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Fatigue Analysis and Experimentation of Two Wheeler Valve Spring

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Abstract: ***Springs are mainly used in the industry as members absorbing shock energy as well as for restoring the initial position of a part upon displacement for initiating a given function. Compression springs are coil springs that resist a compressive force applied axially. In every two-wheeler valve springs play an important role in controlling the breathing in internal combustion engines. The valves are mechanically opened by a camshaft, via valve lifters or tappets, and closed by the valve springs. The analysis would indicate the prominence of the design parameter and its effect over the performance of the spring in terms of fatigue life. The work would be pursued to conclude with a proposal specifying the suitable values (levels) for the significant parameters identified for this study. References are drawn from the literature review as well as the industry. So it is important to calculate the fatigue life and reduce fatigue failure in its intended working period.***

Keywords: Fatigue analysis, Valve compression spring, Geometric modeling, Life analysis, Two wheeler valve.

1. Introduction

A spring is an elastic object used to store mechanical energy. Springs are elastic bodies (Generally metal) that can be twisted, pulled, or stretched by some force. They can return to their original shape when the force is released. In other words it is also termed as a resilient member. A spring is a flexible element used to exert a force or a torque and, at the same time, to store energy. The force can be a linear push or pull, or it can be radial, acting similarly to a rubber band around roll of drawings. Depending on the application, a spring may be in a static, cyclic or dynamic operating mode. Typically, the valve spring is subjected to cyclic loading with a maximum expected frequency of usage at about thousands of cycles per a day. Considering the design life of a two-wheeler at about 15 years, the spring should withstand a cyclic compression loading for about a million times. It has been reported by the warranty/ maintenance department that frequent complaints are being received over the failures of these springs well within their intended life span. The springs must be designed for reliability. The springs must be designed to withstand the cyclic loading during operation.

2. Objective

1) To improve the life and performance of the valve spring, while maintaining or increasing its structural integrity.
2) To reduce the fatigue failure of working components by changing the various design parameter of valve spring.
3) To design the new valve spring by changing the pitch of the spring, material of the spring.

3. Modelling and Analysis of Existing Valve Spring

Reason to use the FEA in valve spring design is it reduces error caused by the simplification of equations. An FEA based design begins with the selection of the element type, how the model should be constructed, how accurate the results should be, and how fast the model should be run. The most accurate FEA results can be obtained by creating 3D model of a valve spring and its followed by meshing the parts with a 3D solid element. Finer meshing with higher order elements in general will produce the most accurate results.

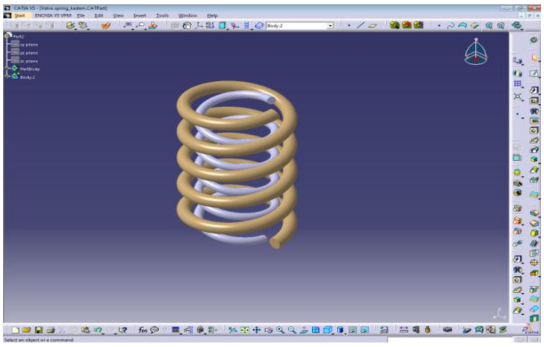

Figure 1: CATIA Model of Existing valve spring

A. Meshing

Meshing involves division of the entire model into small number of pieces called element. It is convenient to select the hex mesh because of high accuracy in result. To mesh the valve spring the element type must be decided first. Here element type is solid. Fig. 2 shows the meshed model of coaxial valve spring.

B. Material

The material used for valve spring is EN 47.The material properties are listed in Table 1.

