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Critical Speed Improvement in Single Cylinder Engine Valve Train

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***Abstract*— In this paper the pushrod type engine valve train is examined for critical speed of valve train. The critical speed is the speed at which the contact loss between the roller and cam occurs due to the over speed running of the engine. The paper consists of the design improvements in valve train to increase the critical speed. The critical speed is improved by changing the valve spring stiffness value. ADAMS simulation is done with existing stiffness and it was found out that, valve train maintains the contact up to the 1.44 times the rated output speed of engine. The static analysis of valve train components is done by using computer aided engineering (CAE). The models of spring for different values of spring rate were prepared in Creo. The analytical and software results are compared with each other and it is found that they are within the specified range. The dynamic analysis of valve train for critical speed analysis done by using the ADAMS. Form analysis it is concluded that there is 8% improvement in critical speed.**

Keywords—Valve Train, Pushrod Stiffness, Computer Aided Engineering, ADAMs,

I. INTRODUCTION

The valve train system is the one of the major sub-systems of an internal combustion engine. The function of the valve train mechanism is to use the intake and exhaust valves to control in a timely way the entry of charge and the exit of the exhaust gas in each cylinder following each cycle of engine operation. When the engine is in motion, the dynamic forces like normal reaction forces, frictional forces, impact forces on the timing chain may cause considerable effect on the function of the valve train & hence on valve. The effect is prominent when the engine is at high speed. In this work, the dynamic analysis of valve train system insights on speed of opening and closing of valves. The existing valve train maintain their contact up to the 1.44 times the rated output speed of engine. To resolve this phenomenon of contact loose between the cam and roller the improvements in the spring stiffness is done. The stiffness value of valve spring should be changed up to the certain value, the spring stiffness value depend up on the wire diameter the change in wire diameter was done up to the package able limit of current engine components with minimum changes in components. The current work includes the software analysis for contact stress, buckling analysis, static analysis and critical speed validation of valve train. [1]

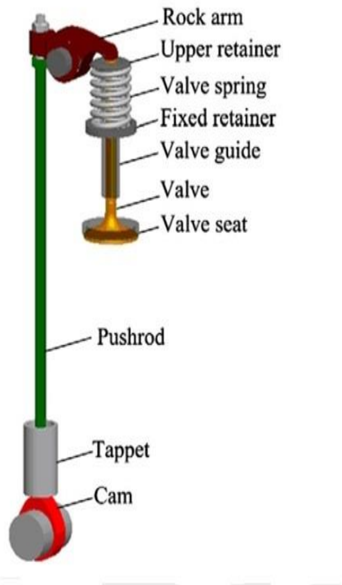

Fig. No 1 Nomenclature of valve train

II. LITERATURE REVIEW

After the study of SAE paper it is found that there is Andrew J G Whitehead [1] proposed the best method to improve the critical speed of engine valve trains. The valve spring parameters are varied based on an iterative logic with constraint on space availability, stress limit, stiffness and natural frequency of the system. The optimized valve spring configuration is used in the push rod type valve train and the valve train dynamics for different engine speed is studied using commercially available multi-body dynamic ADMAS software. The kinematic and dynamic properties are calculated by analytical and by using ADAMS software.

III. OBJECTIVE

- To improve the speed of current engine valve train above the 5200 rpm without any changes in the major valve train components.
- The study of existing valve train i.e. pushrod operated (center pivot rocker arm type) valve train of current engine. Modify the design parameters of valve train components.
- To prepare the CAD model of engine valve train is by using CREO parametric software and analysis of valve train model to be done by using ADAMS multi body dynamics software to achieve the desired valve train operating speed.

IV. DYNAMIC ANALYSIS

With ADAMS multi body dynamic simulation, critical speed is found out with existing stiffness (23.4 N/mm) is 5200 RPM this is shown in figure no. 2. From the graph it is concluded that the existing valve train is safe up to 5200 rpm as there is no contact loss.

