# Investgative Study on Rocker Arm With Aluminum Alloy

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***Abstract-*** *A* ***rocker arm*** *is an oscillating lever that conveys radial movement from the cam lobe into linear movement at the poppet valve to open it. One end is raised and lowered by a rotating lobe of the camshaft (either directly or via a tappet (lifter) and pushrod) while the other end acts on the valve stem. When the camshaft lobe raises the outside of the arm, the inside presses down on the valve stem, opening the valve. When the outside of the arm is permitted to return due to the camshafts rotation, the inside rises, allowing the valve spring to close the valve.*

*The rocker arm is used to actuate the inlet and exhaust valves motion as directed by the cam and follower. It may be made of cast iron, cast steel, or malleable iron. In order to reduce inertia of the rocker arm, an I-section is used for the high speed engines and it may be rectangular section for low speed engines. In four stroke engines, the rocker arms for the exhaust valve are the most heavily loaded. Though the force required to operate the inlet valve is relatively small, yet it is usual practice to make the rocker arm for the inlet valve of the same dimensions as that for exhaust valve.*

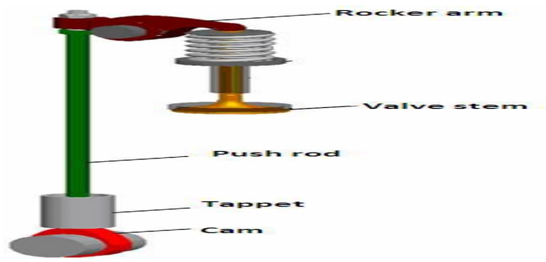
## I. INTRODUCTION

A rocker arm is a valve train component in internal combustion engines. As a rocker arm is acted on by a camshaft lobe, it pushes open either an intake or exhaust valve (Yu and Xu, 2006; and Chin-Sung and Ho-Kyung, 2010). 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 (Yu and Xu, 2006; and Dong-Woo *et al.*, 2005 and 2008).

## WORKING

The rocker arm is an oscillating lever that conveys radial movement from the cam lobe into linear movement at the poppet valve to open it. One end is raised and lowered by a rotating lobe of the camshaft (either directly or via a tappet (lifter) and pushrod) while the other end acts on the valve stem. When the camshaft lobe raises the outside of the arm, the inside presses down on the valve stem, opening the valve. When the outside of the arm is permitted to return due to the camshafts rotation, the inside rises, allowing the valve spring to close the valve (Chin-Sung and Ho-Kyung, 2010). The drive cam is driven by the camshaft. This pushes the rocker arm up and down about the 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 following figure (Figure 2) shows the rocker arm in valve train mechanism with cam at one end and valve stem at the other end of rocker arm.




## TYPES OF ROCKER ARM

Rocker arms are of various types, there design and specifications are different for different types of vehicles (bikes, cars trucks, etc). Even for same type of vehicle category rocker arms differs in some way. Types of rocker arm also depend upon which type of Internal-combustion engine is used in a vehicle (i.e. Push Rod Engines, Over Head Cam Engines, etc).

***A. Stamped Steel Rocker Arm-*** The Stamped Steel Rocker Arm is probably the most common style of production Rocker Arm. They are the easiest and cheapest to manufacture because they are stamped from one piece of metal. They use a turn-on pivot that holds the rocker in position with a nut that has a rounded bottom. This is a very simple way of holding the rocker in place while allowing it to pivot up and down.

***B. Roller Tipped Rocker Arm-*** The Roller Tipped Rocker Arm is just as it sounds. They are similar to the Stamped Steel Rocker and add a roller on the tip of the valve end of the rocker arm. This allows for less friction, for somewhat more power, and reduced wear on the valve tip. The Roller Tipped Rocker Arm still uses the turn-on pivot nut and stud for simplicity. They can also be cast or machined steel or aluminum.

***C. Full Roller Rocker Arm-*** The Full Roller Rocker Arm is not a stamped steel rocker. They are either machined steel or aluminum. They replace the turn-on pivot with bearings. They still use the stud from the turn-on pivot but they don't use the nut. They have a very short shaft with bearings on each end (inside the rocker) and the shaft is bolted securely in place and the bearings allow the rocker to pivot.

***D. Shaft Rocker Arms-*** The Shaft Rocker Arms build off of the Full Roller Rocker Arms. They have a shaft that goes through the rocker arms. Sometimes the shaft only goes through 2 rocker arms and sometimes the shaft will go through all of the rocker arms depending on how the head was manufactured. The reason for using a shaft is for rigidity. Putting a shaft through the rocker arms is much more rigid than just using a stud from the head. The more rigid the valve train, the less the valve train deflection and the less chance for uncontrolled valve train motion at higher RPM.

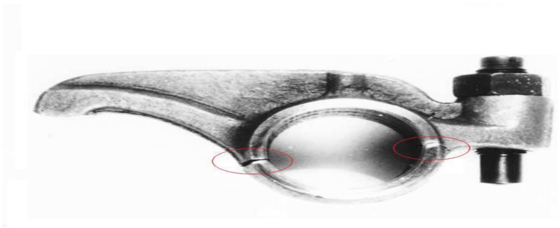
***E. Centre Pivot Rocker Arms-*** The Centre Pivot Rocker Arm looks like a traditional rocker arm but there is a big difference. Instead of the pushrod pushing up on the lifter, the Cam Shaft is moved into the head and the Cam Shaft pushes directly up on the lifter to force the valve down. In this case the pivot point is in the centre of the rocker arm and the Cam Shaft is on one end of the rocker arm instead of the pushrod.

***F. End Pivot (Finger Follower) Rocker Arms-*** The End Pivot or Finger Follower puts the pivot point at the end of the Rocker Arm. In order for the Cam Shaft to push down on the Rocker Arm is must be located in the middle of the rocker arm.

**1.4 FAILURE OF ROCKER ARM**

Failure of rocker arm is a measure concern as it is one of the important components of push rod IC engines. Failure usual occurs at due to fracture at the hole or neck of the rocker arm. Various other factors are also mentioned below.

