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Design and Analysis of Engine Valve Spring

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Abstract—Valve helical spring is a critical part in valve train of the IC engine. It absorbs energy while opening of the valves and release energy during closing of the valves. It is basically a compression types of helical spring used in commercial vehicles. Spring stiffness plays a vital role in design of helical valve spring. The primary part of designing of valve helical spring is to define the stiffness of spring as per requirement of engine design. Then todesignfor space constraints, to design for high fatigue strength, and to design forreliability..

Index Terms—– valve spring, stiffness, fatigue strength.

1 .INTRODUCTION

A spring is an elastic object that stores mechanical energy. Springs are typically made of spring steel. There are many spring designs. In everyday use, the term often refers to coil springs.

A reciprocating internal combustion engine uses valves to control air and fuel flow into and out of the cylinders. All cylinders have two valves, first intake valve and second exhaust valve. Intake valve opens just before the intake stroke start. In the petrol engine this allows the air-fuel mixture to enter the cylinder or in case of diesel engine it is only air is allows to enter into the cylinder. Exhaust valve open before the exhaust stroke begins start so that the burned gases can easily escape. The valves are operated by the valve train. We have two types of valve train used for a reciprocating engine depends on the engine ,firston is overhead camshaft with rocker arms, and second one is camshaft in a block with a pushrod. The valve train consists of valves, rocker arms, pushrods, and camshaft and helical springs and the combination of all. If we analysis the data we found the critical component in the valve train is helical spring. Valve springs plays an important role in the controlling of breathing of internal combustion engine, also provide a resisting force that returns displaced valves to their closed position and seal the combustion chamber during compression and combustion. Spring is used to store energy and to absorb shock, or to maintain a force between contacting surfaces. They are generally made of an elastic material formed into the shape of a helix which returns to its natural length whenunloaded.

2. PROCEDURE FOR PAPER SUBMISSION

2.1 Review Stage

It may be considered the cost of valve helical spring is very low as compared to whole engine sub parts, but the failure of valve helical

2.2 Final Stage

The reciprocating internal combustion engine is that engine in which the combustion is take place inside the engine cylinder. They are differentiate in manly two categories, first one is as per fuel is used and second one a type of stroke is used. Our research is fully based on four stroke engines in which valve train mechanism is used to control breathing of internal combustion engine. The valve train me chanism is consisting of those parts which actuate the inlet and exhaust valve at the required time with respect to position of piston and crankshaft. In this mechanism the most cruises part is helical spring, maybe it is cheapest than all other parts but if this part is disturbed in functioning all engine work and efficiency will disturbed. Based on the data received from the customer, identify the variable and non-variable parameters and study the requirements of the customer.

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3. METHODOLOGY

Firstlywe take design requirement from the engine manufacturer, then we design the component using CAD software after that we performed CAE analysis using HYPERWORKS tools. If there is mismatch between the design requirement and results then make modification as per condition, then manufacture a final product. After that we perform some physical, then again perform fatigue life cycle analysis using CAE software for itssustainability.

4 .DESIGN REQUIREMENTS

The reciprocating internal combustion engine is that engine in which the combustion is take place inside the engine cylinder. They are differentiate in manly two categories, first one is as per fuel is used and second one a type of stroke is used. Our research is fully based on four stroke engines in which valve train mechanism is used to control breathing of internal combustion engine. The valve train mechanism is consisting of those parts which actuate the inlet and exhaust valve at the required time with respect to position of piston and crankshaft. In this mechanism the most cruises part is helical spring, may beit is cheapest than all other parts but if this part is disturbed in functioning all engine work and efficiency will disturbed.so the focus of our research is design of valve spring there are some basic requirementsfollowed.

