Failure Analysis Of Exhaust Valve Spring Of C.I.Engine

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Abstract

This paper presents the premature fatigue failure analysis of an exhaust valve spring of an constant speed C.I. Engine. The failure is occurring with similar pattern. The fractured surface of springs are examined to evaluate several parameters such as hardness, quenching cracks & microstructure. Everything is found according to specification. Static and Dynamic analysis is done using simulation software (ANSYS) . Mapped meshing using quad mesh was used to obtain more accurate results. It is established from the analysis results that the stiffness of spring is less. The stresses are found concentrated where the failure is occurring.

Keywords:- Exhaust valve spring failure, stiffness, fatigue life.

1. Introduction

The basic function of a spring is to store mechanical energy as it is elastically deformed and then recoup this energy at a later time as the spring recoils. Functionally, springs of this type permit both intake and exhaust valves to alternately open and close, as per the cam profile, while engine is in operation. Rotation of camshaft causes the valve to open and its spring to be compressed, so that the load on the spring then forces the valve to close as the camshaft continues its rotation. This process occurs for each engine cycle and occurs many millions of times over the lifetime of engine.

The spring was designed for 1500 rpm diesel engine and now used in 2200 rpm diesel engine. The failure occurs with 2200 rpm engine, with similar pattern ie. at 1.5 to 2 turns as shown in fig 1. There may be one or more reasons for exhaust valve spring failure. Some of these reasons are due to improper metallurgical properties of spring, improper design etc. The effects of this failure results in deterioration of engine performance (brake power & efficiency), failure of other components eg. cylinder head, valve guide, wear in between valve and cylinder head.

Fig-1. Failed spring

The spring was designed for 1500 rpm diesel engine and now used in 2200 rpm diesel engine. The failure occurs with 2200 rpm engine, with similar pattern ie. at 1.5 to 2 turns. There may be one or more reasons for exhaust valve spring failure. Some of these reasons are due to improper metallurgical properties of spring, improper design etc. The effects of this failure results in deterioration of engine performance (brake power & efficiency), failure of other components eg. cylinder head, valve guide, wear in between valve and cylinder head.

The springs are originally produced from cold drawn, heat-treated and chemically cleaned IS4454 Part-III (2D) steel. The valve spring has a total length of 33.20mm. and is produced from a wire having a diameter of 2.6 mm. It has 6.5 turns and mean coil diameter 23.14mm. Each spring failure amounts to a failure cost of an engine as well. As a practical matter, one would have to weigh the cost of replacing these engines against the cost of spring redesign. Redesign options would involve taking measures to reduce the stresses developed in the spring to increase its fatigue life.

This paper describes the detailed investigations carried out on spring which includes visual examination, optical microscopy, hardness test, die – penetration test and analysis using ANSYS.

2. Experimental procedure

2.1. Visual examination

Visual examination of spring sample revealed a generally smooth surface without any apparent indication of cracks at outer surface. However, the fractured portion of the sample revealed a brighter, shiny surface typical of brittle fracture. The coils of broken spring was observed to be deposited with a layer of corrosion which is due to its exposure to the exhaust gases.

2.2. Optical microscopy

Fig-2 image of material containing phases

The optical microscopy of the spring sample revealed a normal structure (containing ferrite and pearlite phases) typical of high strength spring steel.

2.3. Hardness test

The hardness test is done on Rockwell hardness tester, the hardness is found to be 41.5 HRC which is according to the drawing specification ie between 38 HRC- 48 HRC.

2.4. Die-penetration test

Fig-3 die penetration test

The Die-penetration test is done to see the minor cracks or flaws on the surface. In this test spring surface is first cleaned chemically, after 5-7 min fluorescent colour is sprayed on the surface, then for 10-15 min the surface is kept for drying and then after developer is applied. Now clean the spring with tissue paper and the micro cracks or flows are seen to be glowing under ultraviolet light. The surface is observed generally smooth.

2.5. Analysis using ANSYS

The Geometry was modeled in modeling software pro-e wildfire 4.0 . Then the model was imported into ANSYS workbench 13.0 . The meshing was done with tetrahedral elements. After meshing, the run was done but the results were not so accurate. So to increase the accuracy and bring the analysis to practical condition the mapped meshing was done. Fig-4 shows the ANSYS result in which the equivalent stress distribution are shown. The maximum stress is concentrated at the point where the failure occurs. Fig-5 shows the ANSYS result in which the shear stress distribution is shown. The maximum shear stress is seen at the point where the failure occurs. Fig-6 shows the ANSYS result in which the equivalent elastic strain distribution is shown.