***1. The fracture occurred at the hole of the rocker arm-*** The fracture occurred at the hole of the rocker arm. Multiple origin fatigue is the dominant failure mechanism. The spheroidization of commentate in pearlier makes the hardness of the material of the failed rocker arms decrease to result in lower fatigue strength. Initiation and growth of the cracks was facilitated by a microstructure of low fatigue strength.The fracture of rocker arm at the hole is shown in fig.



***2. The fracture occurred at the neck of the rocker arm-*** The ultimate tensile strength (UTS) and elongation of the rocker arm material were 164.0 MPa and 2.5%, respectively. This UTS value is slightly lower than that of normal die-cast Al alloys. In the stress measurement test, the compressive stress exhibits the maximum value at the idling state and decreases as the engine speed increases. The maximum experimental stress at the neck was _21.0 MPa at the engine idle speed. Hence, this rocker arm is deemed to be safe in terms of fatigue fracture, taking into consideration the fatigue endurance limit of 58.8 MPa. The safety factors of this component are 2.6 and 3.8 based on the fatigue endurance limit and the modified fatigue endurance limit, respectively, suggesting that this S.F is appropriate. However, gas porosities introduced during the die-casting process provide sites of weakness at which premature fatigue crack initiation andfinally fatigue fracture of this rocker arm can occur. Therefore, it is necessary to control the melt quality during the die-casting.process in order to secure the safety of this type of rocker arm due to stresses acting on it.

***3. Failure of the rocker arm shaft is caused by the bending load-*** FEA results for the failure boundary condition obtained from orthogonal array indicated that the maximum and minimum stresses were 711 MPa and 161 MPa, respectively. The stress range $\Delta\sigma$ was 550 MPa. The stress range $\Delta\sigma$ obtained from the relationship between striation spacing and the range of the stress intensity factor was 592.42 MPa. The failure boundary condition estimated by using an orthogonal array and ANOVA was very useful because the relative error between the stress ranges obtained from striation and the stress ranges from FEA fell within 7%. Thus this result indicates Failure of the rocker arm shaft is caused by the bending load.

***4. Wear of rocker arm pads-*** The superior wear resistance of silicon nitride pads for LPG taxi engines and it was found, that excessive calcium and phosphorus adsorptions on contact surfaces lubricated with diesel engine grade oil contained primary type zinc dialkyldithiophosphate and large amounts of calcium detergent. The excessive adsorption of some additives caused the micro-pits observed on the cam noses following every test conducted with that grade of oil. It is thought that the pits were formed by acid corrosion following mechanochemical reactions.

***5. Fatigue failure of rocker arm shaft-*** Fatigue crack in rocker arm shaft for passenger car was initiated at through hole and subsequently propagated along its sidewall. If rocker arm shaft is operated under actual failure boundary condition, number of cycles to fracture is expected to be less than 129,650 cycles. The maximum stress measured in failure region under the most dangerous failure boundary condition of rocker arm shaft between each loading condition is 221.2 MPa, which exceeds fatigue limit of 206 MPa and hence rocker arm shaft with this boundary condition has finite fatigue life

.

***6. Carbon builds up at the end of valve stem-*** Due to carbon build up at the end of valve stem. Valve guide wear occurs on the inside diameter of the valve guide in a straight line with the centre line of the rocker arm.

***7. Failure due to friction-*** The continuous interaction with the valve stem and push rod cause friction as they are touching each other this result in cheap formation.

## II. METALS AND ALLOYS

**METALS:**

A metal is a material that is typically hard, opaque, shiny, and has good electrical and thermal conductivity. Metals are generally malleable that is, they can be hammered or pressed permanently out of shape without breaking or cracking as well as fusible and ductile. Metals in general have high electrical conductivity, high thermal conductivity and high density.Mechanical properties of metals include ductility, i.e. their capacity for plastic deformation. Reversible elastic deformation in metals can be described by Hooke's Law for restoring forces, where the stress is linearly proportional to the strain. Forces larger than the elastic limit, or heat, may cause a permanent (irreversible) deformation of the object, known as plastic deformation or plasticity.

This irreversible change in atomic arrangement may occur as a result of:

- The action of an applied force (or work). An applied force may be tensile (pulling) force, compressive (pushing) force, shear, bending or torsion (twisting) forces.
- A change in temperature (heat). A temperature change may affect the mobility of the structural defects such as grain boundaries, point vacancies, line and screw dislocations, stacking faults and twins in both crystalline and non-crystalline solids. The movement or displacement of such mobile defects is thermally activated, and thus limited by the rate of atomic diffusion.

**ALLOYS:**

An alloy is a mixture of two or more elements in which the main component is a metal. Most pure metals are either too soft, brittle or chemically reactive for practical use. Combining different ratios of metals as alloys modifies the properties of pure metals to produce desirable characteristics. The aim of making alloys is generally to make them less brittle, harder, resistant to corrosion, or have a more desirable color and luster of all the metallic alloys in use today, the alloys of ironmake up the largest proportion both by quantity and commercial value. Iron alloyed with various proportions of carbon gives low, mid and high carbon steels, with increasing carbon levels reducing ductility and toughness. The addition of silicon will produce cast irons, while the addition of chromium, nickel and molybdenumto carbon steels results in stainless steels.other significant metallic alloys are those of aluminium, titanium, copper and magnesium. Copper alloys have been known since prehistory bronze gave the Bronze Age its name and have many applications today, most importantly in electrical wiring. The alloys of the other three metals have been developed relatively recently; due to their chemical reactivity they require electrolytic extraction processes. The alloys of aluminium, titanium and magnesium are valued for their high strength-to-weight ratios; magnesium can also provide electromagnetic shielding. These materials are ideal for situations where high strength toweight ratio is more important than material cost, such as in aerospace and some automotive applications.Alloys specially designed for highly demanding applications, such as jet engines, may contain more than ten elements.

**3.3 Ferrous metals and alloys:**

Ferrous metals and alloys can be divided into iron, and iron alloys and materials.

