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Design and Optimization of Four Wheeler Rocker Arm for Neck and Hole

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Abstract:

The aim of the project is to design a rocker arm for a four wheeler using theoretical formulas. In this theoretical calculation, design for fulcrum pin, Design for forked end, Design for rocker arm cross-section, Design for Tappet, and Design for valve spring. A 2D drawing is drafted from the calculations for all parts and assembly. A parametric model and assembly of rocker arm is done in 3D modeling software Pro/Engineer.For validating above design we are going to conduct structural and model analysis for total assembly of the above components by applying the boundary conditions as an exhaust valve gas load, spring force and force due to valve acceleration. In this project, material optimization by applying materials HDPE, steel, and Aluminum alloy. By observing above analysis we are going to find out which material is suitable for this part. Pro/ENGINEER is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design.

I.INTRODUCTION:

As a rocker arm is acted on by a camshaft lobe, it pushes open either an intake or exhaust valve [1][2]. This allows fuel and air to be drawn into the combustion chamber during the intake stroke or exhaust gases to be expelled during the exhaust stroke. Rocker arms were first invented in the 19th century and have changed little in function since then. Improvements have been made, however, in both efficiencies of operation and construction materials [1] [3] [4]. The drive cam is driven by the camshaft. This pushes the rocker arm up and down about the trunnion pin or rocker shaft. Friction may be reduced at the point of contact with the valve stem by a roller cam follower.

A similar arrangement transfers the motion via another roller cam follower to a second rocker arm. This rotates about the rocker shaft, and transfers the motion via a tappet to the poppet valve. In this case this opens the intake valve to the cylinder head.The effective leverage of the arm (and thus the force it can exert on the valve stem) is determined by the rocker arm ratio, the ratio of the distance from the rocker arm's center of rotation to the tip divided by the distance from the center of rotation to the point acted on by the camshaft or pushrod. Current automotive design favors rocker arm ratios of about 1.5:1 to 1.8:1. However, in the past smaller positive ratios (the valve lift is greater than the cam lift) and even negative ratios (valve lift smaller than the cam lift) have been used. Many pre-World War II engines use a 1:1 (neutral) ratio.

II.ROCKER ARM:

A rocker arm is a valve train component in internal combustion engines. As the arm is acted on by a camshaft lobe, it pushes open either an intake or exhaust valve. This allows fuel and air to be drawn into the combustion chamber during the intake stroke or exhaust gases to be expelled during the exhaust stroke.The rocker arm has a roller bearing on one end, riding on a single camshaft lobe, while the other end, two encapsulated hydraulic lifters rides on two exhaust valves. It's topped off with a plastic cap to pivot on the valve tip what a challenge it is to make this part: you have a metal roller bearing pinned to an aluminum body with a metal hydraulic lifter bored inside the aluminum arm. The hydraulic lifter unit's clearance-to-bore is so minute that the inside has to be thermally deburred. Otherwise the lifter may not leak down properly. Reducing the weight of the rockers will reduce the reciprocating mass of the valve train.

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But experts say reducing the weight on the valve side of the rockers usually benefits the engine's rpm more than changing the pushrod side.

Materials used:

For car engines the rocker arms are generally steel stampings, providing a reasonable balance of strength, weight and economical cost. Because the rocker arms are, in part, reciprocating weight, excessive mass especially at the lever ends limits the engine's ability to reach high operating speeds. Truck engines (mostly diesel) use stronger and stiffer rocker arms made of cast iron (usually ductile), or forged carbon steel, aluminum alloys, cast steel.

Use of alloys:

Many lightweight and high strength alloys, and bearing configurations for the fulcrum, have been used in an effort to increase the RPM limits higher and higher for high performance applications, eventually lending the benefits of these race bred technologies to more high-end production vehicles.

Fig.1: Rocker Arm

III.DESIGN OF ROCKER ARM:
Methodology:

Let, mv= 0.09 kg(Mass of the valve), dv= 40mm (Diameter of the valve head), h = 13mm (Lift of the valve), a = Acceleration of the valve,Pc= 0.4 N/mm2 (Cylinder pressure or back pressure), Ps= 0.02 N/mm2 (Maximum suction pressure), d1= 8mm (diameter of fulcrum pin),D1= 18mm (diameter of boss), l = Length of arm, Speed of engine = 3000 RPM Angle of action of cam = 110°.

Calculating Forces Acting:

Gas load on the valve,

P1= /4(dv)2 Pc = /4 x (40)2 x 0.4= 502.4

Weight of associated parts with the valve,

w =m•g= 0.09 x 9.8= 0.882 N

Total load on the valve

P = P1+ w= 502.4 + 0.882 = 503.282 N.

