

DESIGN AND ANALYSIS OF EXHAUST VALVE SPRINGS IN IC ENGINES

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ABSTRACT: The failure of valve spring leads to the failure of the engine parts. Springs are widely used as an elastic member in industries to store mechanical energy and absorb shocks and vibrations. The valve spring is subjected to fluctuating loads. Valve springs are subjected to fatigue failure due to cyclic loading. In this paper, the suitable material for the valve spring of 2956 cc engine is selected. The valve spring is designed for static and variable loading conditions. The specifications obtained from the design are used to create the 3D model of the spring and analysis is carried out using finite element methods. Deformation and shear stress are obtained from static structural analysis of valve spring. The results obtained from the finite element analysis are compared with the analytical calculations. The load deflection behaviour of the spring is studied. This analysis allowing one to determine, whether the valve springs withstand the forces without failure.

KEYWORDS: Valve Spring, Design, FEM, Deformation, Shear Stress.

I. INTRODUCTION

Springs are elastic members used to store mechanical energy, absorb shocks and vibrations, apply and measure force. Springs can be stretched, twisted or pulled. The springs return to their original state upon the release of the force. Depending on the application springs can be in static, cyclic and dynamic mode. Helical springs are made up of wires coiled in the form of helix. The primary purpose of springs in the IC engine is to permit valves to alternately open and close as per the rotation of the cam shaft. As the camshaft rotates the cam pushes the follower and push rod upwards. The rocker arm is pivoted about its centre by means of fulcrum pin. When the right end of the rocker arm is pushed up by the push rod the left end moves downward. This compresses the spring and pushes the valve rod down in the cylinder, thereby causing the valve to open. When the follower moves over the circular portion of the cam, the spring expands and closes the valve. The spring pushes the left end of the rocker arm upward. This causes the right end to move downward and keeps the follower in contact with the cam. One end of the spring is secured to the valve and other end rests on the cylinder. The spring is initially compressed. The force due to initial compression presses the valve down to its seat. The failure of this valve spring results in failure of other components like cylinder head, valve guide etc.

II. LITERATURE REVIEW

Bharathrinath Gorakhnath Kadam, P. H. Jain., Swapnil S. Kulkarni(1) performed static and fatigue life analysis on the valve spring made up of EN 47 steel. Fatigue study is performed to find life of valve spring in terms of number of cycles. The fatigue study was performed by using msc-fatigue software. The above analysis is performed for different values of the pitch. Satbeer Singh Bhatia , Ajeet Bergaley(2) designed the spring based on static load, buckling and natural frequency. The static analysis was performed was two different spring materials namely steel and epoxy composites.

Cingaram Kushal Chary, Dr. Sridara Reddy (3) performed the static, modal, and fatigue analysis of valve spring for two different materials namely steel and CFRC composite material. The composite material spring is stiffer than steel. The dynamic response of CFRC composite spring is superior to steel spring. Gajanan S. Rao, Prof. R. R. Deshmukh(4) performed fatigue analysis of valve spring and suggested that in order to improve the fatigue life the stress induced in the spring must be lower. Shot peening can also improve the fatigue life.

K.V.Sudhakar(5) performed failure analysis of valve spring using optical microscopy and scanning electron microscopy. The inclusions were localised near the region of failure. Syed Mujahid Hussain(6) calculated the forces acting on the rocker arm of the engine and performed the static analysis of rocker arm to verify the maximum shear stress.

IV.DESIGN OF VALVE SPRINGS

While valve springs may cost very little in comparison to the engine as a whole, their fail-safe stability is no significant for a vehicle’s reliable performance. Valve spring failure can cause major damage to the entire engine and should therefore be ruled out with utmost efficiency i.e. by means of reliable design and validation concepts for valve spring. In this work the geometry of the valve spring used for 2956 cc engine is derived using the fundamental design procedure of spring. Maximum displacement and stresses induced in springs under cycling load conditions are calculated analytically and simulated the same using finite element method.

Design of Valve spring

The valve spring of 2956 cc engine is designed based on the operating conditions of rocker arm. The assembly of valve spring with rocker arm is shown in fig.1. Oil tempered and hardened steel- Grade VW material is selected for fluctuating load act on the valve spring.