**Iron:**

Iron is a soft, silvery metal that is the fourth most abundant element in the Earth's crust. Pure iron is unobtainable by smelting, but small amounts of impurities can make iron many times stronger than it exists in its pure form. Iron oxide compounds, when mixed with aluminum powder, are used to create thermite reactions for welding and purification processes. Many lightweight and high strength alloys, and bearing configurations for the fulcrum, have been used in an effort to increase the RPM limits for high performance applications, eventually lending the benefits of these race bred technologies to more high-end production vehicle

**Iron Alloys and Materials:**

There are a number of different types of alloys containing iron. Some of the most important include carbon steels, alloy steels, stainless steels, tool steels, cast iron, and managing steel.

- **Carbon steels** are steels in which the main alloying additive is carbon. Mild steel is the most common due to its low cost. It is neither brittle nor ductile, has relatively low tensile strength, and is malleable. Surface hardness can be increased through carburizing. High carbon steels have a higher carbon content which provides a much higher strength at the cost of ductility.
- **Alloy steels** are steels (iron and carbon) alloyed with other metals to improve properties. The most common metals in low alloyed steels are molybdenum, chromium, and nickel to improve weld ability, formability, wear resistance, and corrosion resistance.
- **Stainless steels** are steels that contain a minimum of 10% chromium. There are many grades of stainless steel, but the most common grade used for typical corrosion resistant applications is type 304, also known as 18-8. The term 18-8 refers to the amount of chromium (18%) and nickel (8%) combined with iron and other elements in smaller quantities. The metal's finish is depicted by a number, 3 to 8, with 3 being the roughest and 8 being a mirror-like finish. Other specifications to consider include textures and coatings.
- **Tool steels** are particular steels designed for being made into tools. They are known for toughness, resistance to abrasion, ability to hold a cutting edge, and/or their resistance to deformation at high temperatures. The three types of tool steel available are cold work steels used in lower operating temperature environments, hot work steels used at

elevated temperatures, and high speed steels able to withstand even higher temperatures giving them the ability to cut at higher speeds.

- **Cast iron** is an iron alloy derived from pig iron, alloyed with carbon and silicon. Carbon is added to the base melt in amounts that exceed the solubility limits in iron and precipitates out as graphite particles. Silicon is added to the melt to nucleate the graphite which optimizes the properties of cast iron. Often dismissed as a cheap, dirty, brittle metal; cast iron is getting much more attention and use today because of its machinability, light weight, strength, wear resistance, and damping properties.
- **Merging steels** are carbon free iron-nickel alloys with additions of cobalt, molybdenum, titanium, and aluminum. The term managing is derived from the strengthening mechanism, which is transforming the alloy to marten site with subsequent age hardening. With yield strengths between 1400 and 2400 MPa, merging steels belong to the category of ultra-high-strength materials. The high strength is combined with excellent toughness properties and weld ability.

**Materials usage:**

Camshafts can be made out of several different types of material. The materials used for the camshaft depends on the quality and type of engine being manufactured.

**Existing Material:**

**Chilled iron castings:**

This is a good choice for high volume production. A chilled iron camshaft has a resistance against wear because the camshaft lobes have been chilled, generally making them harder. When making chilled iron castings, other elements are added to the iron before casting to make the material more suitable for its application.

Chills can be made of many materials, including iron, copper, bronze, aluminum, graphite, and silicon carbide. Other sand materials with higher densities, thermal conductivity or thermal capacity can also be used as a chill. For example, chromate sand or zircon sand can be used when molding with silica sand.

**Manufacturing method of rocker arm:**

1. A method of manufacturing a rocker arm for opening and closing a valve, the method comprising: providing a metallic sheet; bending the metallic sheet to form a pair of predetermined side wall regions and a predetermined connecting wall region for connecting the pair of predetermined side wall regions; first pressing a portion of outer sides of the pair of predetermined side wall regions in a connecting direction in which the predetermined connecting wall region extends, respectively, to plastically flow so that a height of the pair of predetermined side wall regions is gradually increased; second pressing the predetermined connecting wall region so as to be recessed in a height direction perpendicular to the connecting direction; and alternately repeating the first pressing and the second pressing a plurality of times, whereby portions of the pair of predetermined side wall regions are made to be a pair of valve guide walls of a valve engaging portion which extends in the height direction, in which the predetermined connecting wall region is made to be a connecting wall of the valve engaging portion, which connects the pair of valve guide walls with each other at an intermediate portion of the pair of valve guide walls in the height direction, wherein a metal flow continues between the pair of valve guide walls, including distal ends, of the pair.
2. The method of manufacturing a rocker arm according to claim 1, wherein providing said metallic sheet comprises punching said metallic sheet to form a predetermined shape having.
3. The method of manufacturing a rocker arm according to claim 1, wherein prior to bending said metallic sheet, said metallic sheet is punched to form an opening in the center of said metallisheet.
4. The method of manufacturing a rocker arm according to claim 1, further comprising: drawing a central region of a second connecting wall that is disposed on an end of the rocker arm opposite to said predetermined connecting wall region, to form a hemispherical pivot receivingportion.
5. The method of manufacturing a rocker arm according to claim 1, further comprising: softening annealing the rocker arm after first pressing outer sides of the pair of predetermined.
6. The method of manufacturing a rocker arm according to claim 1, wherein said outer sides of said pair of predetermined side wall regions are pressed using a first die.
7. The method of manufacturing a rocker arm according to claim 6, wherein said predetermined connecting wall is pressed using a second die.
8. The method of manufacturing a rocker arm according to claim 7, wherein during the pressing of said predetermined connecting wall region by the second die, the predetermined side wall regions are made to

plastically flow such that a height of the side wall regions increases.