• Initial spring force considering weight of the valve (Fs)= /4 (dv)2Ps– w= /4 x (40)2x0.02– 0.882=24.238

The force due to valve acceleration (Fa) may be obtained as discussed below:

We know that speed of engine 3000 RPM The speed of camshaft = N/2=3000/2 =1500 r.p.mand angle turned by the camshaft per second

= (1500/60) X 360 =9000 deg/s

Time taken for the valve to open and close,

T = Angle of action of cam Angle turned by camshaft=110/9000 =0.012s

We know that maximum acceleration of the valve a = (2/t)2•r = (2 /t)2 • r= (2 /0.012)2 X 0.0065 a = 1780.2 m/s2

Force due to valve acceleration, considering the weight of the valve,Fa= m • a + w= 0.09 × 1780.2 + 0.882= 161.1 N

Now the maximum load on the rocker arm for exhaust valve,Fe= P +Fs+Fa= 503.282 + 24.238 + 161.1= 688.62 N

Since the length of the two arms of the rocker are equal, therefore, the load at the two ends of the arm are equal, i.e., Fe = Fc = 688.62 N.

• We know that reaction at the fulcrum pin

Rf= Fe2Fc22FeFccos

Rf= 688.22 + 688.22-2 688.2*688.2cos176

Rf= 1376.43 N

Calculating Stresses:

Calculating shear stress at the pi, load on the fulcrum pin Rf24 d1

Where,d1is diameter of fulcrum pin (d1= 8 mm)1272.4 24 8 = 13.69 N/mm2

This shear stress is critical.

• Calculating bending stress of cross section.

The Rocker arm may be treated as a simple supported beam and loaded at the fulcrum point. Therefore, due to the load on the valve the rocker arm is subjected to bending moment.

We know that maximum bending moment (M) of cross section,M =FeD12= 688.62 2718 2

M =12387.96 N-mm

The rocker arm is of I-section

Section module Z,

Z=1/12[2.5t6t31.5t4t3]/t6/2

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Where t is thickness
Z = 332.91 mm3
Bending stress=M12387.96/332.91
b= 37.2 N/mm2
This bending stress is near to critical limit (i.e., 40/mm2).

IV.ANALYSIS OF ROCKER ARM:

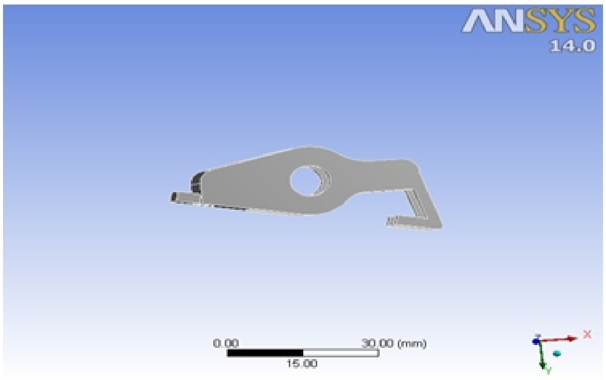

Fig.2: Analysis of Rocker Arm in HDPE

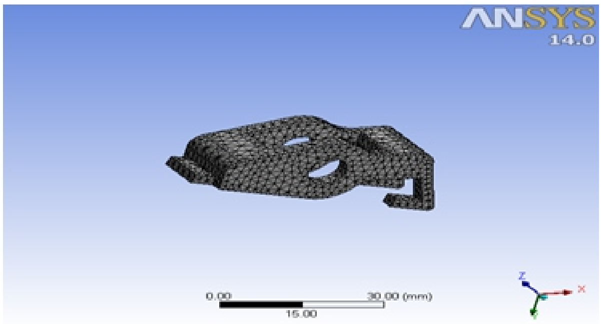

Fig.3. Meshed rocker arm

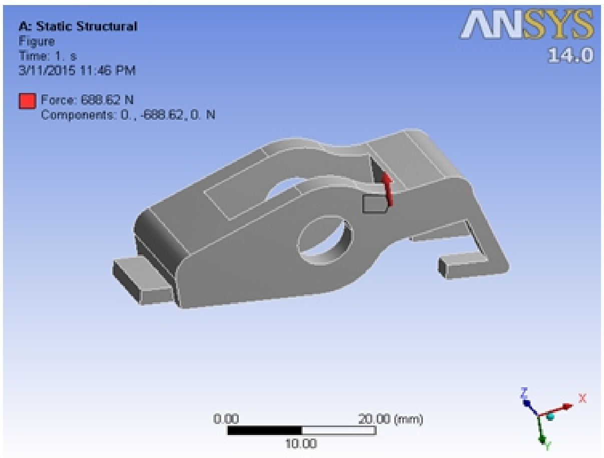

Fig 4: Static Structural Force

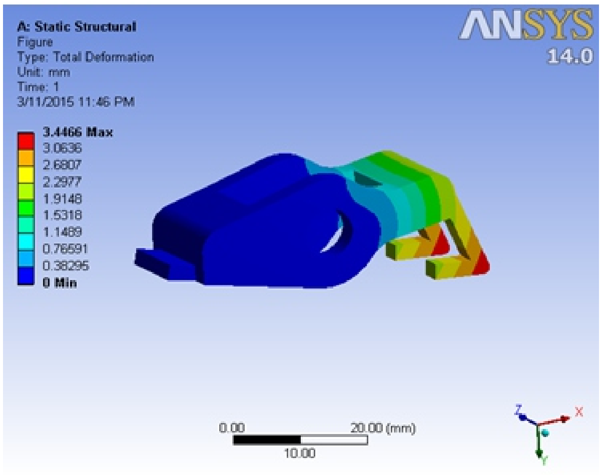

Fig5: Total Deformation in HDPE at Ends

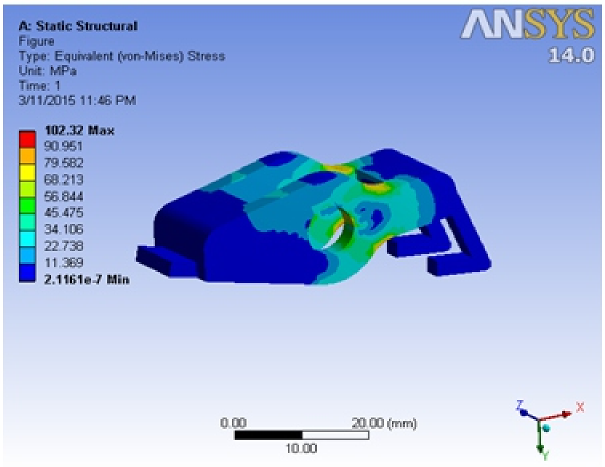

Fig 6: Equivalent Stress in HDPE at Ends

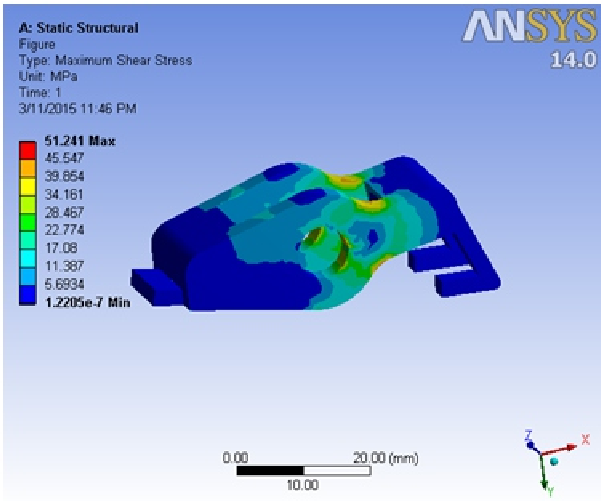

Fig7: Maximum Shear Stress in HDPE at Ends

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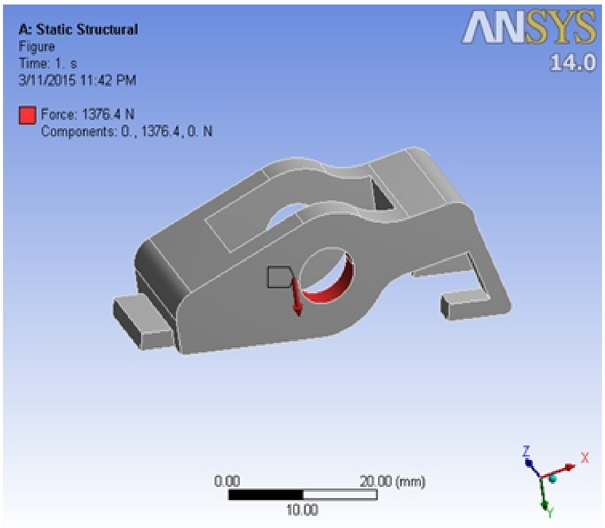