The properties of the oil tempered and hardened steel is given in table.1

Table 1 . material properties

S.No	Property	Value
1	density	7850 kg/ m ³
2	Poisons ratio	0.25
3	Young’s modulus	2*10 ⁵ N/mm ²
4	Shear modulus	81370 N/mm ²
5	Ultimate strength	1400 N/mm ²



Fig 1 valve spring

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Force acting on the valve spring

Forces acting on the valve spring are predicted using the data, (9)

- Pressure exerted on the valve and spring: 0.02 Mpa
- Diameter of the valve head : 40 mm
- Maximum lift of the valve : 13 mm
- Weight of the valve = 0.882N

The total force acting on the spring consists of two factors. The initial spring force and the force required to lift the valve. During the suction stroke, the initial spring force keeps the valve closed against the negative pressure inside the cylinder. The force value are listed in the table 2

Table 2 Force on Valve Spring

Sl No	Force	Magnitude (N)
1.	Minimum force (P_{min})	25.12
2.	Maximum force (P_{max})	155.12
3.	Mean force (P_{mean})	90.12
4.	force amplitude (P_{amp})	65

Geometry of the valve spring

The major dimensions like mean diameter and active number of turns of the springs are calculated with suitable assumptions of spring constant $C = 8$ and stiffness of the spring $k = 10N/mm$. The wire diameter d of the spring is calculated using shear stress of the valve material.

Spring rate $C = D/ d$

Mean diameter $D = 32$ mm

Stiffness $K = Gd^4/ 8D^3N$

Number of active coils $N = 8$

Length of the springs are calculated as follows

For square and ground ends total no of coils $N_t = N + 2 = 10$

Solid length of the spring = $N_t d = 40$ mm

Maximum compression of the spring $\delta_{max} = 8P_{Max}D^3 N/Gd^4 = 15.6$ mm.

Free length of spring = solid length + $\delta_{max} + 0.15 \delta_{max} = 58.018$ mm.

Pitch = free length/ ($N_t - 1$) = 6.4mm

Variable stresses in the valve spring

The valve springs are subjected to millions of stress cycles. Therefore the spring must withstand the fluctuating stresses.

- Mean stress $\tau_{mean} = K_s (8 P_{mean} D/\pi d^3)$, $K_s = 1 + 0.5/C$.
- Stress amplitude $\tau_{amp} = K (8 P_{amp} D/\pi d^3)$, K is wahl factor.
- Substituting the values we get 121.97N/ mm² and 98.03 N/ mm² respectively.
- $S_{sy} = 0.42 \tau_u = 630N/ mm^2$.
- $S'_{se} = 0.21 \tau_u = 308N/mm^2$
- The equation for fluctuating load is $\tau_{amp}/ (S_{sy}/f_s) - \tau_{mean} = 0.5 \cdot S'_{se} / S_{sy} - 0.5 S'_{se}$
- Substituting we get factor of safety = 1.47 < 1.5 which is reasonable.

Design for Buckling

A helical compression spring that is too long compared to mean coil diameter acts as a flexible column. It buckles at comparatively low axial force. The spring should be designed as buckle proof. From thumb rules free length/mean

coil diameter must be less than 2.6. Where as in this valve spring which is less than 2.6 ie l/D is 1.8, hence guide is not needed and spring is buckle proof.

Table 3 Specifications of valve spring

Sl No	Parameters	Values
1.	Mean coil diameter	32mm
2.	Wire diameter	4mm
3.	No of active turns	8
4.	Total no of turns	10
5.	Pitch	6.4mm
6.	Solid length	40mm
7.	Free length	58.108mm
8.	Max compression	15mm
9.	Factor of safety	1.47
10.	Mass of the spring	0.09 kg

V.ANALYSIS OF VALVE SPRING

The 3-d model of the spring was modelled using SOLIDWORKS for the speciation given in the table3. And the model is inserted into ANSYS workbench. The material properties for the spring wire are given. The fine mesh is generated into the spring in order to increase the accuracy of the results. One end of the spring is fixed and axial load of 156 N is applied on the other end. Finally the spring is solved for maximum shear stress and directional deformation.

The maximum shear stress was found to be 270 N/mm^2 and the directional deformation was found to be 16 mm.



