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ROCKER ARM: - A REVIEW

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Abstract: Over the years rocker arms have been optimized in its design and material 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. This paper reviews the various types of rocker arms, based on published sources from the last 40 years in order to understand rocker arm for its problem identification and further optimization. This paper present what rocker arm is, where it is used and why it is used, History related to rocker arm and it working is described. Various types of rocker arm used in vehicles and different materials used for making rocker arm are studied in this paper. Reasons for Failure of rocker arm are also discussed in this paper.

Keywords: Rocker arm, valve train, steel, fracture

I. INTRODUCTION

As a rocker arm is acted on by a camshaft lobe, it pushes open either an intake or exhaust valve [1][2]. This allows fuel and air to be drawn into the combustion chamber during the intake stroke or exhaust gases to be expelled during the exhaust stroke. Rocker arms were first invented in the 19th century and have changed little in function since then. Improvements have been made, however, in both efficiencies of operation and construction materials [1] [3] [4].

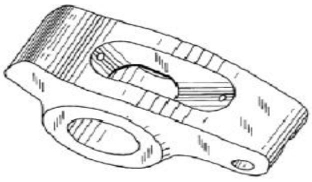

Fig.1. Rocker arm

II. HISTORY

Jonathan "Rundle" Bacon created Rocker arms in the 19th century, rocker arms have been made with and without "rundle" roller tips that depress upon the valve, as well as many lightweight and high strength alloys and bearing configurations for the fulcrum, striving to increase the RPM limits higher and higher for high performance applications, eventually lending the benefits of these race bred technologies to more high-end production vehicles. Even the design aspects of the rocker arm's geometry has been studied and changed to maximize the cam information exchange to the valve which the rocker arm imposes, as set forth by the Miller US Patent, #4,365,785, issued to James Miller on December 28, 1982, often referred to as the MID-LIFT Patent. Previously, the specific pivot points with rocker arm design was based on older and less efficient theories of over-arching motion which increased wear on valve tips, valve guides and other valve train components, besides diluting the effective cam lobe information as it was transferred through the rocker arm's motion to the valve. Jim Miller's MID-LIFT Patent set a new standard of rocker arm geometrical precision which defined and duplicated each engine's specific push-rod to valve attack angles, then designing the rocker's pivot points so that an exact perpendicular relationship on both sides of the rocker arm was attained: with the valve and the pushrod, when the valve was at its "mid-lift" point of motion [5].

Throughout the history of the rocker arm, its function has been studied and improved upon. These improvements have resulted in rocker 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 rocker arm still performs the same basic function.

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.

III. 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 [2].

The drive cam is driven by the camshaft. This pushes the rocker arm up and down about the turn-on 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.

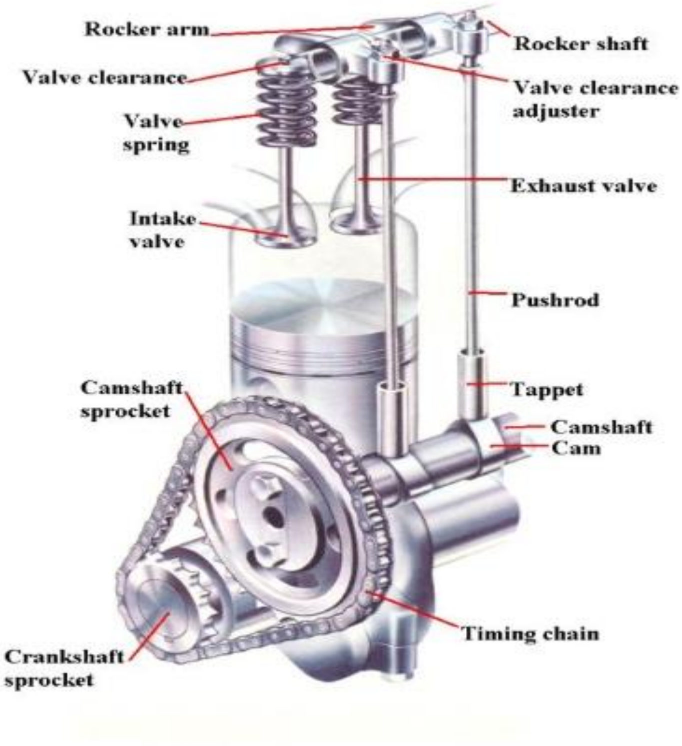

Fig.2. Valve train assembly

IV. ROCKER RATIO

A rocker arm is simply a mechanically advantaged lever that translates camshaft data into valve actuation. The mechanical advantage is defined by a rocker's ratio.