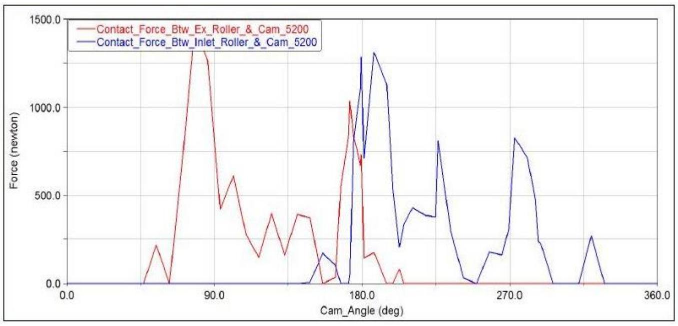

Fig. No 2 Critical Speed analysis of existing valve train

V. SPRING STIFFNESS

To avoid valve jump, the valve train must remain intact i.e. net inertial force should not be greater than spring force. If the spring force is small then valve jumping problem arrives. Increasing spring stiffness is one of the ways to improve critical speed. The stiffness of valve spring is increased to 1.15 times the original by changing the wire diameter from 3.5 to 3.7 mm. From ADAMS, critical speed is 1.44 times the rated output speed of engine i.e. up to 5200 rpm.

VI. NATURAL FREQUENCY

The dynamic analysis of valve train begins with an estimation of the valve train natural frequency. The natural frequency of valve train is calculated for 1.15 times improvement in the spring stiffness value i e. at 27.35 N/mm. The effective stiffness of valve train components is obtained by measuring the valve train components deflection, this is done by using ANSYS workbench. All masses and stiffness values of pushrod, tappet and rocker arm are transferred towards the valve side by using series equation of spring. The figure represents final values of stiffness and mass of valve train.

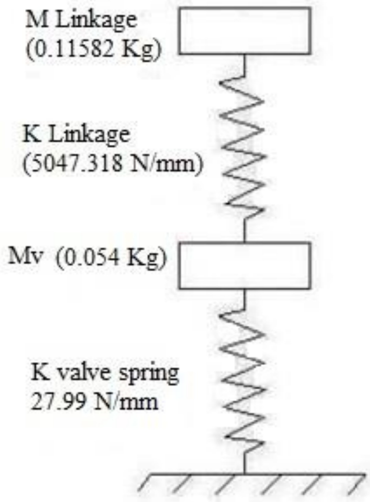

Fig No. 3- Two DOF model with spring stiffness and damping for dynamic analysis

The syntax of problem is written in MATLAB program. The outputs obtained after executing this program in MATLAB and the natural frequency of vibration with new spring design is,

$$f=209.34 \text{ Hz}$$

The natural frequency of valve train is within the allowable limit i.e. below the 710 Hz. [1]

VII. ADAMS ANALYSIS

The simulation of valve train is carried out for new spring stiffness value i.e. 27.99 N/mm. After ADAMS multi body dynamic analysis it is found that there is no contact loss between the cam and tappet up to 5600 rpm rated output speed of engine. The plot of contact pressure vs cam angle represents the critical speed of engine valve train.

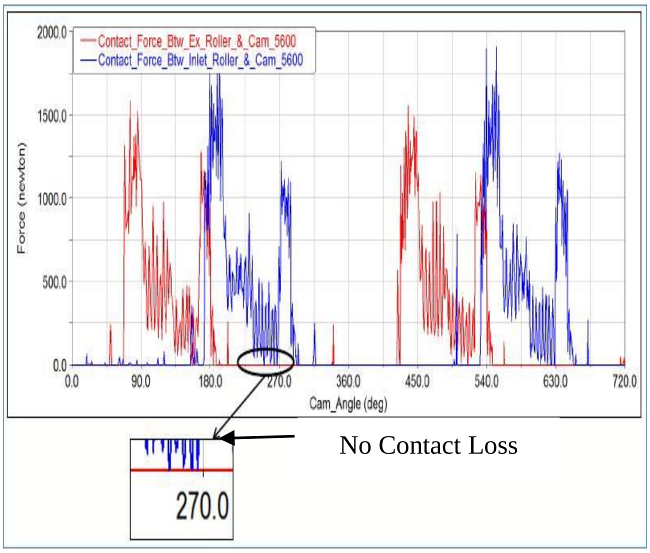

Fig. No 4 Critical Speed analysis of modified valve train

From figure 4 it is observed that there is no contact loss up to 5600 rpm with 1.15 times improvement in the spring stiffness value.