Fig.2 Three dimensional model of the valve spring

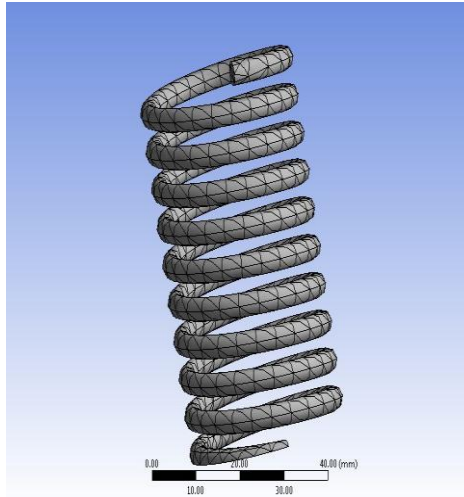
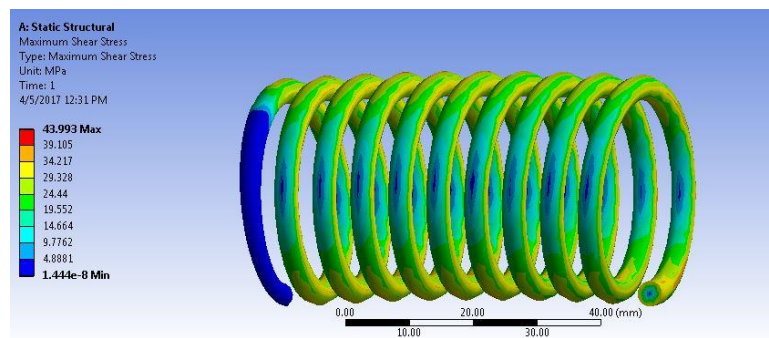
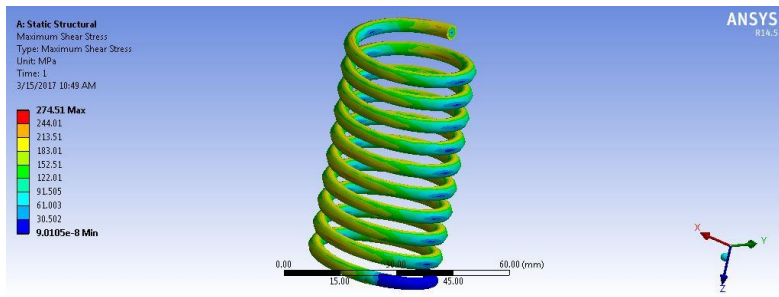


Fig.3 Generating mesh on the spring



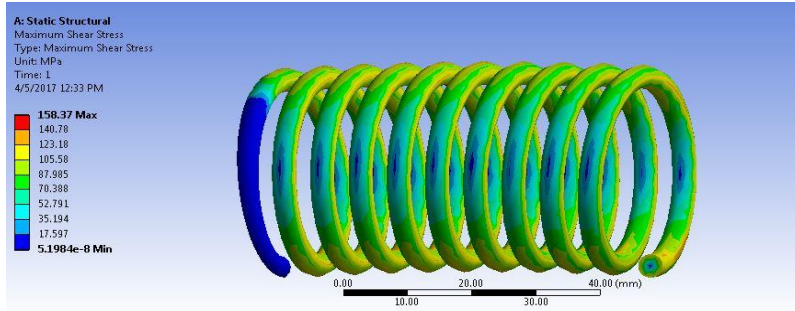


Fig 6 maximum shear stress plot (load = 90 N)

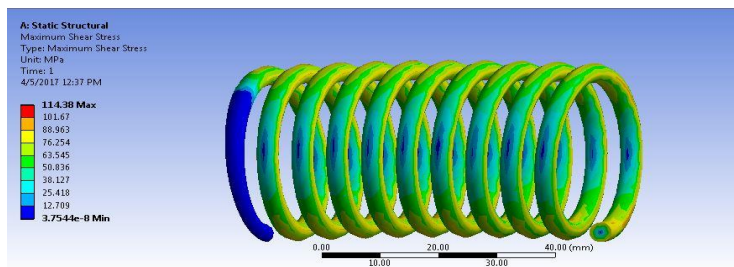


Fig 7 maximum shear stress plot (load = 65 N)