9. The method of manufacturing a rocker arm according to claim 6, wherein the first die is set so a first portion of the outer sides of the predetermined side wall regions are held, and a second portion of the outer sides of the predetermined side wall regions are pressed toward a center of the rocker arm such that a thickness of the connecting wall regions is increased.
10. The method of manufacturing a rocker arm according to claim 1, further comprising: forming a curvature in the surface of said predetermined connecting wall region using a pressingpunch.
11. The method of manufacturing a rocker arm according to claim
12. A method of manufacturing according to claim 1, wherein said portion of outer sides of the pair of predetermined side wall regions comprises an upper portion.
13. A method of manufacturing according to claim 1, wherein said portion of outer sides of the pair of predetermined side wall regions comprises a vicinity of a variation point of metal flow from the predetermined connecting wall regions to the predetermined side wall regions.
14. A method of manufacturing a rocker arm for opening and closing a valve, the method comprising: providing a metallic sheet having a pair of predetermined side wall regions and a predetermined connecting wall region for connecting the pair of predetermined side wall regions; first pressing a portion of outer sides of the pair of predetermined side wall regions in a connecting direction in which the predetermined connecting wall region extends, respectively, to plastically flow so that a height of the pair of predetermined side wall regions is gradually increased; second pressing the predetermined connecting wall region so as to be recessed in a height direction perpendicular to the connecting direction; and alternately repeating the first pressing and the second pressing a plurality of times, whereby portions of the pair of predetermined side wall regions are made to be a pair of valve guide walls of a valve engaging portion which extends in the height direction, in which the predetermined connecting wall region is made to be a connecting wall of the valve engaging portion, which connects the pair of valve guide walls with each other at an intermediate portion of the pair of valve guide walls in the height direction, wherein a metal flow continues between the pair of valve guide walls, including distal ends, of the pair of valve guide walls and the connecting wall.
15. A method of manufacturing according to claim 14, wherein a metal flow continues between the valve guide walls including distal ends thereof and the connecting wall.
16. A method of manufacturing according to claim 16, wherein said alternately repeating is performed so as to adjust pressing forces for a predetermined gradual deformation of said
17. A method of manufacturing according to claim 14, wherein said portion of outer sides of the pair of predetermined side wall regions comprises an upper portion.
18. A method of manufacturing according to claim 14, wherein said portion of outer sides of the pair of predetermined side wall regions comprises a vicinity of a variation point of metal flow from the predetermined connecting wall regions to the predetermined side wall regions.

**Implemented Material:**

Alloy Steel

**Alloy Steel**

Alloy steels are steels containing elements such as chromium, cobalt, nickel, etc. Alloy steels comprise a wide range of steels having compositions that exceed the limitations of Si, Va, Cr, Ni, Mo, Mn, B and C allocated for carbon steels.

**MATERIAL PROPERTIES:**

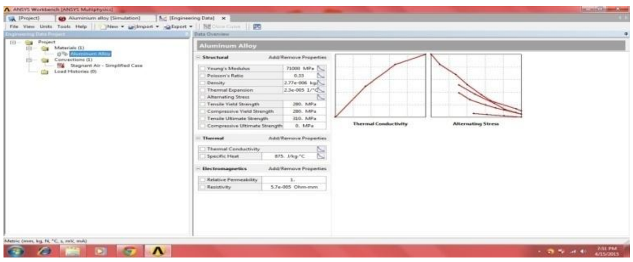


Fig Aluminum alloy Material Properties

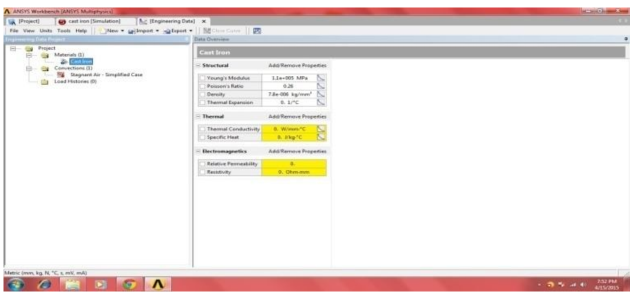


Fig: Cast iron Material Properties

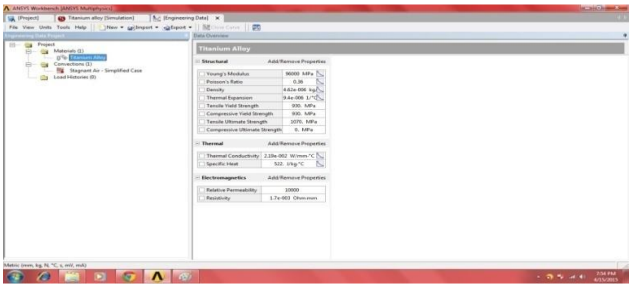


Fig: Titanium alloy Material Properties

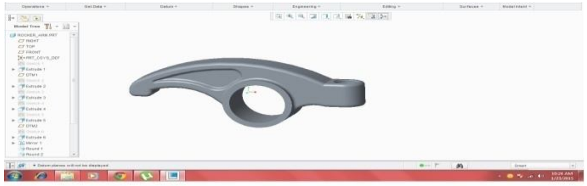
## III. INTRODUCTION TO SOFTWARES COMPUTER AIDED DESIGN (CAD)

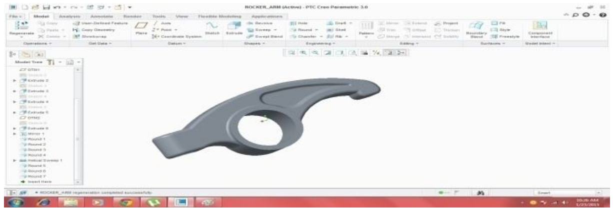
Computer Aided Design (CAD) is the use of wide range of computer based tools that assist engineering, architects and other design professionals in their design activities. It is the main geometry authoring tool within the product life cycle management process and involves both software and sometimes special purpose hardware. Current packages range from 2D vector based drafting systems to 3D parametric surface and solid design modelles.

### INTRODUCTION TO PRO/E:

***PRO/E*** is the industry's de facto standard 3D mechanical design suit. It is the world's leading **CAD/CAM /CAE** software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed to its technology which spurs its customer's to more quickly and consistently innovate a new robust, parametric, feature based model. Because that ***PRO/E*** is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains.***PRO/E*** is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. ***PRO/E*** provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly. Electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly solid and surface modeling can be done easily.