The ADAMS multi body dynamic analysis of valve train is carried out above the 5600 rpm to check whether this is safest critical working speed of valve train. The figure represents the cam angle vs contact fprce plot. From this plot it is found that there is contact loss between cam and roller in between the 260^0-270^0 of cam angle. Therefore the current valve train is safe for 5600 rpm.

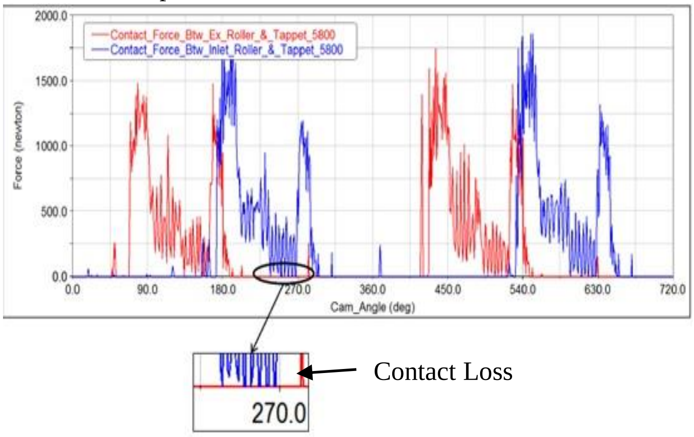

Fig. No 5 Critical Speed analysis of modified valve train

VIII. PUSHROD BUCKLING

The buckling analysis of pushrod is carried out for finding out the buckling load of pushrod. The Euler's theory of buckling is used for the buckling analysis of pushrod.

$$P_c = 3936.79 \text{ N}$$

The major forces come on pushrod are spring force, Gas force and the inertia force due to rotation of cam. The figure represents the software result of buckling analysis of the pushrod.

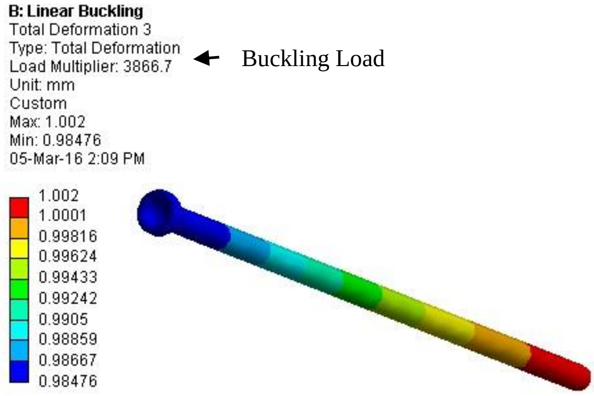

Fig No 6 Buckling analysis of pushrod

The analytical and software results are within the specified error limit i.e. up to 10 %. Since the load acting on pushrod is less than the crippling load of pushrod, therefore pushrod is safe in buckling. [14]

IX. CAM CONTACT STRESS

Due to the continuous contact between cam and the roller there maximum contact stresses are come on cam. Contact loss occurs at 1.44 times the rated output speed of engine. At that speed the contact pressure is within the limit i.e. below the 1200 Mpa. The contact pressure analysis of current valve train was done by using Ansys workbench, following figure represents the maximum contact pressure on cam.

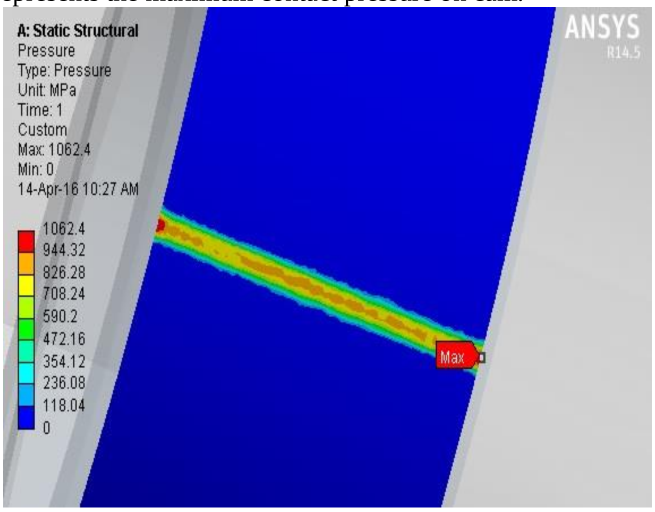

Fig No.7 Contact stress analysis between cam and roller for existing engine valve train

Due to the change in valve spring stiffness the forces on cam increased by 117%. The following table represents the contact stresses between cam and roller before modification and after modification.