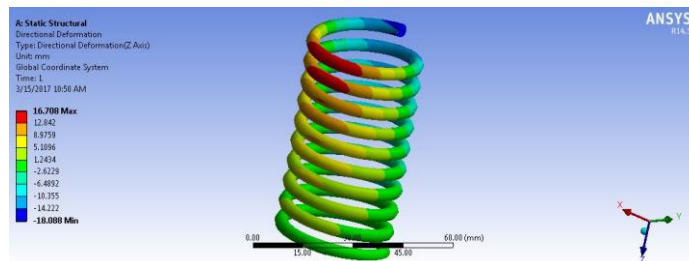


Fig 8 Directional deformation plot (load = 156 N)

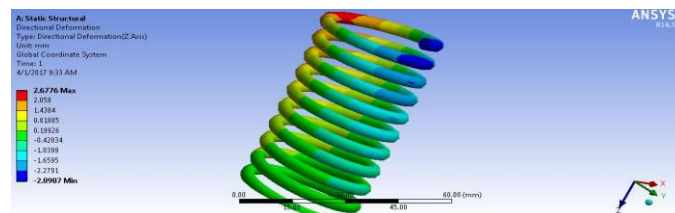


Fig 9 Directional deformation plot (load = 25 N)

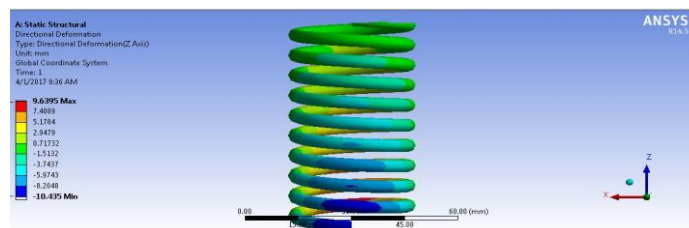


Fig 10 Directional deformation plot (load = 90 N)

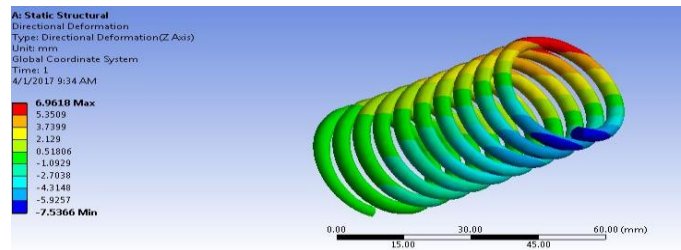
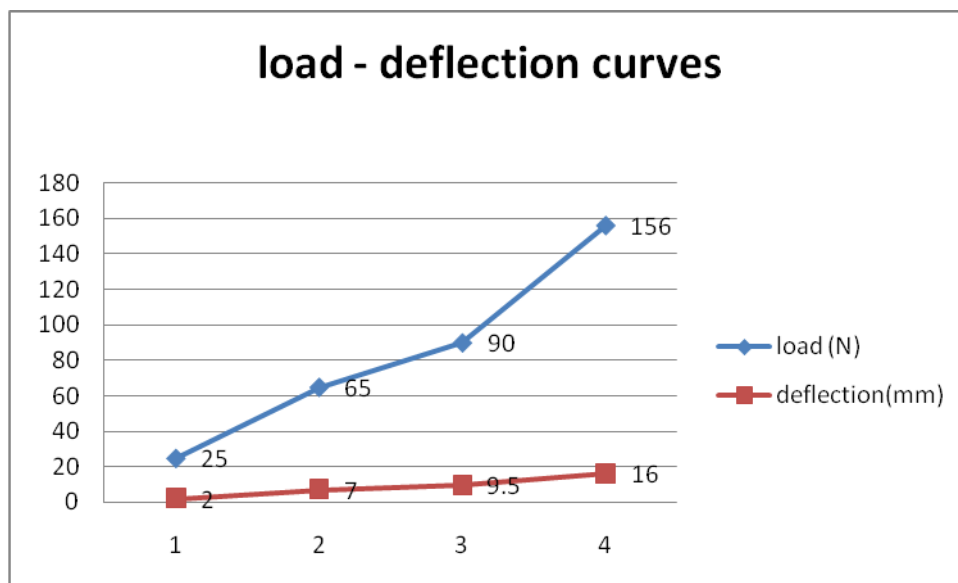


Fig 11 Directional deformation plot (load = 65 N)