### MODEL PREPARED





### INTRODUCTION TO ANALYSIS

The finite element method is numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in almost every industry. In more and more engineering situations today, we find that it is necessary to obtain approximate solutions to problem rather than exact closed form solution. It is not possible to obtain analytical mathematical solutions for many engineering problems. The finite element method has become a powerful tool for the numerical solutions of a wide range of engineering problems. It has been developed simultaneously with the increasing use of the high- speed electronic digital computers and with the growing emphasis on numerical methods for engineering analysis. This method started as a generalization of the structural idea to some problems of elastic continuum problem, started in terms of different equations.

### PROCEDURE:

**Importing the Model:**

In this step the PRO/E model is to be imported into ANSYS workbench as follows:

In utility menu file option and selecting import external geometry and open file and click on generate. To enter into simulation module click on project tab and click on new simulation

**Defining Material Properties:**

To define material properties for the analysis, following steps are used. The main menu is chosen select model and click on corresponding bodies in tree and then create new material enter the values again select simulation tab and select material

**Defining Element Type:**

To define type of element for the analysis, these steps are to be followed:

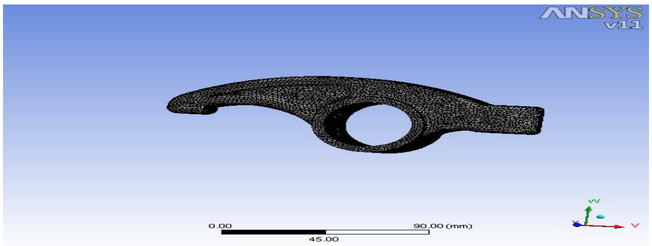
Chose the main menu select type of contacts and then click on mesh-right click-insert method

Method - Tetrahedrons
Algorithm - Patch Conforming
Element Mid side Nodes – Kept

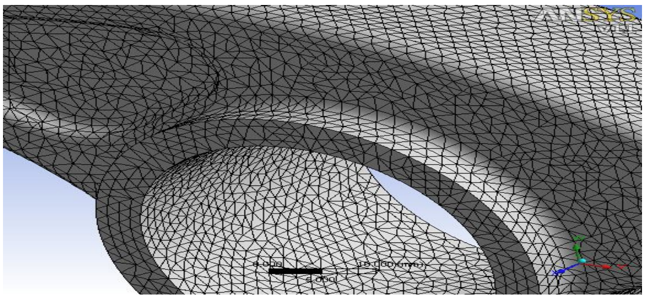
**Meshing the model**

To perform the meshing of the model these steps are to be followed:

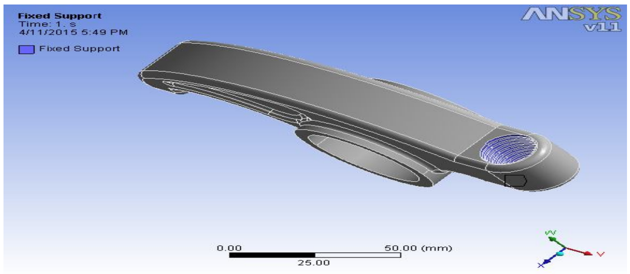
Chose the main menu click on mesh- right click- insert sizing and then select geometry enter element size and click on edge behavior curvy proximity refinement and then right click generate mesh.