The standard small-block Chevy (SBC) uses a 1.5:1 ratio rocker arm. In other words, the rocker-arm tip (output) moves 1.5 times the displacement of its pushrod socket (input), or camshaft-lobe lift. The 1.5:1-ratio rocker arm translates 0.350 inches of camshaft-lobe lift into 0.525 inch of valve lift (0.350 inch x 1.5 = 0.525 inch). By increasing the rocker-arm ratio, it's possible to increase valve lift without ever touching the camshaft. A 1.6:1-ratio rocker arm translates the same 0.350 inch of camshaft-lobe lift into 0.560 inch of valve lift (0.350 inch x 1.6 = 0.560 inch). This is a lift increase of about 6.7 percent. Valve lift can typically be increased as much as 10 percent by increasing rocker ratio.

Since rocker arms are used to control both the intake and exhaust valves, swapping high-ratio rocker arms onto an engine increases both the intake-air command and the exhaust-scavenging potential. Generally speaking, a bump in rocker-arm ratio results in a noticeable performance gain. The almighty General knows this; GM swapped in a set of high-ratio 1.6 (up from the LT1's 1.5) rockers on the LT4 and later specified the LS7 ratio at a healthy 1.8 (up from the LS2's 1.7).

V. 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.

Fig.3. Stamped Steel Rocker Arm

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 aluminium.

Fig.4. Roller Tipped Rocker Arm

C. Full Roller Rocker Arm- The Full Roller Rocker Arm is not a stamped steel rocker. They are either machined steel or aluminium. 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.

Fig.5. Full Roller Rocker Arm

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.

Fig.6. Shaft Rocker Arms

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.

VI. **MATERIALS**

Beyond high ratios and friction-abatement technologies, performance-rocker-swap talk must include discussions of materials, strength, and stability. The most common rocker materials are steel and aluminium.

Expounding on the material engineering of rocker arms, Scooter Brothers, cofounder of Comp Cams, explains some interesting facts about steel-bodied rocker arms. Scooter states that chrome-moly steel, although heavier than other materials, can offer some design advantages and have much thinner sections than aluminium due to its superior strength density. Generally speaking, it takes at least two times the aluminium to approach the strength of steel. The moment of inertia, or performance mass, of properly engineered steel parts can actually be close to that of aluminium. In other words, before jumping for lightweight aluminium rockers, it's important to realize that the effective weight of a quality steel unit may be comparable

A. Steel- Many automotive applications make use of steel for these reasons, as this material can provide a balance between weight and durability. Stamped steel was the OEM standard for Gen I and II, while cast steel was and is the standard for Gen III and IV While these are suitable for OEM and basic performance, the aftermarket and racing communities demand more exotic options [1].

B. Anodized-aluminium roller rockers-Nothing screams high performance more than a set of anodized-aluminium roller rockers, regardless of their true positive effect

C. High-strength alloy aluminium rocker- High-strength alloy aluminium rocker arms are good, lightweight performers. Basic aluminium rocker arms are available with cast-alloy or extruded bodies, and high-end aluminium rocker arms are available machined from billet alloys [2].

D. Chrome-moly steel- Chrome-moly steel is a common material for high-performance parts, and rocker arms are no exception. The strength and rigidity of this material is hard to beat.

E. High-strength alloy steels- High-strength alloy steels are used in high-end, precision rocker arms, with rock-like rigidity for high-rpm race applications.

VII. 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 cementite in pearlite 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 [1].The fracture of rocker arm at the hole is shown in fig.7.

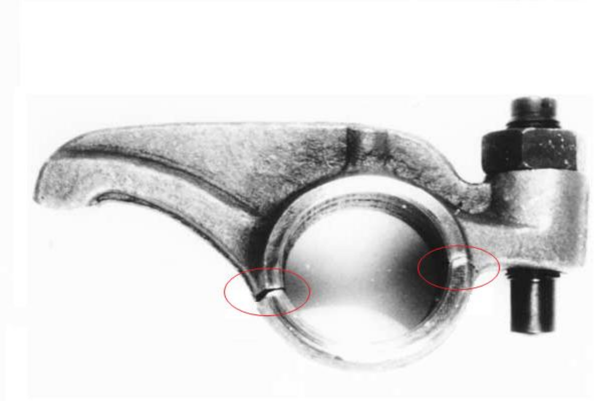

Fig.7. Fracture at the hole of the rocker arm

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 [2].

Fig.8. Fracture at the neck of the rocker arm

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].

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 [6].

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 [3].

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.

VIII. 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. The finite element method is the most popular approach and found commonly used for analysing fracture mechanics problems.

Lightweight rocker arms are a plus for high rpm applications, but strength is also essential to prevent failure. In recent years, aftermarket steel roller tip rockers have become a popular upgrade for the most demanding racing applications. Some of these steel rockers are nearly as light as aluminium rockers. But their main advantage is that steel has better fatigue strength and stiffness than aluminium. So we can say that steel is the better material in terms of strength and aluminium is good for making low cost rocker arms.

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BIOGRAPHY

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