Table 1: The Material Properties

Density	7850 kg/m^3
Elongation	16
Tensile strength	600-800 MPa
Yield strength	700 MPa
Young's modulus	210000 MPa

C. Loading and Boundary Condition

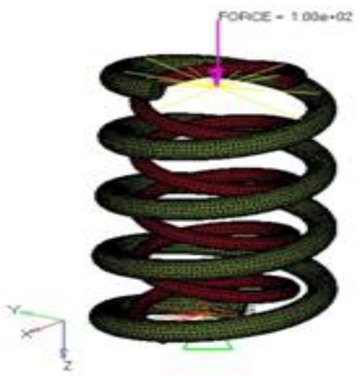

Figure 2: Meshing, Loading and boundary condition

The load is applied along F_z direction. To apply load, it is necessary to select the nodes associated at the centre along z direction. It is necessary to observe the number of nodes associated at the centre along z direction, because the applied load needs to be divided with the number of nodes associated with it. After the pre-processing, the solution has to be done. From solution phase, choose the new analysis as static, then solve the current load step option, the solution will be done. A load of 100 N is applied on the top of the crankpin with rigid element RBE3 at the master node, whereas the boundary condition is applied at the end of the valve spring.

4. Result and Discussion

Static analysis is carried out by using NASTRAN software. And all the output result from this software is read in HYPERWORK software. NASTRAN file contains the result of the analysis such as displacement, max.shear stress and von-misses stresses. The result is shown below.

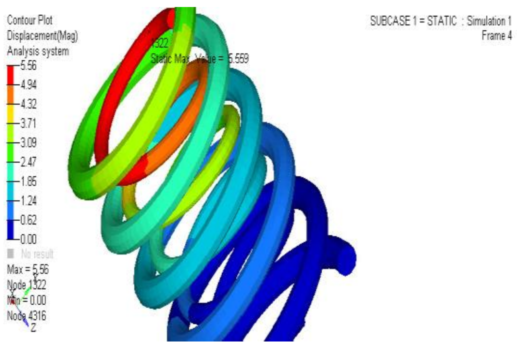

Figure 3: Maximum Deflection of Existing Valve Spring is 5.56 mm.

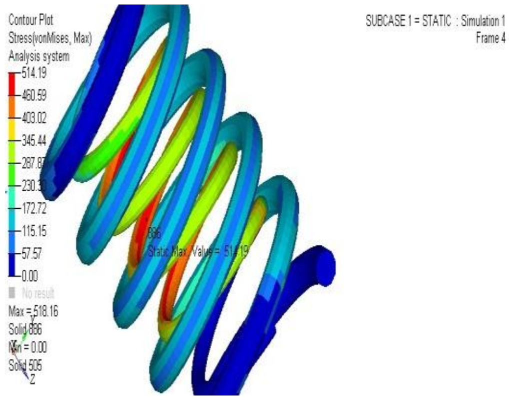

Figure 4: Maximum Von-mises Stress of Existing Valve Spring is 514.19 MPa

A. Fatigue Life

After NASTRAN solver the result file and the input deck file is imported in the MSC FATIGUE software for fatigue life prediction of a given valve spring. Fatigue study is performed to find life of valve spring in terms of number of cycles. The minimum life of existing valve spring is 6.53×10^5 Cycles.

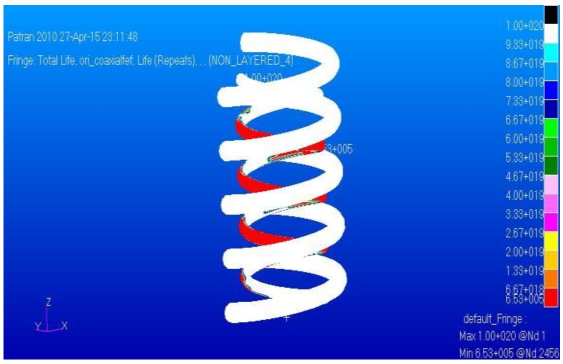

Figure 5: Minimum Fatigue Life of Existing Valve Spring is 6.53×10^5 Cycles

5. Experimentation

Figure 6: Life testing special purpose machine

The experimentation for coaxial valve spring is carried out using a Life Testing special purpose machine. The spring is held in position with other operating conditions identical to the application. Typically, the loading cycles are repeated for a million or more for ensuring that the spring stays intact during its operation. The number of trials is conducted in a very controlled environment with focus on the variables influencing the fatigue life. The trial runs are conducted to ensure consistency/repeatability of the spring behavior. The virtual validation of the spring (simulation using software) should address the given problem during the design selection stage. While the spring is made available in the physical form, the trials and testing would address the phase of validation. Comparison result of existing valve spring shown in table 2.

