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Analysis and Optimization of Rocker ARM

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Abstract:
A rocker arm is a valve train component in internal combustion engines. As rocker arm is acted on by a camshaft lobe, it pushes and opens either the 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. Rocker arms were first invented in the 19th century and have been changed a little in function since then. Improvements have been made, however, in both efficiencies of operation and construction materials. About Rocker arm of Tata Sumo, vista. We will make the exact design of rocker arm of Tata sumo, vista in reverse engineering process. We analyze rocker arm by using composite materials. Over the years Rocker Arm have been optimized in its design and different materials (Cast iron, Aluminum Alloy and Titanium) for better performance. Durability, Toughness, high dimension, stability, wear resistance, strength, and cost of materials as well as economic factors are the reasons for optimization of Rocker Arm. The CAD models of Rocker Arm will be created using Pro/E and ANSYS software will be used for analysis of rocker arm. The CAD model will be inputted in ANSYS Workbench and Equivalent Stress and Maximum Shear Stress will be found. The obtained results provided by ANSYS Workbench are compared to the results obtained by manual calculation.

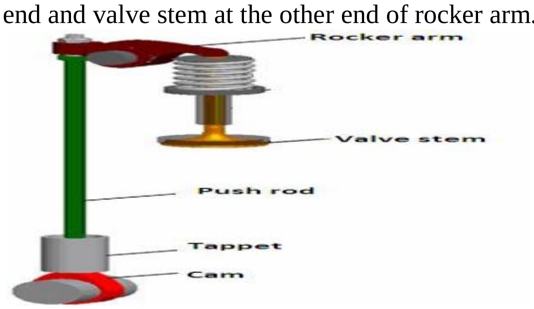
I. INTRODUCTION

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.

WORKING

The rocker arm (Figure 1) 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.



II. 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.

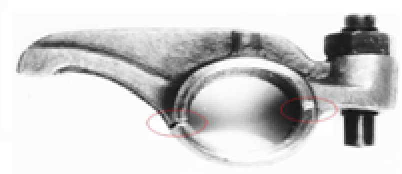
E. Centre Pivot Rocker Arms- The Centre Pivot Rocker Arm looks like a traditional rocker arm but there is a big difference. Instead of the pushrod pushing up on the lifter, the Cam Shaft is moved into the head and the Cam Shaft pushes directly up on the lifter to force the valve down. In this case the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

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 and Finally 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 Δσ was 550 MPa. The stress range Δσ 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.

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.

III. 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, and 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 receiving portion.
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 pressing punch.

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:

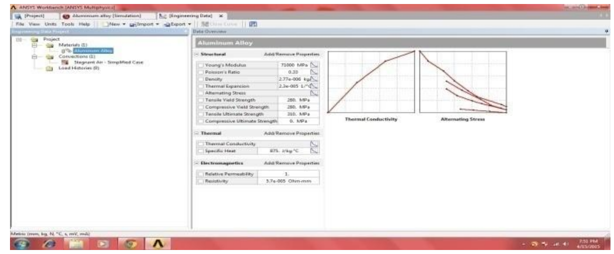


Figure.1. Aluminum alloy Material Properties

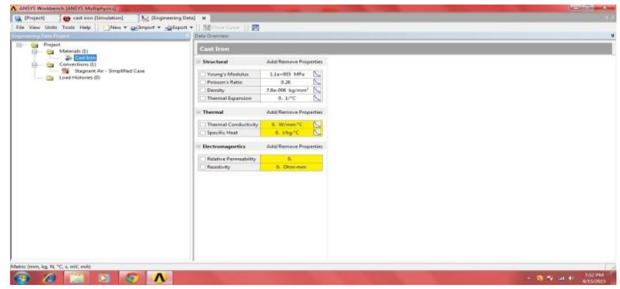


Figure.2. Cast iron Material Properties

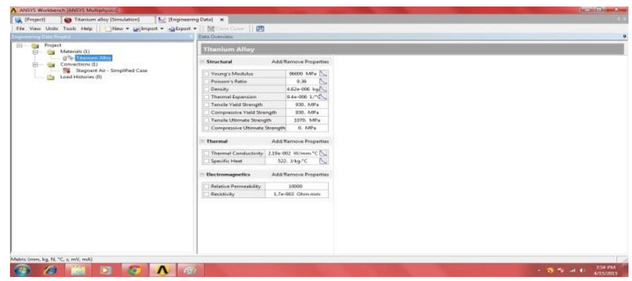
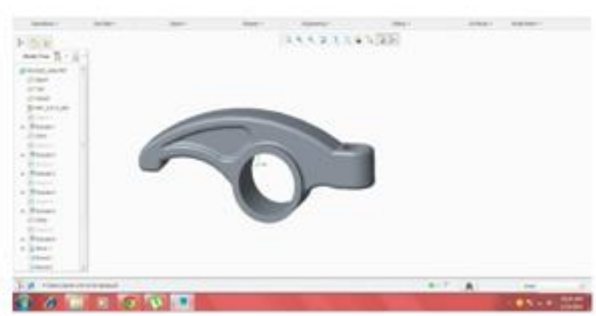
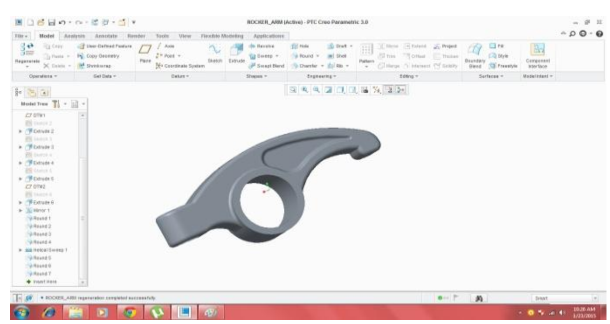


Figure.3. Titanium alloy Material Properties

MODEL PREPARED IN PRO / E





IV. ANALYSIS IN ANSYS (FEM/A) 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

5.13.4 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.