Fig8: Load Acting At the Hole

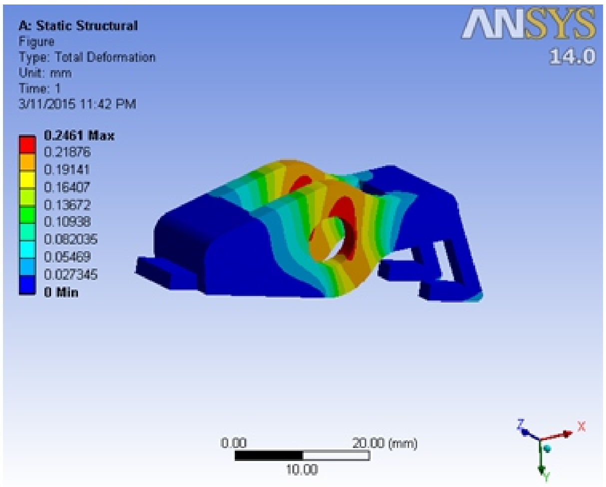

Fig9: Total Deformation in HDPE at Hole

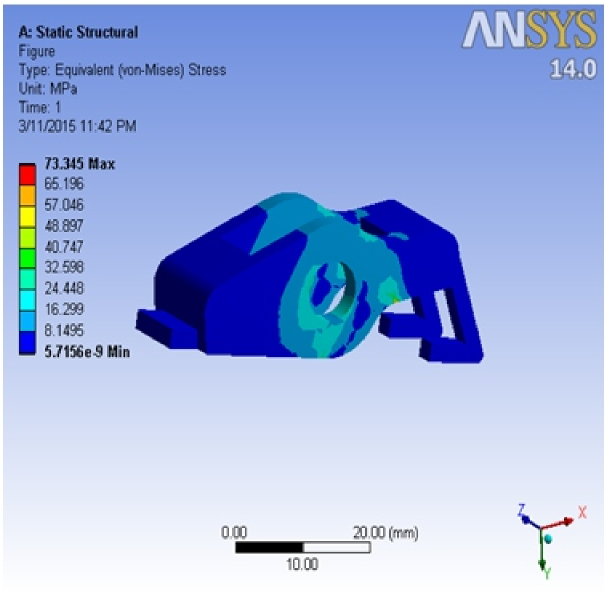

Fig10: Equivalent Stress in HDPE at Hole

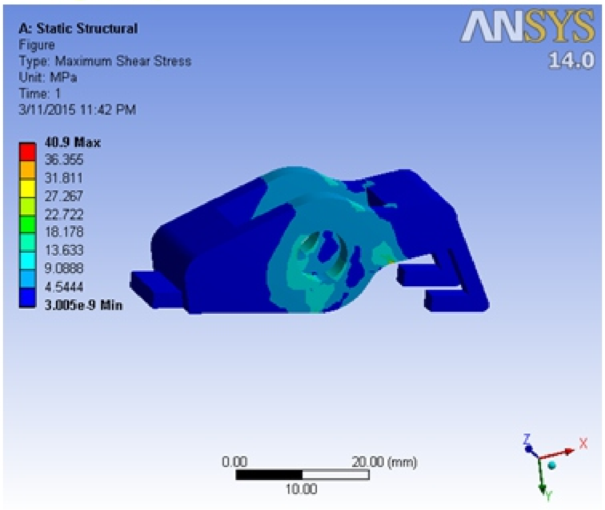

Fig11: Max Shear Stress in HDPE at Hole

Load Acting At the Rocker Arm with Steel Material:

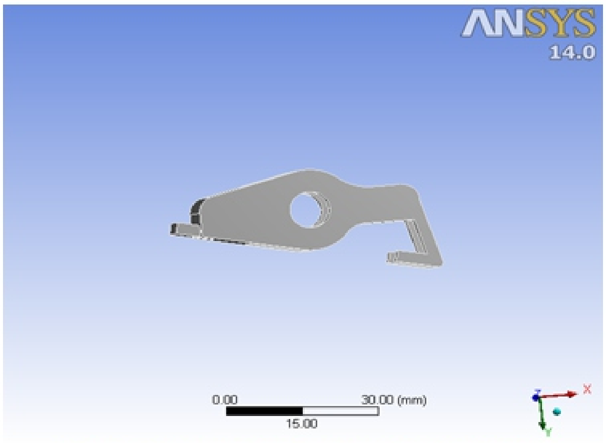

Fig12: Analysis of Rocker Arm in Steel

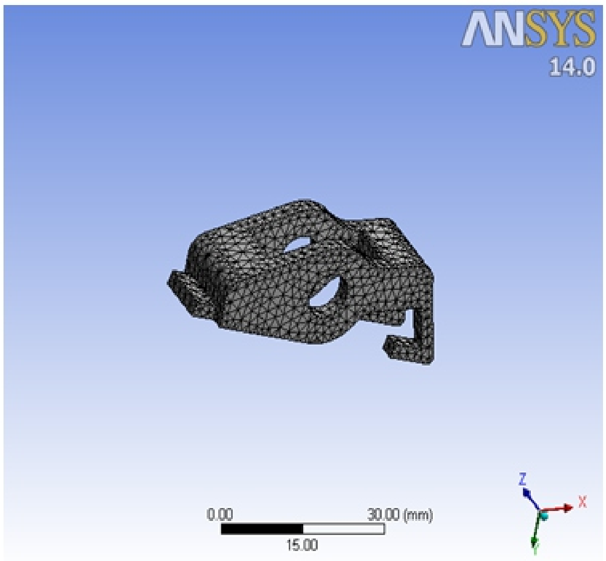

Fig13: Mesh with Steel Material

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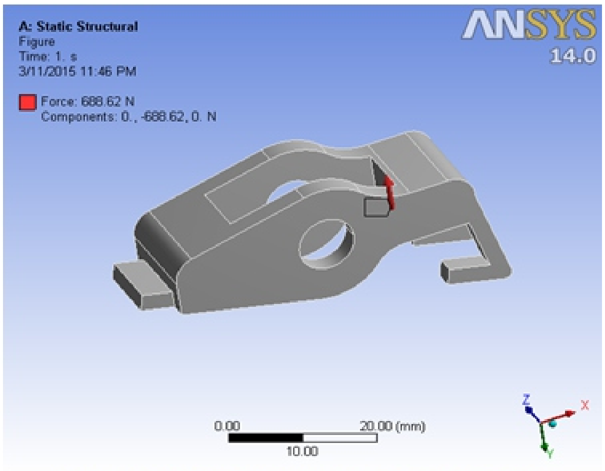