From the results obtained from the ANSYS the force reaction in Y-direction is 122.36N for total displacement ie.15mm. Therefore stiffness can be calculated from the same

Stiffness = force / deflection

The stiffness of spring from above calculated results is 8.15 N/mm, which is less than the specification of the spring. The spring was designed for 1500 rpm and now it is used in 2200 rpm. Engine. The inertia forces have increased and so the reaction force in spring should also be increased. This can be increased by increasing the stiffness of the spring. There are some limitations for

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redesigning the spring. The length of the spring should be kept same so that the other parts can be used without alterations. The new spring is designed by increasing the wire diameter to 3mm from 2.6mm and decreasing the number of coils to 5.5 turns from 6.5 turns. In this spring the stress value will decrease and the reaction force in spring will increase.

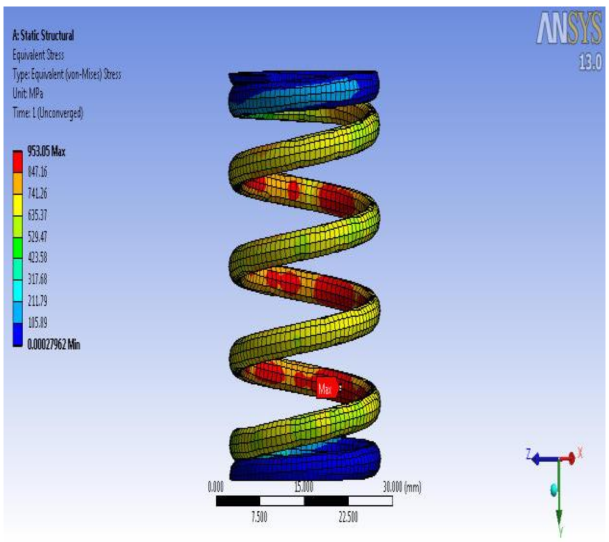

Fig-4 Equivalent (Von-Mises) stress distribution.

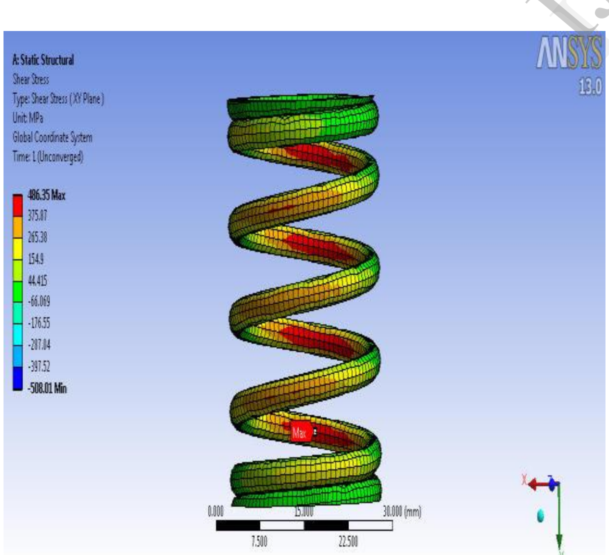

Fig-5 shear stress distribution.

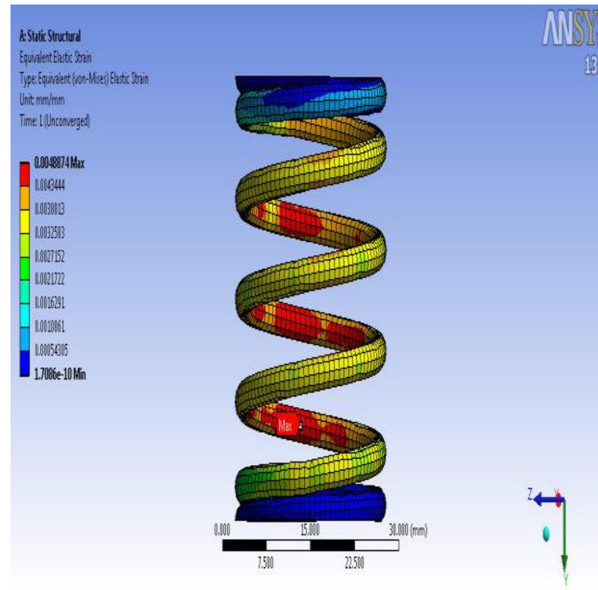

Fig-6 equivalent elastic strain

3. Scope

The spring is to be manufactured according to the new design and then testing is to be done to check the spring failure and performance of the engine.

4. Conclusions

The present exhaust valve spring failure examined is typically caused due to insufficient fatigue life and lesser stiffness of the spring. The spring has sufficient fatigue life for 1500 rpm engine but life decreases as the revolution per minute and inertia forces increases in 2200 rpm engine. The stress seemed to be more localized at the place of failure. There may be a little effect of higher temperature, due to increase in engine speed, in the failure of spring.

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