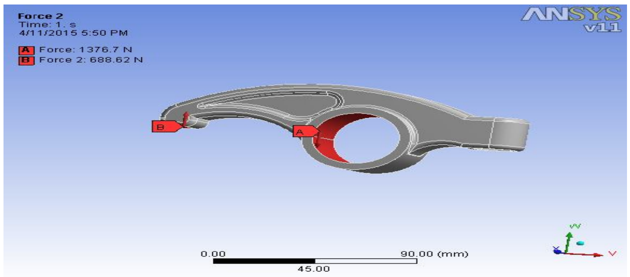

mesh generation



Meshing preview

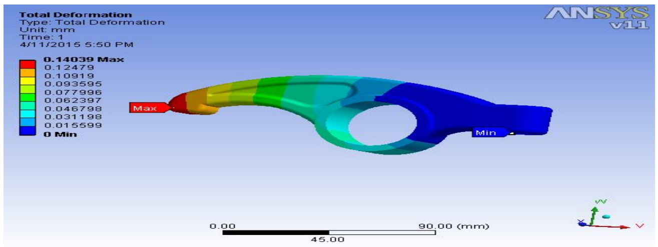



Fixed supports

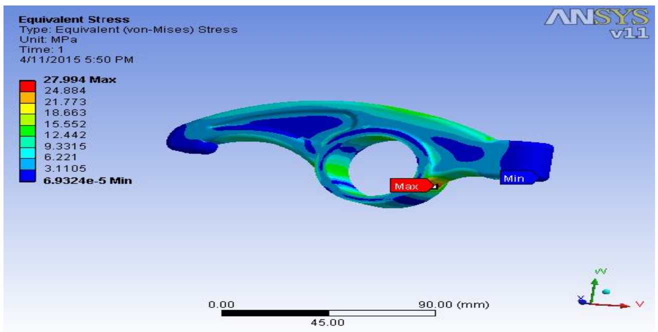



Force application

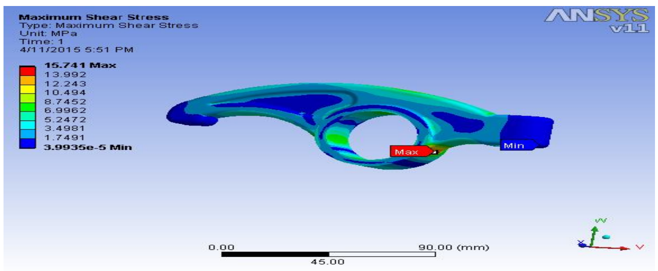
**ALUMINUM ALLOY RESULTS:**




Total deformation

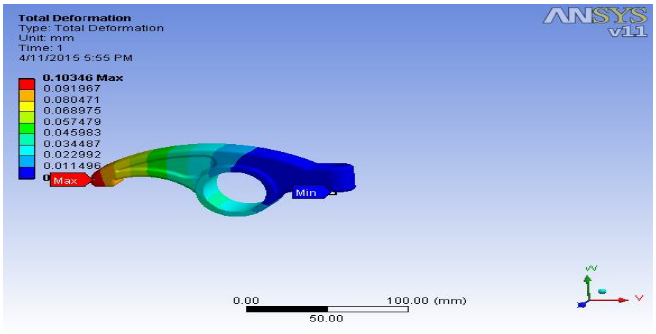



Equivalent Stress

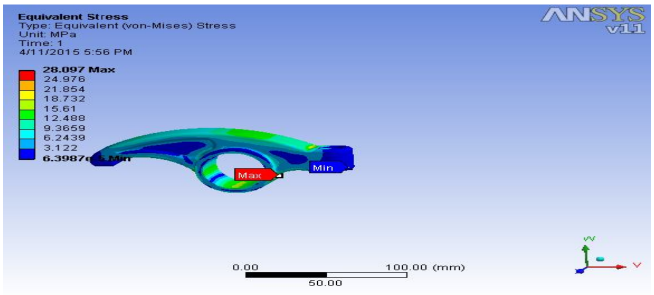



Maximum Shear stress

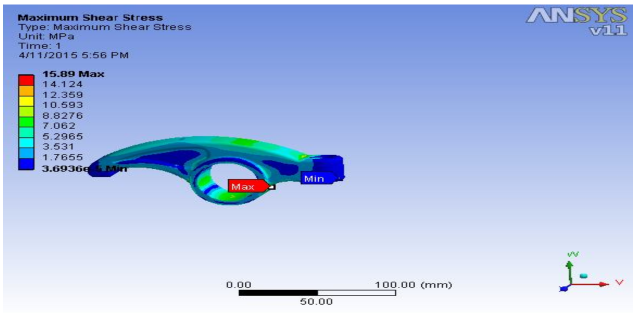
## TITANIUM ALLOY RESULTS:




Total deformation

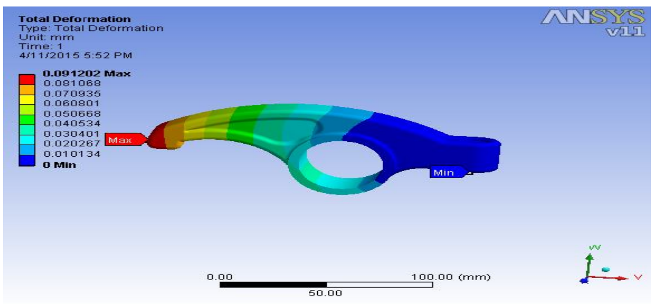



Equivalent Stress

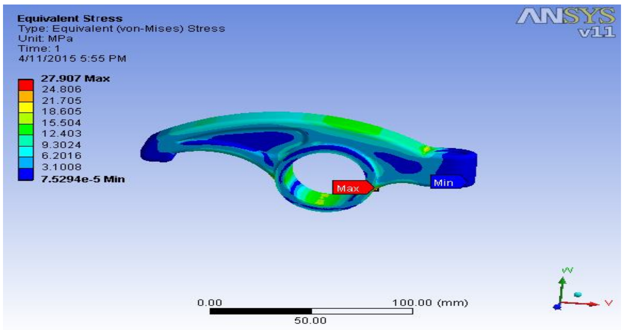



Maximum Shear stress

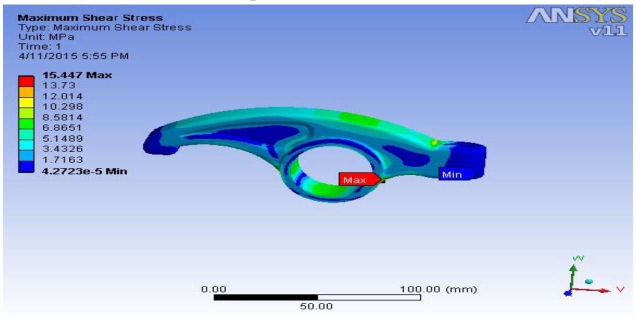
## CAST IRON RESULTS:




Total deformation




Equivalent Stress

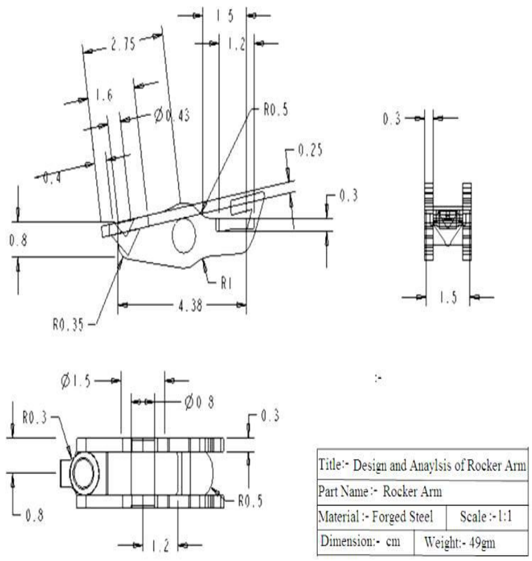



Maximum Shear stress

## METHODOLOGY

Let,
*mv* = Mass of the valve,
*dv* = Diameter of the valve head,

## ROCKER ARM DESIGN SPECIFICATION




*a* = Acceleration of the valve,
*Pc* = Cylinder pressure or back pressure,
*Ps* = Maximum suction pressure,

$d1$ = is diameter of fulcrum pin,
$D1$ = is diameter of boss,
$l$ = Length of arm
We have,
$mv$ =.09 kg
$dv$ = 40 mm
$h$ =13 mm
$r$ = 13/2
$Pc$ = 0.4 N/mm2
$Ps$ = 0.02 N/mm2
$d1$ = 8 mm
$D1$ = 18 mm
Speed of engine = 3000 RPM
Angle of action of cam = 110°

**CALCULATING FORCES ACTING**

We know that gas load on the valve,

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

Weight of associated parts with the valve,

$w = m \cdot g$
= 0.09 x 9.8
$w$ = 0.882 N

Total load on the valve,

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

Initial spring force considering weight of the valve,

$Fs$ = □/4 ($dv$)2 $Ps$ – $w$
= □/4 x (40)2 x 0.02 – 0.882
$Fs$ = 24.238 N

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.m
and 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
$t$ = 0.012 s