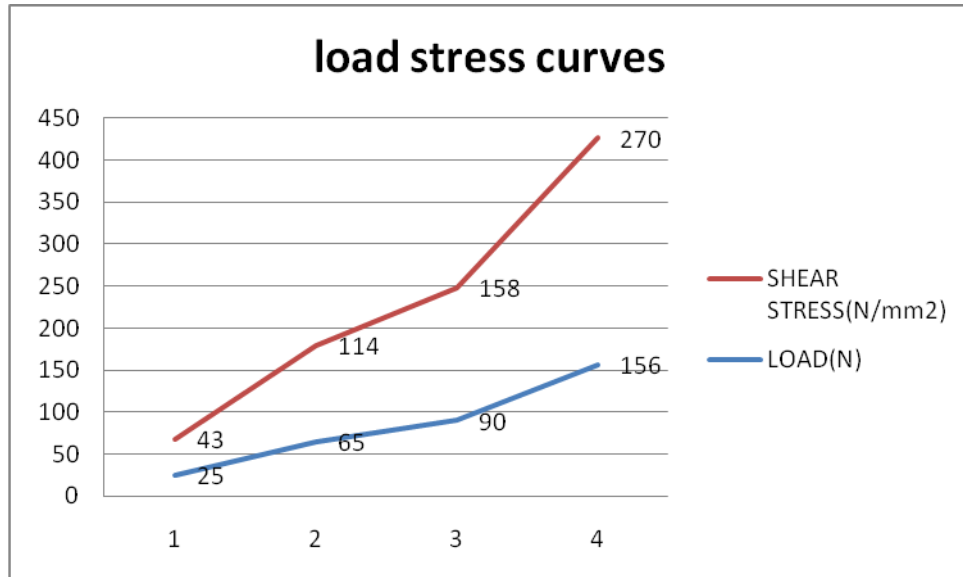
VI. CONCLUSION

1. The oil and tempered hardened steel is selected as a material for the valve spring.
2. The deflection of the spring for various loads is given in graph 1



Graph 1 load deflection curves

3. The load deflection characteristic of the spring is not perfectly linear. The initial compression of the spring is 2mm when the valve is on its seat.
4. The maximum compression of the spring is 16mm when the valve is lifted down.
5. The shear stress induced in the spring for the various loads is given in graph 2.



Graph 2 load stress curves.

6. The maximum shear stress induced in the spring is 270 N/mm^2 .
7. The maximum shear stress induced in the spring is within the permissible limits. Therefore the design is safe.
8. The factor of safety obtained from the alternating stress calculations was found to be 1.47 which is reasonable.
9. The spring is safe under buckling and guide is not needed.

REFERENCES

1. Bharathrinath Gorakhnath Kadam, P. H. Jain., Swapnil S. Kulkarni "DESIGN AND FATIGUE ANALYSIS OF VALVE SPRING USED IN TWO WHEELER" International Journal of Scientific Research and Management Studies Volume 1 Issue 10, pg: 307-316 .
2. Satbeer Singh Bhatia , Ajeet Bergaley "ANALYSIS OF THE DESIGN OF HELICAL COMPRESSION SPRING TO STUDY THE BEHAVIOUR OF STEEL AND COMPOSITES USED AS SPRING MATERIALS" International journal of engineering sciences & research technology vol 3 Issue 8 pg no 576-581.
3. Cingaram Kushal Chary, Dr. Sridara Reddy "DESIGN AND ANALYSIS OF HELICAL COMPRESSION SPRING OF IC ENGINE" International Advanced Research Journal in Science, Engineering and Technology Vol. 3, Issue 10, pg no 153-157.
4. Gajanan S. Rao, Prof. R. R. Deshmukh "ART OF FATIGUE ANALYSIS OF HELICAL COMPRESSION SPRING USED IN TWO-WHEELER HORN" International journal of mechanical engineering and technology, Vol. 3, Issue 10, pg.no 196-208.
5. Sudhakar V "FAILURE ANALYSIS OF AUTOMOBILE VALVE SPRING" Elsevier journals pg.no 513-514.
6. Syed Mujahid Husain and Siraj Sheikh "DESIGN AND ANALYSIS OF ROCKER ARM" International journal of mechanical engineering and robotics research.