Design and Analysis of Inlet and Exhaust Valve Springs for High Speed Engines using Finite Element Method

Rahul Patidar [1], Kamlesh Gangrade[2]

[1]*SAGE University, Indore, India*
[2]*Assistance Professor, Dept. of Mechanical Engineering, SAGE University, Indore, India*

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Abstract – *A valvetrain is a system that controls the operation of an internal combustion engine like inlet and exhaust and the valve spring can maintain the required amount of force to hold the valve in the closed position until the cam opens the valve for pressure release so it plays an essential role in respect to the engine performance but sometimes it may fail due to high rotational speed and high temperature around 150º C. Valve spring are required to be lighter and smaller to improve the fuel efficiency, reduce the inertia weight of valve train and it also help to reduce the size of the engine. So in this research work, we design the valve spring for high-speed engines using the finite element method.*

In this paper we discuss about helical valve spring which used in IC engine, subjected to fluctuating loads, static and variable load. It gets compressed and absorbed energy while opening of the valves and release energy during closing of the valves. Spring stiffness plays a vital role in design of helical valve spring, its help to improve reliability and fatigue life. This stiffness valve can be managed using elasticity of modules for the software's but in real we have to manage stiffness value using heat treatment process; there are many different type of heat treatment there according to stiffness value. So in our research we also describe the heat treatment according to our stiffness requirement and also described physical test on stiffness testing machine.

Key Words: *Valvetrain, FEM*

1. Introduction

An internal combustion engine is a type of heat engine in which the combustion of fuel occurs in combustion chamber and produces high temperature and pressurised gasses and converts this fuel energy into mechanical power which is transferred to the wheels to run the vehicle through power train system. Usually there are two types of internal combustion engine used in automobile industries; first one is 2 stroke engines is a type of internal combustion engine that complete a power cycle witch two stroke, this power cycle is completed in one revolution of the crack shaft. The end of combustion stroke and starting of compression stroke performed at the same time and as per design of engine, inlet and exhaust controlled through ports so there is no need of valve train. The second type of engine is 4 stroke engines in which there are four separate strokes of the piston to complete power cycle during two revolution of the crankshaft.

The four separate stokes are termed as inlet, compression, combustion and exhaust. The four stroke engine is most common now in automotive industries being used in automobiles, light aircrafts and motor cycles. As per engine design inlet and exhaust controlled by valve train mechanism to improve the engine performance and it basically controls the breathing of engine.

The valve train is an assembly of valves, valve spring, rocker arm, retainer, push road, tappet and cam etc. The intake valve control the flow of fuel inside the combustion chamber while the exhaust valve control the out flow of exhaust gasses and the timing of opening and closing controlled by cam shaft.

A valve spring is a compression type of helical spring, it is behave like elastic component Store a mechanical energy and get deformed in shape and when the load is removed is gain its original shape again. A valve helical spring is working with very high working stress and it is working in very high fluctuating load. A simple type of helical spring cannot sustain this type of loading, for that purpose we designed a special type of helical spring with some advanced techniques.

2. Objective

The valve springs are used in valve train mechanical system to maintain the pressure on inlet and exhaust valves to be in closed condition. In some cash this valve springs get damage or fail in high rotational engine because unable to retract the valve quickly enough to release the pressure for piston in exhaust stroke and also has to endurable fluctuating load while working in extremely high temperature because valve spring subjected to thousands of cycle per minute.

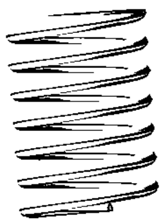
3. Methodology

We followed the methodology as shown in figure first off all we find the design and operational requirement of existing engine valve train having some dimensional specification and operational specification in terms of load v/s displacement of spring according to opening and closing of valve while intake and exhaust operation, thus we have given dimensional specification so we can't any change the *dimensions of spring to improve the performance that's why in this research work we changed the material properties to enhance the performance and make the design suitable for engine operational requirements. Firstly we design valve spring on creo parametric design software using existing spring dimensions and use material property which is easily available or usually used for spring manufacturing like Chromium-Vanadium Steel then we perform stiffness analysis using finite element method and find out the approximate value of E (Elasticity of modules) which value suitable for operational performance of the engine. After that we have to perform the specific heat treatment process to maintain mechanical and chemical properties through this method we also try to improve the fatigue life. At last we performed the physical test using pressure testing machine to validate or correlate the CAE and physical results.*

4. CAD modeling

The design of valve spring is as important as cam design because is operate in extremely violent environment so our design is based on dimensional requirement of engine as shown in below tables.