We know that maximum acceleration of the

valve $a$ = □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,

$Fa = m \cdot a + w$
= 0.09 × 1780.2 + 0.882
$Fa$ = 161.1 N

Now the maximum load on the rocker arm for exhaust valve,

$Fe = P + Fs + Fa$
= 503.282 + 24.238 + 161.1
$Fe$ = 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
$R$
$Rf$ = 1376.43 N
where,
$d1$ is diameter of fulcrum pin ($d1$ = 8 mm)
4
1272.4 2
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,

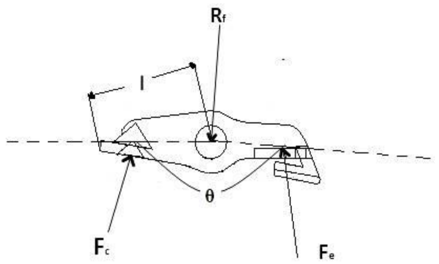
*M* =12387.96 N-mm
The rocker arm is of I-section
Section module *Z*,
Where *t* is thickness
*Z* = 332.91 mm3
Bending stress,

**FORCES ACTING ON ROCKER ARM**

**Calculating Stresses**

• Calculating shear stress at the pin

We have, load on




the fulcrum pin

*Rf*

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332.91
*M*12387.96 □
= 37.2 N/mm2
This bending stress is near to critical limit
(i.e., 40/mm2).

**THEORETICAL INVESTIGATIONS AND MODEL FORMULATION**

Short fiber composites = 10%
Volume fraction of S-Glass fibres has been considered with random distribution.
The chopped fibres are of 3-4 mm length and 25 micron diameter.
i.e ρc = ρf VF + ρm vm (1)
Where ρf = Density of fiber,
ρm = Density of matrix,
vf = Volume fraction of fiber,
vm = Volume fraction of matrix,
ρc = Density of composite.
Ec = 1/6 Φe Ef vf + (1-vf ) Em (2) Ef = Young's modulus of fibre,
Em = Young's modulus of matrix and Ec = Young's modulus of Composite and modulus reinforcing efficiency

Φe = 1-(tan hp)/p and p = 2(l/d)(Gm /Ef )1/2 (-1/lnvf )1/2 (3)
Where l/d = Aspect ratio and Gm = Modulus of rigidity of matrix The Poisson's ratio of the composite is given by
νc = νf vf + νm vm (4) νc = Poissons ratio of the composite,
νf = Poisson's ratio of fibre and νm = Poisson's ratio of matrix.
Further σc = σf vf + σm vm (5) σf = Strength of fibre,
σm = Strength of matrix and σc = Strength of composit

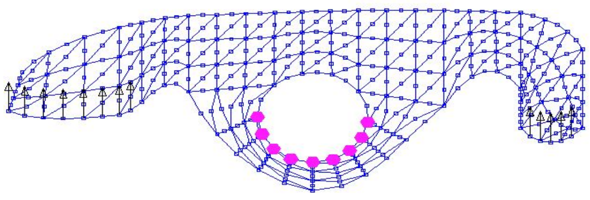
| Properties | Steel | S-Glass fibre | HDPE | Composite |
|---|---|---|---|---|
| Density ( kg/m3 ) | 7750 | 2500 | 941 | 1097 |
| Modulus of elasticity( GPa) | 200 | 87 | 1.24 | 2.242 |
| Tensile strength( MPa) | 410 | 4750 | 20 | 493 |
| Poissons ratio | 0.28 | 0.2 | 0.4 | 0.38 |

**MODEL FORMULATION:**

A general arrangement of the valve train assembly has been shown in Fig.2.for the fuel injection pump of the diesel engine. The 2D graphics of composite rocker arm has been developed by shadowgraph technique. The coordinates have been incorporated and key points along with grid lines have been developed using NISA (Ver 8.0/9.0, DISPLAY-III) finite element package. All total 79 key points and 42 lines have been generated to draw the near exact 2-D graphics of the rocker arm.

**DISCRETIZATION:**

The entire continuum has been discretized with the help of six nodded isoperimetric triangular elements of NISA finite element package. The discretized body along with boundary conditions has been shown below.



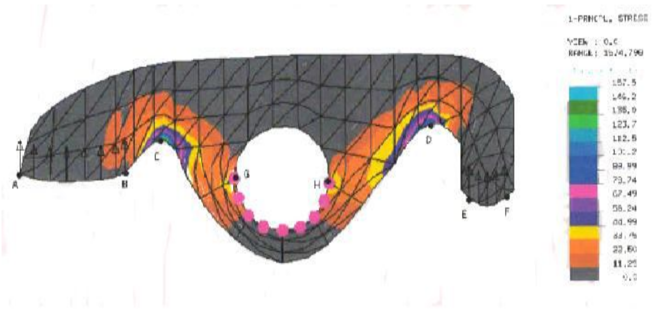
**Mesh with boundary conditions (177 Elements and 411 nodes)**

## LOAD AND BOUNDARY CONDITIONS:

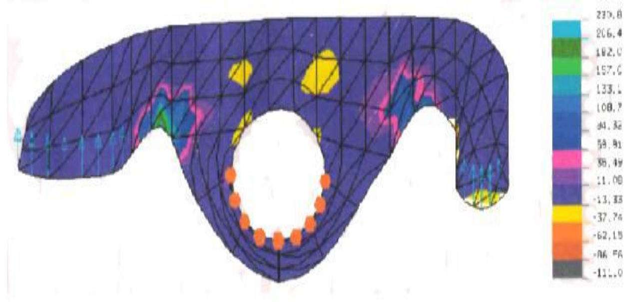
It has been observed from the general arrangement diagram (Fig.2) that at maximum pressure (Cam angle degrees) the maximum load on the rocker is 1275 N. This uniformly distributed load is to be distributed at both the ends (valve spring end and push rod end) in terms of point loads. Thus load on the valve spring end is distributed at five nodes and at eight nodes on the push rod end . After calculation, each node at the valve spring end is having 255 N and 165N at each node on the push rod side respectively. Since the rocker is rotating about the fulcrum 50% of the nodes (Nine numbers) at the inner side are fixed. The boundary conditions have also been shown in Fig.

