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Design and Analysis of Rocker ARM

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Abstract

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. 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.

In this paper we discussed about Rocker arm of Tata Sumo victa that was designed and analyzed to find the critical regions. CAD models of Rocker Arm were created using Pro/E and ANSYS workbench software was used for analysis of rocker arm. The CAD model was inputted in ANSYS Workbench and Equivalent Stress and Maximum Shear Stress was found. The obtained results provided by ANSYS Workbench are compared to the results.

And also checking results with different materials with existing material and applying same boundary conditions on it and then finally we can conclude which material is can be replace with existing material.

INTRODUCTION

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. Rocker arms were first invented in the 19th century and have changed little in function since then. Improvements have been made, however, in both efficiency of operation and construction materials. Many modern rocker arms are made from stamped steel, though some applications can make use of heavier duty materials. In many internal combustion engines, rotational motion is induced in the crank shaft as the pistons cause it to rotate. This rotation is translated to the camshaft via a belt or chain. In turn, lobes on the camshaft are used to push open the valves via rocker arms. This can be achieved either through direct contact between a camshaft lobe and rocker arm or indirectly though contact with a lifter driven pushrod. Overhead cam engines have lobes on the camshaft which contact each rocker arm directly, while overhead valve engines utilize lifters and pushrods. In overhead cam engines, the camshaft can be located in the head, while overhead valve engines have the camshaft in the block. Both varieties are seen in the US, but regulations have contributed to the decline of overhead valve applications elsewhere in the world. Throughout the history of the rocker arm, its function has been studied and improved upon. These Improvements have resulted in arms that are both more efficient and more resistant to wear. Some designs can actually use two rocker arms per valve, while others utilize a "rundle" roller bearing to depress the valve. These variations in design can result in rocker arms that look physically different from each other, though every arm still performs the same basic function.

A rocker arm (in the context of an internal combustion engine of automotive, marine, motorcycle and reciprocating aviation types) 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 drive cam is driven by the camshaft. This pushes the rocker arm up and down about the trun-ion pin or rocker shaft. Friction may be reduced at the point of contact with the valve stem by a roller tip. A similar arrangement transfers the motion via another roller tip 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.

Working of Rocker arm:

Rocker arm is an important part of the valve train in fuel injection system providing not only the means of actuating the valves through a fulcrum utilizing the lifter and the push rod but also provide a means of multiplying the lift ratio. Cam shaft design has advanced in leaps and bounds over last three decades but overhead valve engines with centrally located camshafts still use lifters and push rod and rocker arms as a means of opening and closing the intake and exhaust valves in fuel injection pumps. Advancement in materials used in construction of rocker arm for reducing the noise, weight and higher strength for efficient operation is going on throughout the globe since long. The usual materials used for such purpose are Steel, Aluminium, and Forged steel to Stainless steel, alloys and composites. The success to investigate the possibility creating a light weight rocker arm that could provide a friction reducing fulcrum using needle bearings and a roller tip for reduced friction between the rocker and the valve stem but still be less expensive than steel lies in the development of composite rocker arms. Lighter mass at the valve is also allowed for increased speed while strength of the material caters to durability. The rocker arm usually operates at 40-500 C and the maximum pressure is exerted by the gas. Therefore in this investigation it has been thought proper to analyze a composite rocker arm of high density polyethylene (HDPE) reinforced with short S-glass fibres of 10% volume fraction. Finite element analysis may be carried out to determine the stresses and make a comparison between steel and composite to predict the failure modes Since energy is required to move a rocker arm and depress a valve, their weight can be an important consideration. If a rocker arm is excessively heavy, it may require too much energy to move. This may prevent the engine from achieving the desired speed of rotation. The strength of the material can also be a consideration, as weak material may stress or wear too quickly. Many automotive applications make use of stamped steel for these reasons, as this material can provide a balance between weight and durability. Some applications, particularly diesel engines, may make use of heavier duty materials. Engines such as these can operate at higher torques and lower rotational speeds, allowing such materials as cast iron or forged carbon steel to be used.

Rocker Arm- Form & Function:

For all the changes in the performance engine over the years, one constant remains - no matter what series they're running, no matter what the payout, no matter if it's just a couple of guys trying to outdo each other stoplight to stoplight, racers will often spend money they don't have in search of the most horsepower from hopefully, a durable engine. Engine builders are faced with the challenge of answering that call. Luckily, advancements in the upper valve train components

mean there's a much broader list of components to choose from when it comes to designing the perfect engine; not only for racing - performance is apparent everywhere today, even at the standard production engine level. Rocker arms have come a long way since just opening valves with a pushrod. In modern automotive engines today, rocker arms serve double duty, Opening the valves, pushrods and lifter bore. Take the Chrysler Neon 2.0L SOHC engine, for example. The exhaust rocker arm is designed like a wishbone. 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 aluminium body with a metal hydraulic lifter bored inside the aluminium arm. The hydraulic lifter unit's clearance-to-bore is so minute that the inside has to be thermally debarred. Otherwise the lifter may not leak down properly. Contrast that with another popular engine, the Nissan KA24, which is found in Altimas,