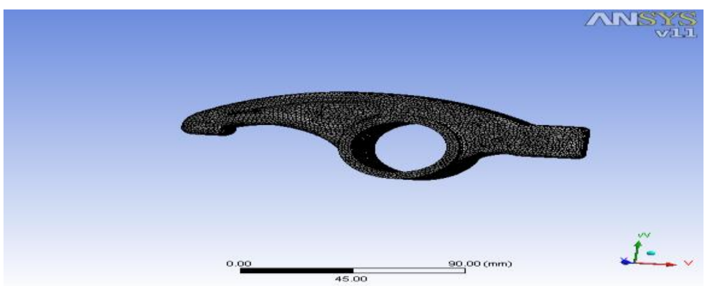


Figure.4. mesh generation

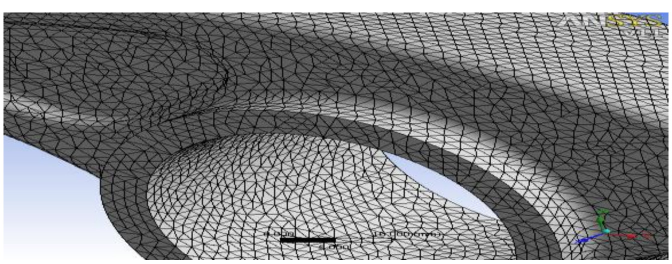


Figure.5. Meshing preview

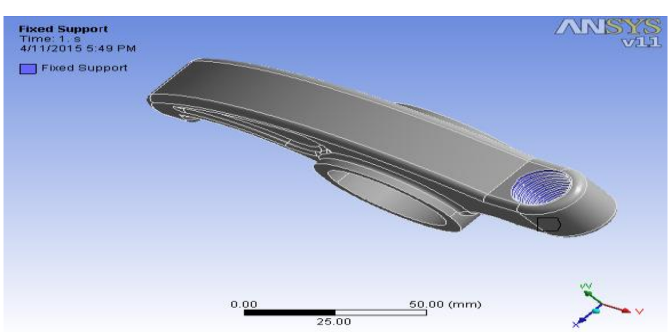


Figure.6. Fixed supports

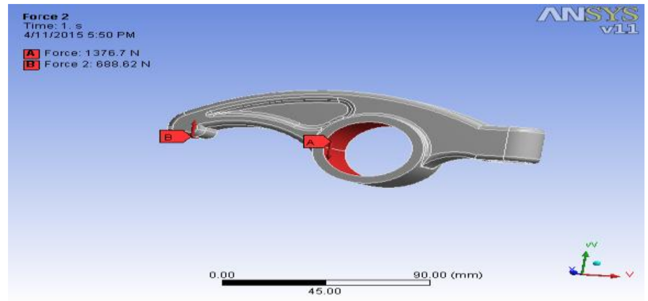


Figure.7. Force application

Aluminum alloy Results:

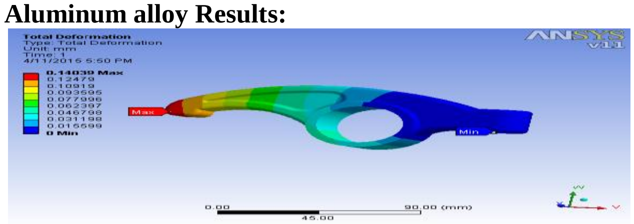


Figure.8. Total deformation

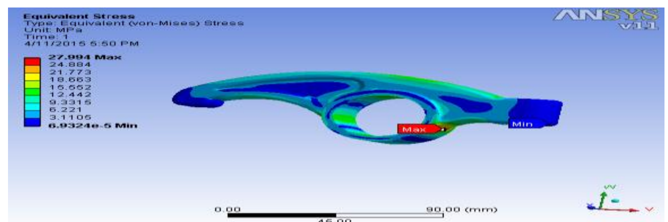


Figure.9. Equivalent Stress

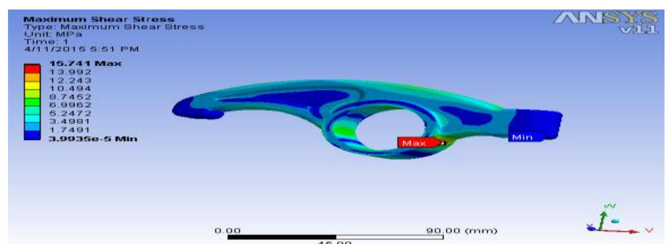


Figure.10. Maximum Shear stress

Titanium Alloy Results:

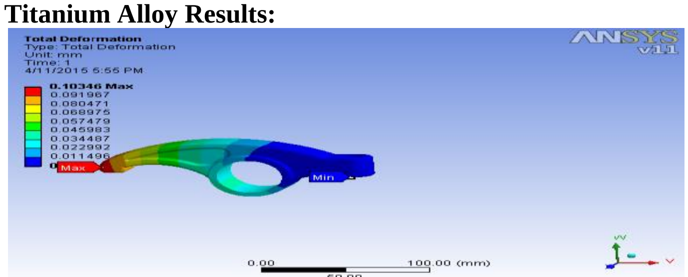


Figure.11. Total deformation

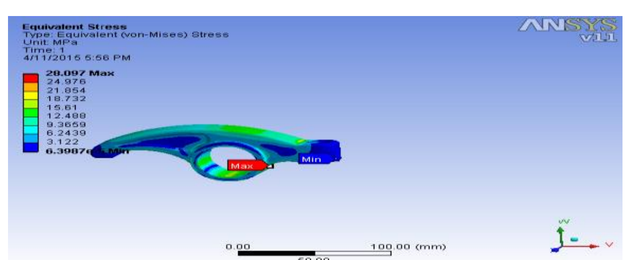


Figure.12. Equivalent Stress

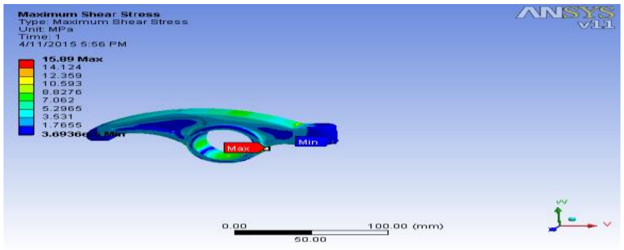


Figure.13. Maximum Shear stress

Cast Iron Results:

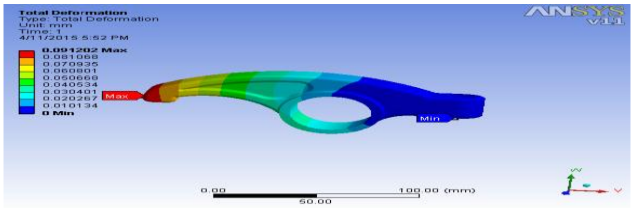


Figure.14. Total deformation

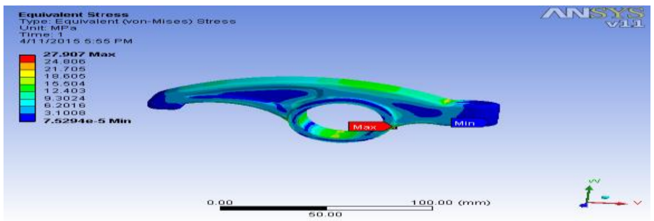


Figure.15. Equivalent Stress

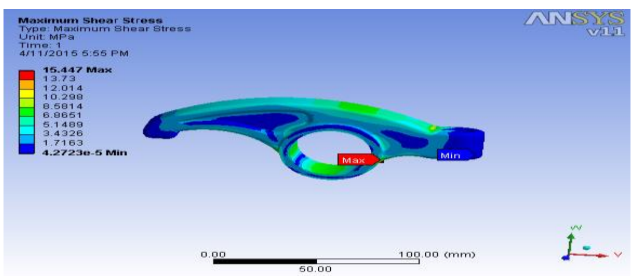
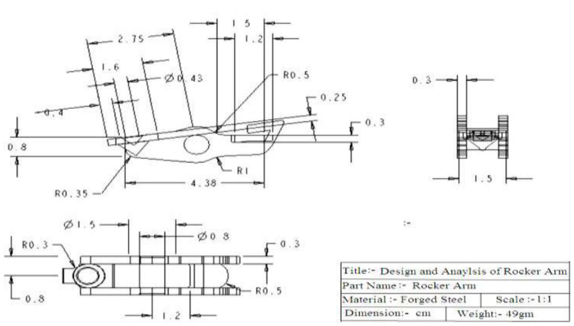


Figure.16. Maximum Shear stress

V. 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,
*d*1 = is diameter of fulcrum pin,
*D*1 = 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
*d*1 = 8 mm
*D*1 = 18 mm
Speed of engine = 3000 RPM
Angle of action of cam = 110°

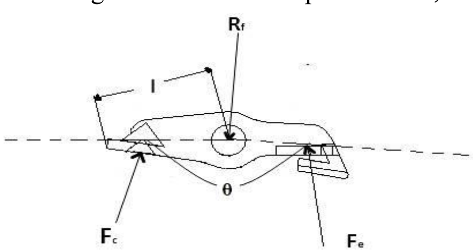
Calculating Forces Acting

We know that gas load on the valve,
*P*1 = /4(*dv*)2 *Pc*
= /4 x (40)2 x 0.4
*P*1 = 502.4
Weight of associated parts with the valve,
w = *m* · *g*
= 0.09 x 9.8
w = 0.882 N
Total load on the valve,
P = *P*1 + *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* · *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, loaded on



The fulcrum pin Rf

This article can be downloaded from http:// www.ijmerr. Com/currentissue.php

332.91
M12387.96 =
= 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	Composit e
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 discredited body along with boundary conditions has been shown in Fig.3.

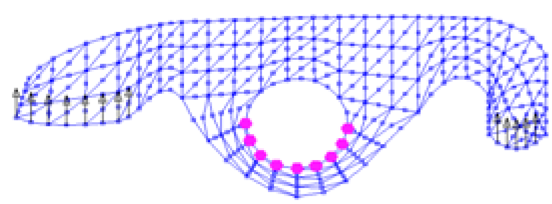


Figure.17. Mesh with boundary conditions (177 Elements and 411 nodes)

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.3.