Table 1: Design specification

WIRE DIAMETER(mm)	d	1.7 ± 0.02
INNER DIAMETER(mm)	di	15.1±0.25
OUTER DIAMETER(mm)	do	18.5
RATE(N/mm)	k	4.55
FREE HEIGHT(mm)	H_{FREE}	97.60
INSTALLED HEIGHT(mm)	H_{INS}	87.78
WORKING HEIGHT(mm)	H_{WORK}	64.39
SOLID HEIGHT(mm)	H_{SOLID}	57.78

5. COMPUTER AIDED DESIGN

CAD stands for Computer-Aided Design; with the help of computer aided design software we can create new design, modified it or may analysis it also. There are so many cad software are used in industries currently like pro-e, cre-o, catia, solid works etc.CAD software are used to increase the productivity, improve the quality of design, improve communication between deign and requirement virtually. That is not only for mechanical engineering but it is also useful for other engineering's also. That'ssoftware are very useful in automobile industries for making virtual prototype.

The 3d model will be generated by using CATIA V5 software, before generating the 3D model we have to generate the center curve of the spring co-ordinates by using formula. The Y value will be generated based on the pitch of spring. Here are the co-ordinates of the spring.

FIG 1: 3D CAD MODEL OF SPRING

6. DESIGN CALCULATIONS:

- Mean Coil Diameter(D_m):

$$D_m = 15.1 + 1.7 = 16.8 \text{ mm}$$

- Total number of active coils (n):

$$n = \frac{(78450 * 1.7^4)}{(8 * 16.8^3 * 4.55)} = 3.8$$

- Total no of coils (n_t):

$$n_t = 3.8 + 1.5 = 5.3$$

Here, consider 0.75 dead coils on each side

- Spring index (C):

$$C = \frac{16.8}{1.7} = 9.88$$

- Wahl's factor $(k) = \frac{(4*9.88-1)}{(4*9.88-4)} + \frac{0.615}{9.88} = 1.1466$

- Solid height of the spring (H_{solid}):

$$H_{solid} = (5.3 + 1) * 1.7 = 10.71\ mm$$

- Load at Working Height (P_{work}):

$$4.55 = \frac{(190 - P_{work})}{(24 - 44)} \rightarrow P_{work} = 281\ N$$

- Load at Solid Height (P_{solid}):

$$22 = \frac{(P_{solid} - 0)}{(85.75 - 10.71)} \rightarrow P_{solid} = 341.432\ N$$

- Pitch of the spring (P):

$$P = \frac{85.75 - 1.7 - 0}{5.3 - 2} = 25.46\ mm$$

- Pitch helix angle (θ):

$$\theta = tan^{-1}\left(\frac{25.46}{\pi * 16.8}\right) = 25.74^0$$

- Slenderness ratio or Aspect ratio ($\frac{l_o}{D_m}$):

$$= \frac{85.75.}{16.8} = 5.1041$$

- Corrected stress at Installed Height (ζ_{ins}):

$$\zeta_{ins} = \frac{(8 * 16.8 * 190 * 1.1466)}{\pi * 1.7^3} = 1897.0091\ Mpa$$

- Corrected stress at Working Height (ζ_{work}):

$$\zeta_{work} = \frac{(8 * 16.8 * 281 * 1.1466)}{\pi * 1.7^3} = 2805.5767\ Mpa$$

- Corrected stress at Solid Height (ζ_{solid}):

$$\zeta_{solid} = \frac{(8 * 16.8 * 341.43 * 1.1466)}{\pi * 1.7^3} = 3408.9254\ Mpa$$

