometrical considerations and load on both Al7075 and Al6061 is same, from analysis stress acting on Al7075 and Al6061 is 132.2 Mpa.

4.3 Displacement

Al7075



Al6061

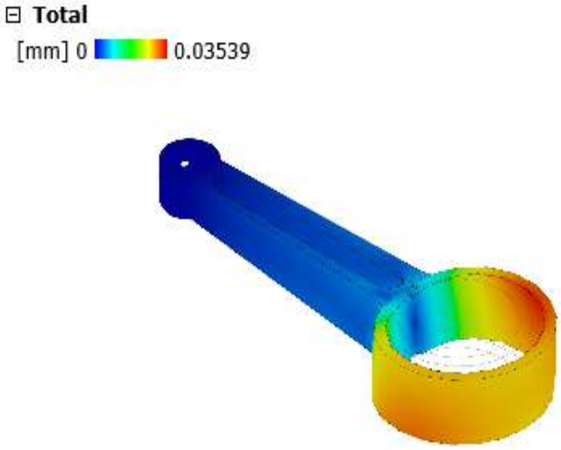


Fig- 9: Displacement of Al7075 and Al6061

The stress induced due to the external load caused high elongation and deformation in the Al6061 material comparedto Al7075. From analysis displacement of Al6061 is more, therefore Al7075 is preferred.

4.4 Result Summary

Table-2: Result summary of Al7075 and Al6061

Name Al7075	**Minimum**	**Maximum**
Safety Factor		
Safety Factor (Per Body)	2.08	15
Stress		
Von Mises	1.51E-06 MPa	132.2 MPa
1st Principal	-4.035 MPa	136.2 MPa
3rd Principal	-36.39 MPa	19.3 MPa
Normal XX	-35.67 MPa	81.31 MPa
Normal YY	-24.62 MPa	135.3 MPa
Normal ZZ	-12.58 MPa	35.18 MPa
Shear XY	-51.17 MPa	52.11 MPa
Shear YZ	-38.02 MPa	23.54 MPa
Shear ZX	-6.347 MPa	7.533 MPa
Displacement		
Total	0 mm	0.03539 mm
X	-0.003925 mm	0.03149 mm
Y	-0.03213 mm	0.03247 mm
Z	-0.007846 mm	0.007809 mm
Reaction Force		
Total	0 N	6.528 N
X	-5.417 N	0.4298 N
Y	-3.471 N	2.278 N
Z	-1.137 N	1.813 N
Strain		
Equivalent	2.99E-11	0.002372
1st Principal	3.038E-11	0.002347
3rd Principal	-0.001677	-1.527E-11
Normal XX	-7.791E-04	0.001283
Normal YY	-6.544E-04	0.001909
Normal ZZ	-4.899E-04	2.682E-04
Shear XY	-0.001975	0.002012
Shear YZ	-0.001468	9.084E-04
Shear ZX	-2.455E-04	2.908E-04

Table-3: Result summary of Al7075 and Al6061

Name Al6061	**Minimum**	**Maximum**
Safety Factor		
Safety Factor (Per Body)	0.4171	15
Stress		
Von Mises	1.51E-06 MPa	132.2 MPa
1st Principal	-4.035 MPa	136.2 MPa
3rd Principal	-36.39 MPa	19.3 MPa
Normal XX	-35.67 MPa	81.31 MPa
Normal YY	-24.62 MPa	135.3 MPa
Normal ZZ	-12.58 MPa	35.18 MPa
Shear XY	-51.17 MPa	52.11 MPa
Shear YZ	-38.02 MPa	23.54 MPa
Shear ZX	-6.347 MPa	7.533 MPa
Displacement		
Total	0 mm	0.03537 mm
X	-0.003925 mm	0.03145 mm
Y	-0.03213 mm	0.03245 mm
Z	-0.007846 mm	0.007824 mm

Reaction Force		
Total	0 N	6.528 N
X	-5.417 N	0.4298 N
Y	-3.471 N	2.278 N
Z	-1.137 N	1.813 N
Strain		
Equivalent	2.999E-11	0.002372
1st Principal	3.038E-11	0.002347
3rd Principal	-0.001677	-1.527E-11
Normal XX	-7.795E-04	0.001283
Normal YY	-6.544E-04	0.001909
Normal ZZ	-4.89E-04	2.687E-04
Shear XY	-0.001975	0.002012
Shear YZ	-0.001468	9.089E-04
Shear ZX	-2.45E-04	2.908E-04

From Analysis results Al7075 is preferred for manufacturing of connecting rod.

5. CONCLUSION

For the selection of a suitable material for connecting rod design, the Aluminium alloys Al6061 and Al7075 were investigated for their stress analysis. For the stability of these materials, the connecting rod is then analysed under same load conditions. In this method, the connecting rod is subjected to pressure of 16 Mpa by defining the constraint according to their function. The results obtained from simulation were analysed for both materials, individually as well as comparatively. The results in Figure 6.3 shows that Al6061 deform more as compared to Al7075 (0.03401 for Al7075 and 0.03539 for Al6061), because the stress induced due to the external load caused high elongation and deformation in the Al6061 material. Therefore, the study has concluded that Al7075 material is more suitable for this type of connecting rod.

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