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 $\{qe\} = [ke]\{ae\}$ (6) Where qe = Nodal force vector, ke = Element stiffness and ae = Nodal displacements and $[ke] = \iiint [B]^T [D] [B]\, dV$, (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.

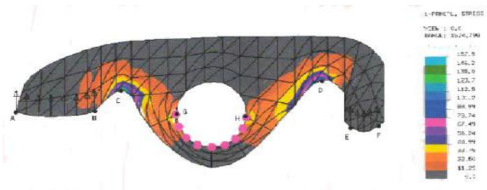


Figure.18. Principal Stress distribution

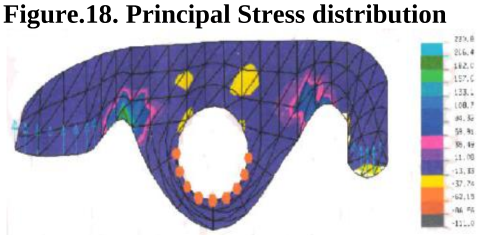


Figure.19. Principal Stress distribution

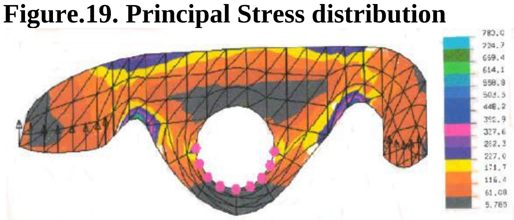


Figure.20. Principal Stress distribution

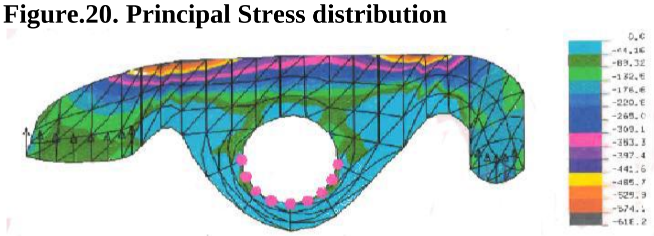


Figure.21. Distribution of maximum shear stress

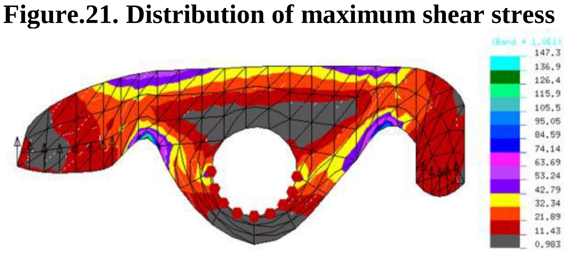


Figure.22. Distribution of equivalent stress

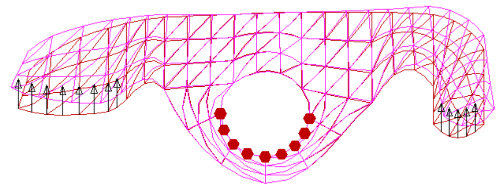


Figure.23.The deformed shape of the rocker arm

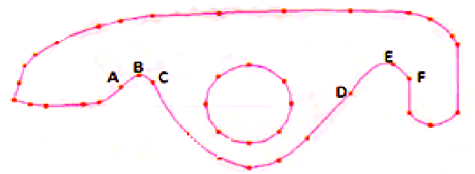


Figure.24. Locations of maximum stresses

VI. 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 has been given for 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.**

VII. 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 exist. 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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IX. NOMENCLATURE

X, Y,Z**:** Three linear axes
E: Young's modulus (N/mm^2)
μ: Poisson's ratio
Ɛ: Strain
Ϭ: Stress (N/mm^2)
τ: shear stress
ρ:Density (Kg/m^3)
D: Mean diameter of a coil
D: Diameter of wire
N: Total no of coils
Do: Outer diameter of spring coil
G: modulus of rigidity (Gpa)
Kg: Kilogram
Mpa: Mega pascal
FEM: Finite element method
FEA: Finite element analysis
CAD: Computer aided design
Mm: Millimeter
C: spring index
P: Pitch of coil
W: weight (Kg)
F: Frequency (HZ)