## SOLUTION:

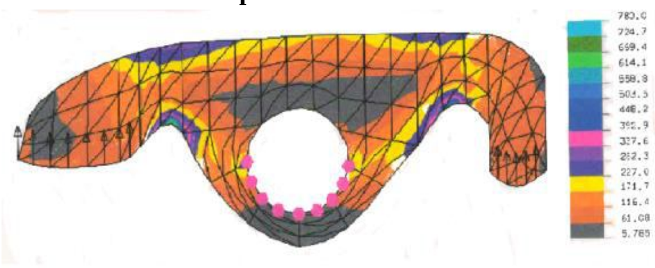
The force-displacement method of solution has been envisaged in this analysis considering the problem to be of plane stress type. The elemental solution has been found out along with stiffness matrix for each element as under $\{q_e\} = [k_e]\{a_e\}$ (6) Where $q_e$ = Nodal force vector, $k_e$ = Element stiffness and $a_e$ = Nodal displacements and $[k_e] = \iiint [B]^T [D] [B]\, dV$, (7) Where [B] = Strain displacement matrix and [D] = Elasticity matrix and dV is the element volume From the elemental solutions the nodal forces, displacements and nodal stresses are found out and finally the global solution is obtained as $\{Q\} = [K]\{\delta\}$ (8) Where {Q} = Global forces, [K] = Global stiffness and $\{\delta\}$ = Global displacements After obtaining the above results the strains and stresses have been found out along with the deformed shape of the structure. Thus the relation $\{\sigma\} = [D]\{\epsilon\}$ is established.



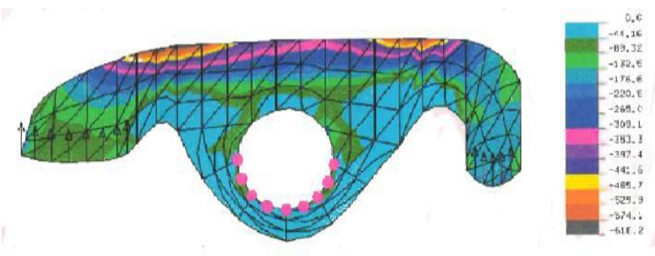
**Principal Stress distribution**



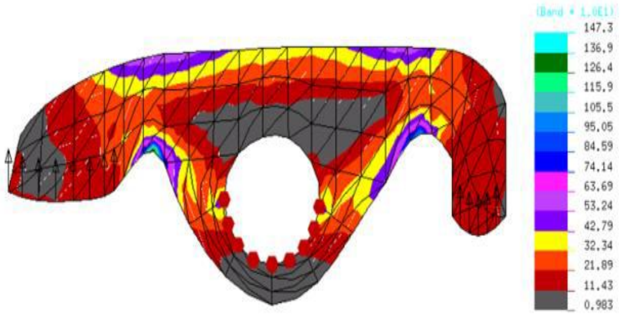
**Principal Stress distribution**



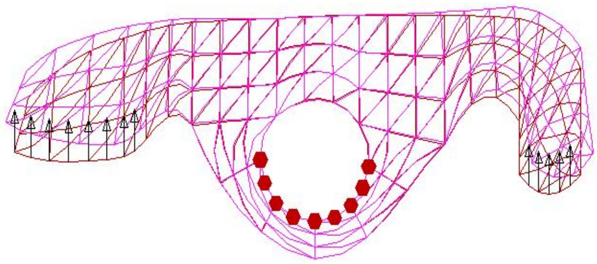
**Principal stress distribution**



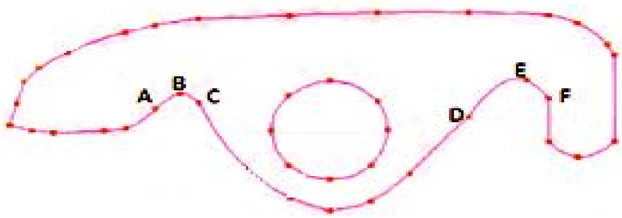
**Distribution of maximum shear stress**




**Distribution of equivalent stress**



The deformed shape of the rocker arm




**Locations of maximum stresses**

## IV. RESULT

| Material Name/Results | Aluminum Alloy | Titanium Alloy | Cast Iron |
|---|---|---|---|
| Total Deformation | 0.14039 | 0.103 | 0.0912 |
| Equivalent /stress | 27.994 | 28.097 | 27.907 |

The variation of Equivalent stresses (1, 2, 3 ) have been shown in Fig.. Similarly distribution of Total Deformation. It is observed from the results that maximum stresses are developed at sharp corners of the rocker arm. A comparison of stress values have been given for both Aluminum alloy, Titanium Alloy and Cast Iron rocker arms in Table. For such a loading system of the rocker arm it is seen that there is very less difference in the stress values between Aluminum alloy, Titanium Alloy and Cast Iron. The deformed shape has been depicted in Fig.9. The distribution of maximum shear stress and equivalent stress indicates the location of high value stresses at the nodes. The maximum value of equivalent stress obtained is around 27.994 Mpa.

According to the above table the preferable material of the Rocker Arm is **ALUMINUM ALLOY.**

## V. CONCLUSION

From the above studies it is observed that a light weight and reasonably high strength composite of **Aluminum Alloy** can be used as rocker arm. Even at rigorous loading conditions the composite rocker arm can withstand the load equivalent to that sustained by a steel rocker arm which is still in use. The maximum stress location as shown in Fig. indicates that may be after a prolonged period of use the rocker will fail at where sharp corners are existing. The highest Maximum equivalent stress is 27.994Mpa. From this it may be inferred that these values of stresses are well within the limits of calculated strength of the composite i.e. 280 MPa. Therefore the proposed material for rocker arm will not fail. A die for compression moulding of **Aluminum Alloy** composite has already been developed in house so that a composite rocker arm can be fabricated in future.

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