Table 2: Comparison of Mathematical, FEA and Experimental Result of Existing Valve Spring

Sr. No	*Parameter*	*Mathematical*	*FEA*	*Experimental*
1	Fatigue Life (cycles)	5.21×10^5	6.53×10^5	6×10^5
2	Deflection (mm)	5.71	5.56	5.9
3	Maximum stress (MPa)	485.52	514.19	511

6. Modelling and Analysis of Modified Valve Spring

According to existing work modified spring is designed by changing the pitch of the spring. The pitch of the spring changes to 9 mm where as the valve spring diameter and free length is considered to be same as that of original valve spring design. Spring Specification of the Existing and Modified Valve Spring shown in table 3.

Table 3: Spring Specification

Sr. No	Parameters	Existing Valve Spring		Modified Valve Spring	
		Outer Spring (mm)	Inner Spring (mm)	Outer Spring (mm)	Inner Spring (mm)
01	Outside Diameter	25	18	25	18
02	Inside Diameter	19	14	19	14
03	Wire Diameter	3	2	3	2
04	Pitch	8	7	9	8
05	Mean Coil Dia.	22	16	22	16
06	Total No. of Coil	5	5	5	5
07	Free Length	40	38	40	38

The modified design of valve spring is modelled using CATIA software. The following images show the modified 3D modelling of valve spring.

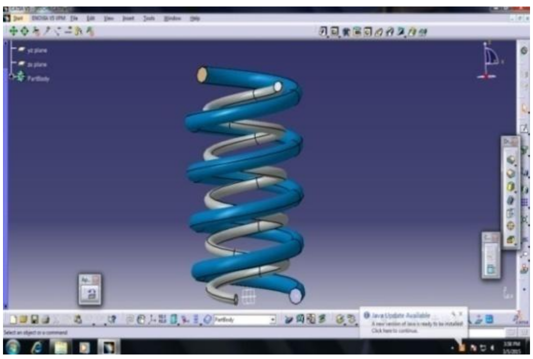

Figure 7: CATIA Model of Modified valve spring

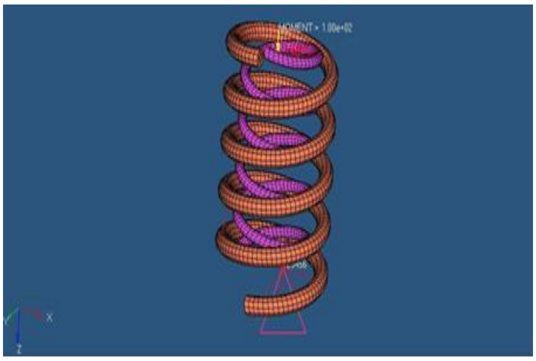

Figure 8: Meshing of Modified Spring

After applying load and boundary condition import HM file to the NASTRAN solver and run the analysis and results are shown below.