Fig14: Static Structural in Steel at Ends

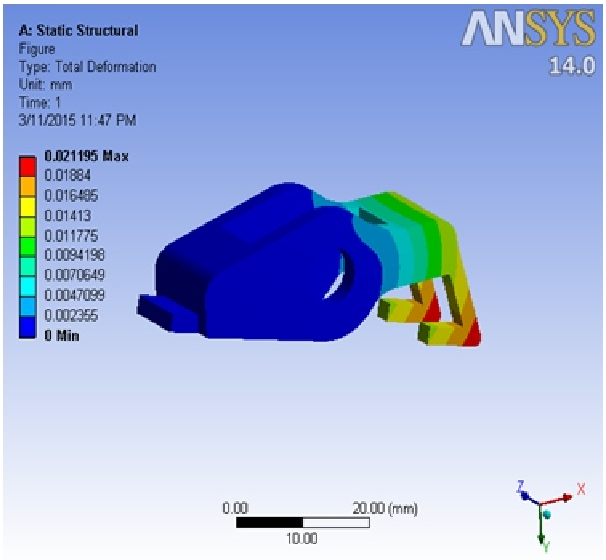

Fig15: Total Deformation in Steel at Ends

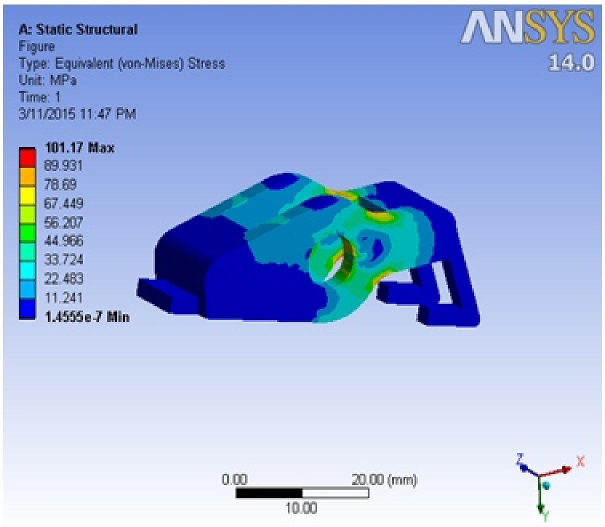

Fig16: Equivalent Stress in Steel at Ends

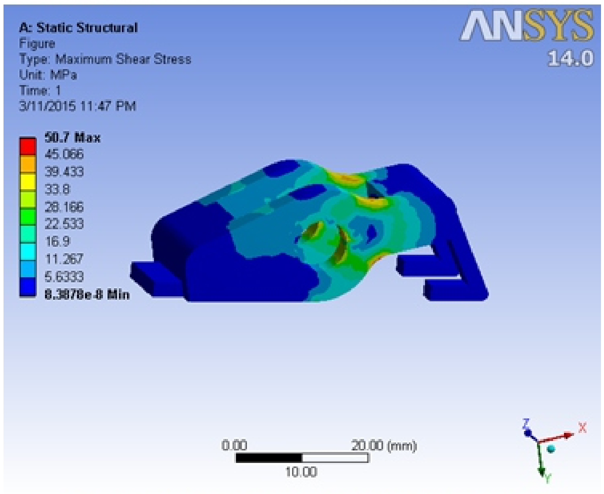

Fig17: Max Shear Stress in Steel at Ends

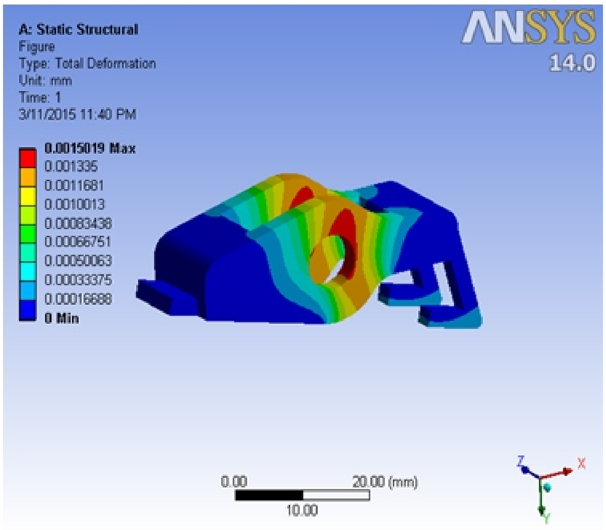

Fig18: Total Deformation in Steel at Hole

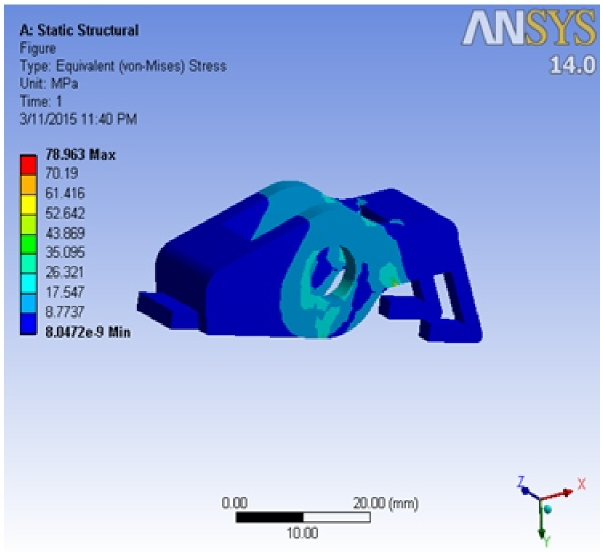

Fig19: Equivalent Stress in Steel at Hole

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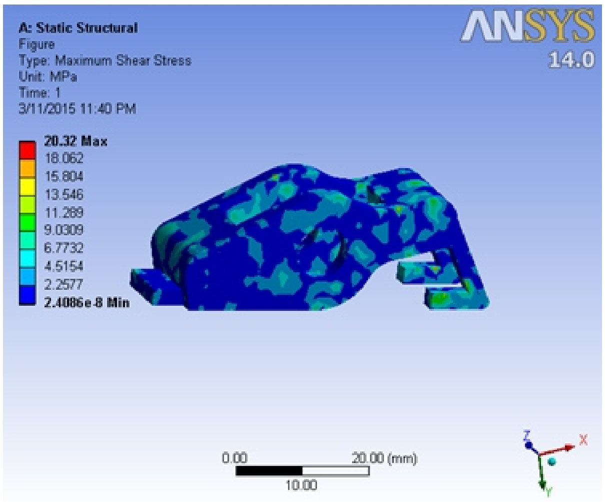