240SX and pickups. That engine has a steel rocker arm with a sintered hardened pad that rides on the camshaft lobe with an encapsulated hydraulic lifter built inside on the other end to open the valve. Rocker arms simply aren't what they used to be. With lighter, stronger materials, as well as computer-aided design, modelling and manufacturing, it is easier and faster for rocker arm manufacturers to develop new parts in faster time, in an effort to keep up with the latest demands of their customers. As it turns out, keeping up with those changes can be a challenge, because racers tend to be a fickle bunch, according to manufacturers we've spoken with. Steel or aluminum?Lightweight components or heavy duty? What was popular 10 years ago - or 10 minutes ago - may be outdated now.

Regardless of application, the demand flip-flops.

Types of rocker arms:

There are various types of rocker arms, and the design specifications are not the same 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 depend also on which type of Internal-combustion engine is used in a vehicle (i.e. Push Rod Engines, Over Head Cam Engines etc

Stamped Steel Rocker Arm-

The Stamped Steel Rocker Arm is the most common style of production of rocker arms. The manufacture of stamped steel rocker is the easiest and the cheapest 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

Roller Tipped Rocker Arm-

This type of a rocker arm is just as it sounds. It's similar to the Stamped Steel Rocker and they differ slightly in a way that you just add a roller on the tip of the valve end of the rocker arm. This addition of a roller is to lessen the 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 aluminium

Full Roller Rocker Arm-

This type of a Roller Rocker Arm is not a stamped steel rocker. They are machined and the materials used are either steel or aluminium. They replace the turn-on pivot with bearings. This type of rocker arm still uses 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

Shaft Rocker Arms-

This type of rocker arm is build off from the full roller rocker arm. They have a shaft that goes through the rocker arms and 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 importance of the 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

Centre Pivot Rocker Arms-

In appearance, a centre pivot rocker arm looks like a traditional rocker arm but there is a much bigger 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

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 it must be located in the middle of the rocker arm.

Applications of Rocker arms

A rocker arm is an important component and it is used in the operation of an internal combustion engine because it is responsible for translating the profile of the camshaft into motion for opening and closing the intake and exhaust valves.

Causes of failure in rocker arms

Failure analysis is a broad discipline that includes sectors of engineering such as metallurgy and mechanical engineering. There are a number of failures that might occur, some appear more often than others, which include various types of corrosion or wear by itself, corrosion in combination with wear, and compression to name a few. Failure of engineered products and structures can occur by cyclic application of stresses (or strains), the magnitude of which would be insufficient to cause failure when applied singularly. Structural and mechanical components subjected to fluctuating service stress (or more appropriately, strain) are susceptible to failure by fatigue (Lee et al., 2008). Fatigue is considered as one of the most common causes of structural and machinery component failures which are frequently found in engineering services Fatigue failure is localised structural damage that occurs when a material is subjected to variable cyclic stresses. These stresses are much lower than the ultimate tensile stress limit when under the application of a single static stress

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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

LITERATURE REVIEW

Christer Spiegelberg, soren Anderson et.al [1] presented a paper, Simulation of friction and wear in the contact between the valve bridge and rocker arm pad in a cam mechanism .In this paper the surface velocities obtained from a rigid body model are used to simulate friction and wear in the contact between the rocker arm pad and valve bridge in the cam mechanism of a diesel engine. The friction is simulated with two different friction models, a 3D brush model capable of handling transient conditions such as an varying normal load and varying surface velocities and a Coulombian friction model. The wear simulations are based on a generalised form of Archard's wear model. The results presented here show that both the maximum wear depths and the wear distributions are influenced significantly by the mbination of wear pad radius and the position of the wear pad radius centre relative to the rocker arm bearing centre. A combination with wear pad radius of 20 mm and centre position of 5 mm is found to give the least wear depths on both the wear pad and the valve bridge. It is also seen that the contact between the wear pad and the valve bridge is mainly a sliding contact and that the transitions from sliding in one direction to the opposite are very rapid. The change of the surface shapes due to wear has a negative effect on the contact situation causing very high contact pressuresIt can be concluded that the contact between the wear pad and the valve bridge is mainly a sliding contact and that the transitions from sliding in one direction to the opposite are very rapid. This makes it possible to use a oulombian friction model. It can also be concluded that the wear pad radius and position of the wear pad radius centre have a significant influence on both the maximum wear depth and the wear distribution. The motion of the rocker arm can explain the shape of the wear distributions. One of the sixteen combinations of wear pad radiuses and centre positions studied was found to be optimal giving the least wear depths on both the wear pad and the valve bridge. For both the typical wear distributions the change of surface shapes due to wear leads to high contact pressures that would be a serious problem for the life of the contact. The highest pressures are found near the end points of the contact point motion and are most likely due to that edges formed from the wear of the surfaces comes into contact. These effects are already seen in simulations corresponding to 100 h of running in an engine.