	Force on pushrod(N)	Contact width (mm)	Contact Pressure (Mpa)
Existing Valve Train	1489	0.1406154	1121.532
Modified Valve Train	1689	0.152011	1192.711

Table No. 1 Contact Pressure between cam and roller

The modification in valve train causes 1.08 times increase in contact pressure. The following figure represents the software evaluation of contact pressure after 1.55 times the speed improvement in rated output speed of engine.

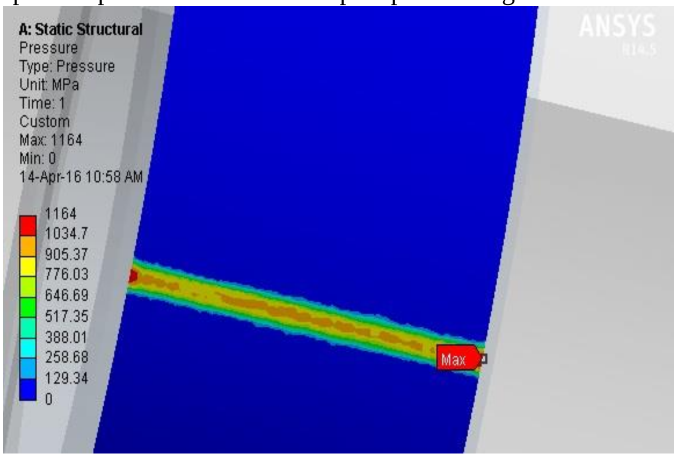

Fig No.8 Contact stress analysis between cam and roller for modified engine valve train

The analytical and software results are within the specified error limit i.e. up to 10 %. For CAM material the allowable contact pressure is 1200 MPa. [13]

X. RESULTS

The dynamic analysis of modified valve train is done by using ADAMS multi body dynamics. The analysis is done for 1.15 times the improved spring stiffness value. From the dynamic analysis it is found that there is no contact loss between cam and roller @5600RPM. Based on the design modifications valve train components were developed and miss-gearing trial was conducted on vehicle. After validation trail it is found that the engine valve train is safe up to the 5669 RPM. Hence critical speed is improved by 1.55 times the existing value.

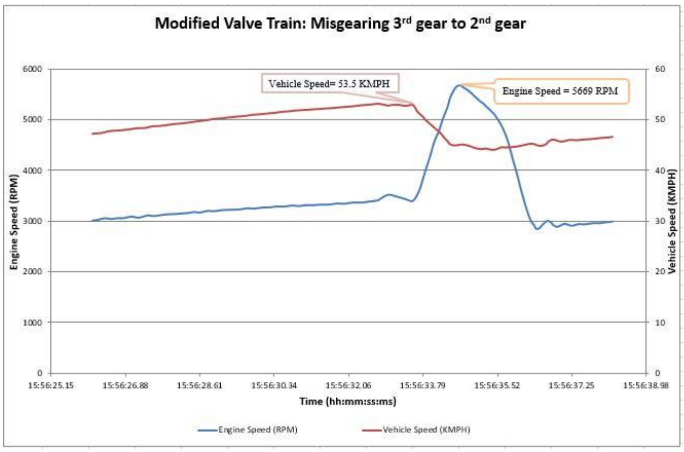

Fig No. 9 Actual Validation result

XI. CONCLUSION

- The actual validation results shows that the current valve train is safe up to 5669 rpm.
- The contact stresses are within the allowable limit.
- The pushrod is safe from buckling.

The modified valve train design gives 8% improvement in safe speed of engine valve train. The modified valve train is safe and this design should be implemented for future production.

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