Spring length	55mm
Coil diameter	37mm
Wire diameter	4.2mm
no. of coils	7
coil pitch	8mm



5. Boundary Condition

The valve spring in internal combustion engine are subjected to dynamic loading to control the operation of valves, resulting high stress and premature failure. As per engine valve train requirement this valve spring subjected to two different loads.

a. *A spring load when the valve is closed – 250 N*
b. *A spring load when the valve is open – 360 N*

6. Analytical Results

Maximum load – 360N

Minimum load – 250N

Displacement on 250N is 12mm

Displacement on 370N is 17mm

Spring total Length – 55mm

Coil diameter – 37mm

Wire diameter – 4.2mm

No. of coils – 7

Coil Pitch – 8mm

From Torque Formula - $F_{max} \cdot \frac{Dm}{2} = \frac{\pi}{16} \tau d^3$

$$Dm = (Di + d)$$

$$F_{max} \cdot \frac{(Di+d)}{2} = \frac{\pi}{16} \tau d^3$$

After equate that values we got a value of maximum permissible stress

$$\tau = 606.7471\ Mpa$$

Stiffness of the spring

$$\frac{Load}{Displacement}$$

$$\text{When valve is closed} - \frac{250}{13.5} = 19.23\ N/mm$$

$$\text{When valve is open} - \frac{360}{17} = 21.17\ N/mm$$

Spring Index -

$$C = \frac{Dm}{d}$$

$$C = \frac{(Di+d)}{d} = 9.8$$

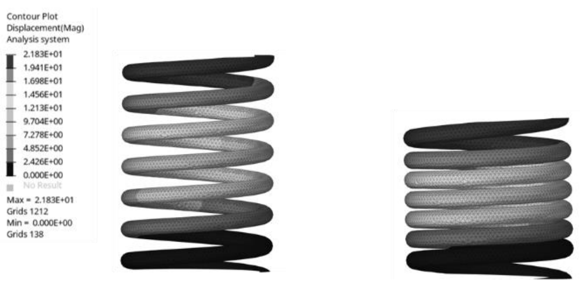
Wahl's factor –

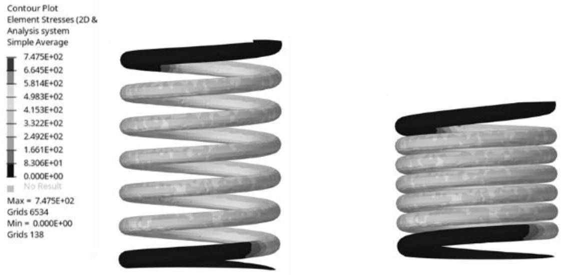
$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

$$= 1.15$$

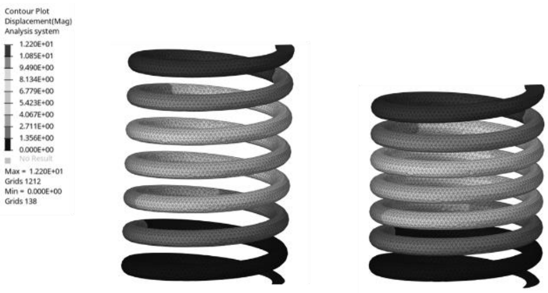
6. Results

In this static analysis we considered Chromium-Vanadium Steel as a material for valve spring and apply 250N load when valve is closed condition. As shown in results the maximum displacement is 21.83mm and maximum stress are 747 Mpa

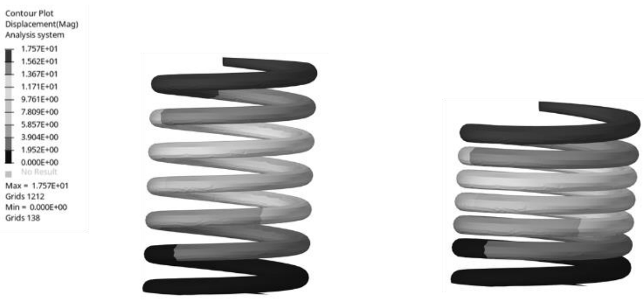


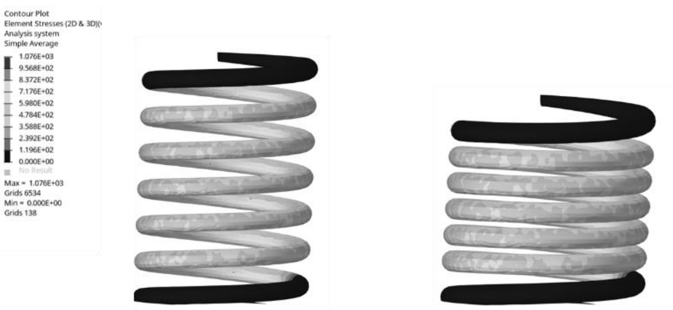


In the direction to meet the max displacement of valve spring upto 12mm me need to consider some other material with high ultimate tensile strength.



The same updated material properties applied in second load case where the maximum load is 360N when valve is in open condition and got the maximum displacement 17.57mm and stress 1076Mpa.





7. Conclusion

Valve springs are one of the most important part of the engine may be its cost is very less as compared with any other engine part but any failure in valve spring structure can reduce the performance of the engine. This research work we performed static structural analysis using element method which is a good approach to predict the failure in high performance valve spring design then we finds out the suitable material property to meet the engine requirement and avoid failure

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