C.G.Provatidis et.al [2] presentedforced precession in a spinning wheel supported on a rotating pivot.This paper deals with the mechanics involved in a spinning wheel of which the pivot is not fixed as usual but is forced to rotate along the circumference of a circle on the horizontal plane. The usual Euler equations are extended so that, in addition to the three well-known rotations (Euler angles), they also include a fourth one related to the rotation of the motor that induces the forced precession. This study aims at offering a first insight in one of the renowned Laithwaite's experiments. The derived theoretical expressions are accompanied by computer simulation The results of the mechanical simulation confirm the following: 1) The kinematics of the wheel highly depends on the type of the joint between rotating arm and wheel's axle. (2) Unlike the usual spinning top, in the forced precession there is always power exchange between motor and axle, except when the axle is horizontal and the motor works at the condition of slow precession. (3) The wheel generally performs an alternating motion, rising and sinking with respect to the horizontal plane, which is not generally the average position. (4) The mean average of the alternating vertical force was found always to coincide with the weight.

Z.W. Yu, X.L. Xu et.al [3] in this paper Failure analysis of diesel engine rocker arms. This paper presents a failure analysis of two diesel engine rocker arms used in trucks, which failed in service. The fracture occurred at the hole of the rocker arm shaft in two cases. Beach marks and fatigue stepscan be observed on the fracture surface. Multiple-origin fatigue is the dominant failure mechanism. A detailed metallurgical investigation was conducted on the failed rocker arms, and compared with a new one. The failed rocker arms present general metallurgical characteristics that the spheroidization of cementite in pearlite appears in all the matrix structure, and a banded structure was observed in the crack origin region. The appearance of the granulated pearlite makes the hardness of the material decrease so as to reduce the fatigue strength of the rocker arms. A normalizing treatment test was performed on the material of the failed and new rocker arms. The formation of a well-distributed lamellar pearlite structure, the increase in hardness, and the disappearance of the banded structure indicate that the unsuitable normalizing technology was responsible for the microstructure defects. Following conclusions are evaluated (1)The fracture occurred at the hole of the rocker arm shaft. Multiple-origin fatigue is the dominant failure mechanism. (2) The spheroidization of cementite in pearlite makes the hardness of the material of the failed rocker arms decrease to result in a lower fatigue strength. Initiation and growth of the cracks was facilitated by a microstructure of low fatigue strength. (3) The spheroidization of cementite in pearlite is the general metallurgical feature of the matrix of the failed rocker arms and a banded structure has been found in the crack origin region. The disappearance of the banded structure and the formation of well-distributed lamellar pearlite by renormalizing the material of the failed rocker arms indicates that unsuitable normalizing technology is responsible for the metallurgical defect

Chin-Sung Chung, Ho-Kyung Kim et.al [4] Safety evaluation of the rocker arm of a diesel engine in order to evaluate the fatigue endurance for the rocker arm of a diesel engine, stress measurements were performed using strain gages attached near the neck, which is one of the most critical regions in the rocker arm, while varying the engine speed. Fatigue life experiments were carried out on miniature specimens taken from rocker arms. To evaluate the fatigue endurance of the rocker arm, the S–N data were compared with the stress analysis results obtained through a Finite Element Modelling (FEM) analysis of the rocker arm. The von-Mises effective stress of the rocker arm neck region was determined to be 22.4 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 safety factor is appropriate.Heconcluded that The fatigue endurance of a rocker arm was evaluated by experiments and FEM analyses, and possible cause of failure were assessed. 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

Dong woo lee et.al [5] Failure of rocker arm shaft for 4-cylinder SOHC engine. Failure analysis of mechanical components is useful in predicting applied load as well as load type. This study examines the failure of a rocker arm shaft in the design stage and the robustness of its boundary condition using orthogonal arrays and ANOVA. 1. Fatigue crack in rocker arm shaft for passenger car was initiated at through hole and subsequently propagated along its sidewall. 2. 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. 3. 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. 4. In the case of the component with unstable boundary condition such as rocker arm shaft, we must discuss effect of boundary condition on fatigue life in design process using orthogonal array and ANOVA.

Conclusion

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.

In this project we designing one rocker arm by using cad tool creo-2 and then imported into cae tool Ansys workbench here we have steel is an existing material to improve its efficiency here we also analysing with another 2 materials. And calculating results like deformation stress and strain values from all these results here we can say that HMC FUD polymer material producing less stress and high strength values and also we were decreasing weight up to 25%. And also increasing total strength of the object.

Finally we can conclude that we can replace hmcfud polymer material with steel material to get better results.

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