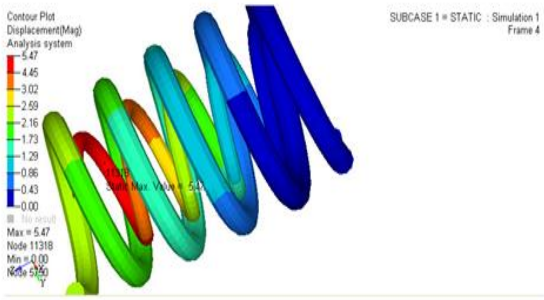

Figure 9: Maximum Deflection of Modified Valve Spring is 5.47 mm

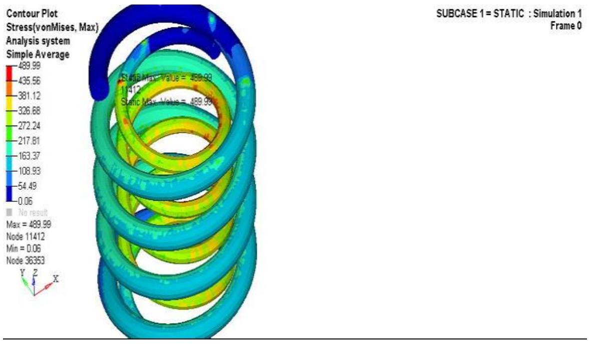

Figure 10: Maximum Von-mises Stress of Modified Valve Spring is 489.99 MPa.

The minimum life shown in the simulation is 9.92×10^5 which is more than required life of the existing valve spring. Hence the modified design also shows the permissible life of fatigue. The result obtained is as shown in figure 11.

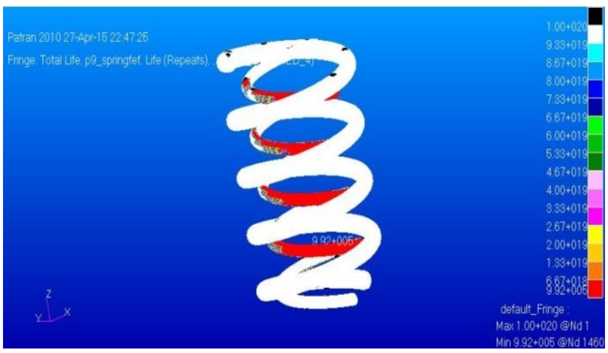

Figure 11: Minimum Fatigue Life of Modified Spring is 9.92×10^5 Cycles

7. Fea Result and Discussion

This section presents the final results for the forming simulations after valve spring is loaded by a force. Maximum stresses are generated inner surface of the spring. Finite element analyses of the valve spring were conducted to obtain stress distributions, determine the critical location of the coaxial spring. Based on the finite element analysis performed for the number of Iteration of a valve spring. The results are summarized as below.

Table 4: Comparison of FEA result

Sr. No.	*Pitch of the Spring (mm)*		*Maximum Deflection (mm)*	*Maximum Von-Mises stress (MPa)*	*Minimum Fatigue Life (No. of cycle)*
	Outer Spring	*Inner Spring*			
Iteration I	6	5	8.47	528.72	2.47×10^5
Iteration II	7	6	6.03	518.16	3.37×10^5
Original	8	7	5.56	514.19	6.53×10^5
Iteration III (Modified)	9	8	5.47	489.99	9.92×10^5
Iteration IV	10	9	4.88	499	4.39×10^5

A. Comparison Result of Existing and Modified Valve Spring

Table 5: Comparison of Mathematical, FEA and Experimental result

Sr. No.	Parameter	Mathematical		FEA		Experimental	
		Existing Spring	Modified Spring	Existing Spring	Modified Spring	Existing Spring	Modified Spring
1	Fatigue Life (cycles)	5.21×10^5	9.23×10^5	6.53×10^5	9.92×10^5	6×10^5	10×10^5
2	Deflection (mm)	5.71	5.84	5.56	5.47	5.9	6
3	Maximum stress (MPa)	485.52	485.52	514.19	489.99	511	504

8. Conclusion

The following important conclusions emerge from this study.

1. In the present work, helical compression spring is modelled and static analysis is carried out by using NASTRAN software. It is observed that the maximum stress is developed at the inner side of the every coil.
2. It can be observed from table 4. Minimum fatigue life of the modified valve spring is 9.92×10^5 cycles which is greater than the fatigue life of existing valve spring.
3. Modified valve spring shows the maximum deflection of 5.47 mm which is less than the deflection of Existing spring.
4. Selecting Iteration III as an optimized valve spring because the maximum Von-Mises stress is to be 489.99 MPa which is less than Von-Mises stress of existing valve spring.
5. Mathematical life of optimized valve spring is 9.23×10^5 cycles which is greater than the mathematical life of existing valve spring.

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