Fig20: Max Shear Stress in Steel at Hole

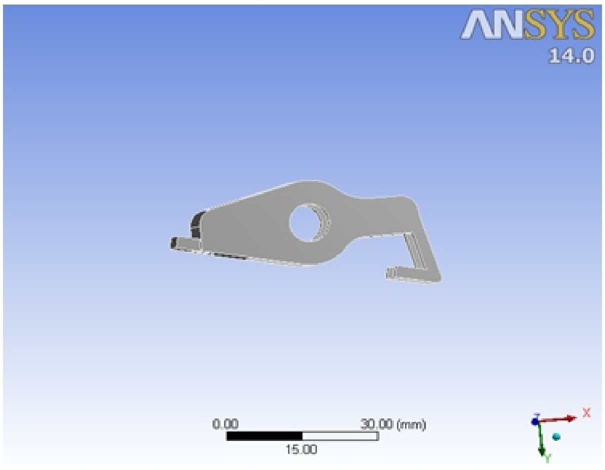

Fig21: Analysis of Rocker Arm In aluminum alloy

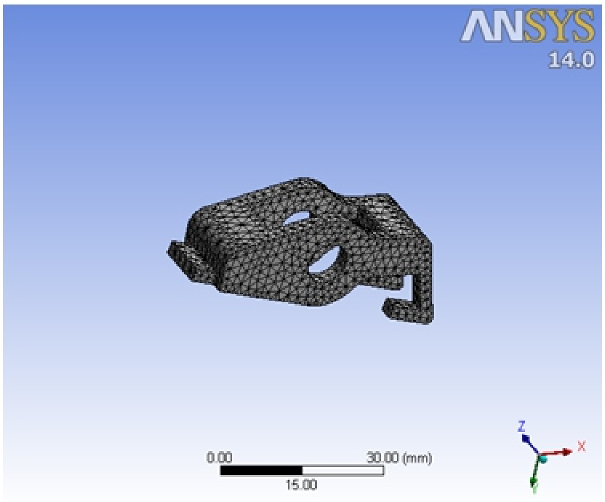

Fig22: Mesh with aluminum alloy Material

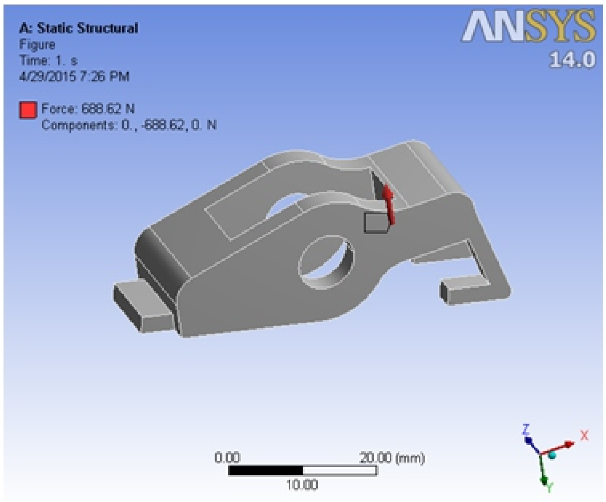

Fig23: Static Structural force in aluminum alloy at Ends

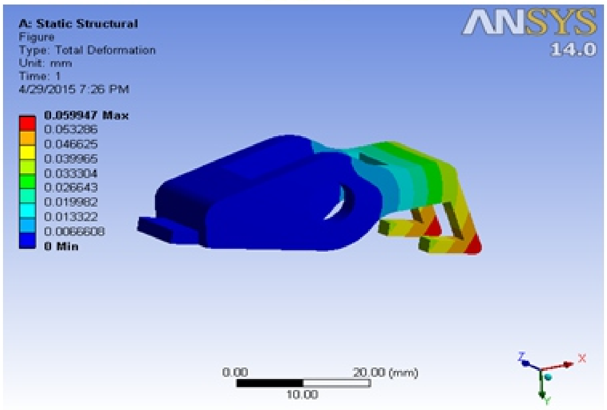

Fig24: Total Deformation in aluminum alloy at Ends

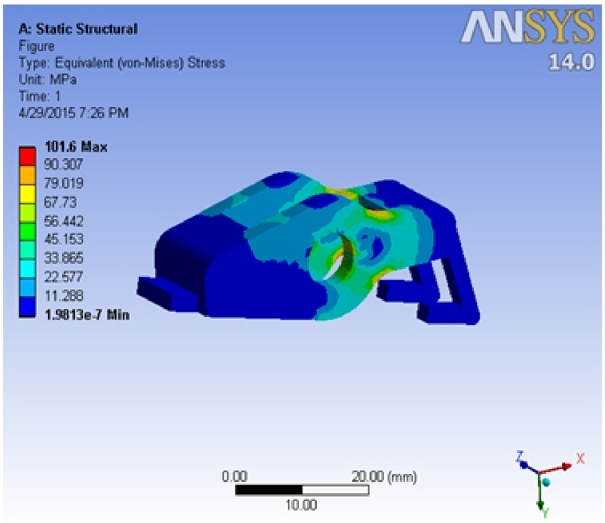

Fig25: Equivalent Stress in aluminum alloy at Ends

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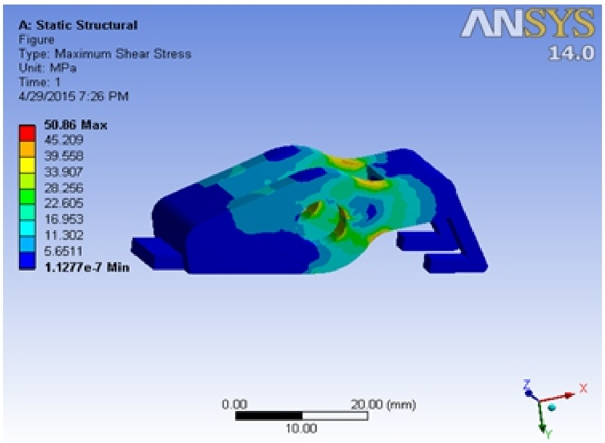