Table 2 : Co-ordinates of the spring

TURNS	X	Y	Z	TURNS	X	Y	Z
0	0	8.4	0	2.8	-7.988	2.595	22.7
0.2	7.988	2.595	0.34	3	-6.20E-15	8.4	25.0
0.4	4.937	-6.795	0.68	3.2	7.988	2.595	27.4
0.6	-4.937	-6.795	1.02	3.4	4.937	-6.795	29.7
0.8	-7.988	2.595	1.36	3.6	-4.937	-6.795	32.1
1	-2.10E-15	8.4	1.7	3.8	-7.988	2.595	34.4
1.2	7.988	2.595	4.039	4	-8.20E-15	8.4	36.7
1.4	4.937	-6.795	6.378	4.2	7.988	2.595	39.1
1.6	-4.937	-6.795	8.718	4.4	4.937	-6.795	40.4
1.8	-7.988	2.595	11.057	4.6	-4.937	-6.795	40.8
2	-4.10E-15	8.4	13.396	4.8	-7.988	2.595	41.1
2.2	7.988	2.595	15.736	5	-1.00E-14	8.4	41.4
2.4	4.937	-6.795	18.075	5.2	7.988	2.595	41.8
2.6	-4.937	-6.795	20.415	5.3	7.988	-2.595	42

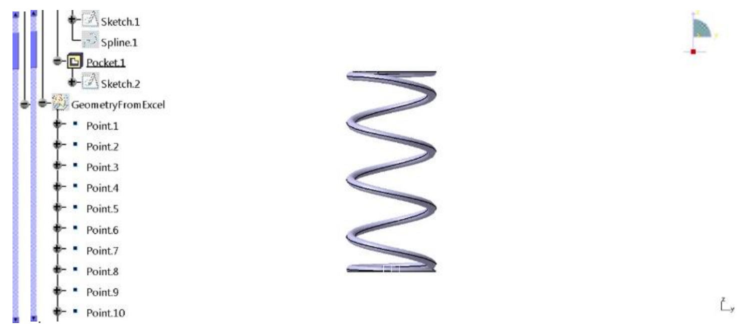
7. CAE ANALYSIS

Generally we have three types of technique to solve any engineering problem, first one is Analytical method in which we reached to our solution through formulas and hand calculations, it is a classical approach , it is assumed to 100 % accurate , but this solution only applicable for simple problems . A second technique is numerical method; it is basically a mathematical presentation of a problem in which we use matrix to solve any engineering problem using CAE software(ABAQUS), in this technique we does not need to make prototype , it is a simple technique in which we design and analysis our product using computer system. Using this technique we can easily test our product, or make changes according to requirements, but the results cannot be believed blindly, we need to verify our results by other any techniques

8. FINITE ELEMENT ANALYSIS FOR THE PRESENT

Generally we have three types of technique to solve any engineering problem, first one is Analytical method in which we reached to our solution through formulas and hand calculations, it is a classical approach , it is assumed to 100 % accurate , but this solution only applicable for simple problems . A second technique is numerical method; it is basically a mathematical presentation of a problem in which we use matrix to solve any engineering problem using CAE software, in this technique we does not need to make prototype , it is a simple technique in which we design and analysis our product using computer system. Using this techniquewe can easily test our product, or make changes according to requirements, but the results cannot be believed blindly, we need to verify our results by other any techniques. A third one technique is physical experiments, in this technique we need to make a real product prototype and test it, if the test will goes failed need to design and modify, and again test is so we can see it was very long term process and very costly also, along with that, we needed an experienced workers for this work. So finally we solved our problem through numerical method, the numerical method basically based on discretization to convert our model from infinite to finite one, assume we have a geometry have infinite number of points, so if we want to analysis it , we have to solve infinite number of equations means we can't achieve the exact solution of our problem. Sowith the help of discretization, divide our model into countable number of nodes and elements, at the end we got final and exact answer of our equation

Fig 2: FEA model



9. .DESIGN

Meshing is process to generate elements in our model or in other term to replace surface or volume by element generation. Basically it is a process of subdivision of geometry in to discrete geometry. There are four types of elements used in mesh generation according to cad model geometry.

10. CONCLUSION

May be considered the cost of valve helical spring is very low as compared to whole engine sub parts, but the failure of valve helical spring can cause major damages in the engine. And also as per the literature the performance and reliability of an engine is depends on valve spring performance, so that is not a negligible thing in the internal combustion engine , although it is most crucial part of the engine and valve train mechanism.

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