Fig26: Maximum Shear Stress in aluminum alloy at Ends

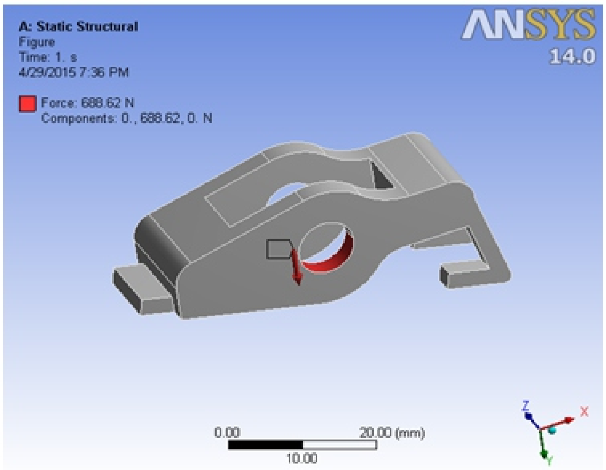

Fig27: Static structural force in aluminum alloy material at hole

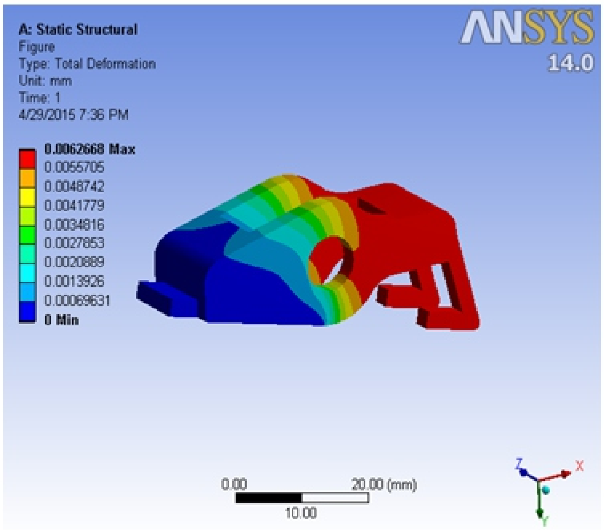

Fig28: Total Deformation in aluminum alloy at hole

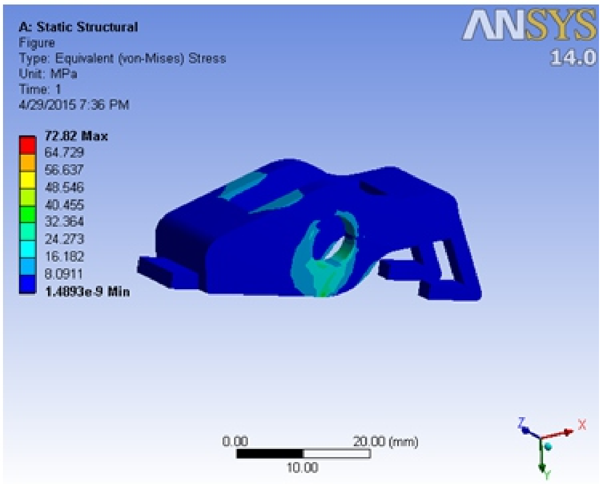

Fig29: Equivalent Stress in aluminum alloy at Hole

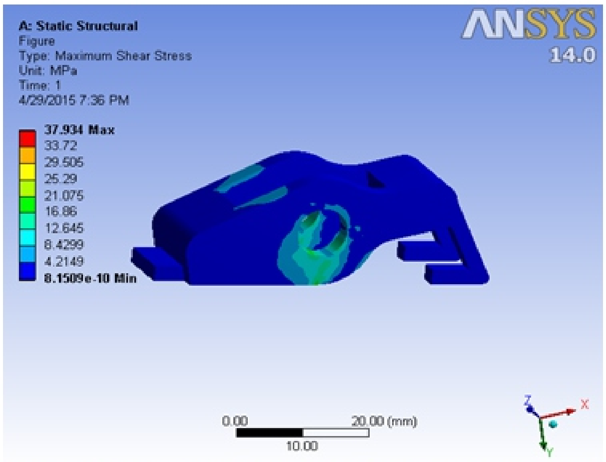

Fig30: Maximum Shear Stress in aluminum alloy at Hole

Results discussion:

It is observed from the results that maximum shear stresses are developed at sharp corners and hole of the rocker arm. A comparison of maximum shear stress, total deformation and equivalent stress values for hdpe, steel and aluminum alloy are done. To compare the hdpe, steel and aluminum alloy, the maximum shear stress values nearly equal to the steel (T max =50.7 Mpa) and aluminum alloy (T max =50.86 Mpa) load acting on the both ends of the rocker arm. The load acting on the hole maximum stress values of steel and aluminum alloy is T max =20.32 Mpa and T max = 37.934. The deformed shape has been depicted in Fig.5, 9, 15, 18, 24, and 28. So the above results are to given steel as the high strength and stiffness than aluminum alloy. Aluminum alloy is light weight and less cost to replace easy.

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V.CONCULSION:

Rocker arm is an important component of engine, failure of rocker arm makes engine useless also requires costly procurement and replacement. An extensive research in the past clearly indicates that the problem has not yet been overcome completely and designers are facing lot of problems specially, stress concentration and effect of loading and other factors. The finite element method is the most popular approach and found commonly used for analyzing fracture mechanics problems.

Lightweight rocker arms are a plus for high rpm applications, but strength is also essential to prevent failure. In recent years, after market steel roller tip rockers have become a popular upgrade for the most demanding racing applications. Some of these steel rockers are nearly as light as aluminum rockers. But their main advantage is that steel has better fatigue strength and stiffness than aluminum. So we can say that steel is the better material in terms of strength and aluminum is good for making low cost rocker arms, HDPE is compare to steel and aluminum alloy low strength and stiffness. Now we can conclude that both steel and aluminum alloy is better for design a rocker arm based on strength, weight and cost.

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