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VIBRATION TESTING AND PERFORMANCE ANALYSIS OF IC ENGINE EXHAUST VALVE USING FINITE ELEMENT TECHNIQUE

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ABSTRACT

During running condition of engine it allows the burned gasses to go out in the environment through the silencer. Hence the engine valve operated at high pressure and temperature. Also the very important part of its movement is that, it should operate within a fraction of second so as to allow burned mixture to go out. The vibrations at a particular frequency range also can create the resonance phenomenon which can also cause damage of valve. Hence the study of vibrations set up in the valve is very important. In this paper we are testing vibration effects on IC engine exhaust valve and also finding out the natural frequency of valve to identify the resonance phenomenon frequency level. The obtained results and effects are illustrated further so as to prevent valve damage. To perform overall process. Finite Element Technique is very useful and convenient which provides better approximate solution. Exhaust valves are exposed to thermal stress more than intake valve because intake valve are virtually cooled by fresh air. However burnt gases have very high temperature in the range of 800 to1000^{0}C because of this frequency of failure of exhaust valve is higher than inlet valve.

Keywords: Exhaust Valve ,CatiaV5, Ansys14.5

I. INTRODUCTION

Two stroke engine valves operated at high loading condition. Due to this failure chances are more. So it needs regular inspection and maintenance so as to reduce failure chances. Hence the operating cost will gate reduced and the life of component is more. Wear effects will produce various issues related to failure, but due to regular inspection and maintenance we are able to increase the life of component. As the valve material is hardest and having good working properties, there are less chances of damage due to the resonance effect. But we know that exhaust valve operates at high temperature and hence at high working temperature there are chances of losing the properties and may get damaged due to vibration. The vibrations are specified in the form of frequency in this paper. The study illustrates the effects of vibration on exhaust valve at high temperature.

II. LITRATURE SURVEY

Following litratures are studied ,

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[3]Miroslaw Wendeker, Pawel Magryta,Adam Majczak, Michal Bialy Modeling the thermal loadsnin the SUBARU EJ25 Engine Lublin University ofb Technology, Nadbystrzycka Street 36/605A, 20- 618 Lublin, Poland, email: p.magryta@pollub.pl, mJournal of KONES Powertrain and Transport, Vol. 18, No. 1 2011

[4] A. Hornik, D. Jędrusik, K. Wilk Unsteady state heat flow in the exhaust valve in turbocharged Diesel engine covered by the layer of the carbon deposit Department of Automotive Vehicle Service, Faculty of Transport, Silesian University of Technology, ul. Krasińskiego 8, 40-019 nKatowice, Poland, International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering,
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[5] M. Azadi1*, M Roozban2, A. Mafi ,Failure analysis of an intake valve in a gasoline engine
Fatigue and Wear Workgroup, Irankhodro Powertrain Company (IPCO), Tehran, Iran,
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III. MODES OF FAILURES OF VALVES

Following are different types of failure and their causes of inlet & exhaust valve.

Failure Due to Fatigue

The meaning of word fatigue means "to tire" which is derived from latin word "Fatigue". In engineering language/terminology fatigue failure is a progressive structural damage of the material of the component when the component under goes cyclic loading. There are two important categories of fatigue failure a) Mechanical failure due to fluctuating stresses due to cyclic load at high temperature. b) Thermal fatigue due to cyclic changes in component material temperature.

3.2 Failures Due to High Temperature

Exhaust valves operate at very high temperatures usually above 6000 C and are subjected to cyclic loading. The failure of the conical surface/sealing area of valve is mainly caused by the elastic and plastic deformation. Exhaust valve stem generally fails by overheating because the temperature of the exhaust valve is about 600 ºC. The fracture surface of the valve stem is covered with a black oxide scale formation. Fracture surface in the fatigue area is smooth and is covered with thick oxide or deposits that cannot be removed satisfactorily.

Failure of Valve Due to Erosion-Corrosion

Surface material is removed in service life and it is the result of erosion by small, solid, impacting particles. In most elevated - temperature erosion environments, the eroding surface is undergoing corrosion as well as erosion. In one test series, a nickel oxide scale was formed up to 100 µm thick at1000ºC on commercially pure nickel

Failure of Valve Due to Vibrational Effects

Exhaust valves are exposed to thermal stress more than intake valve because intake valve are virtually cooled by fresh air. However burnt gases have very high temperature in the range of 800 to1000^{0}C because of this frequency of failure of exhaust valve is higher than inlet valve

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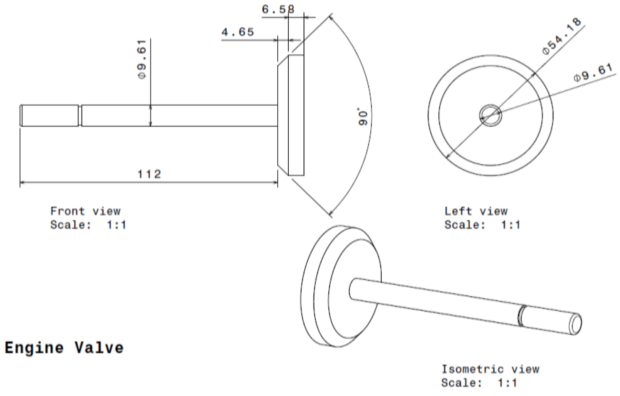

Fig.3 Geometry of Valve

IV. VALVE MODELING PROCESS BY CATIA SOFTWARE

There are several CAD software are available for 3D modeling. To model the exhaust valve we have chosen CATIA V5.

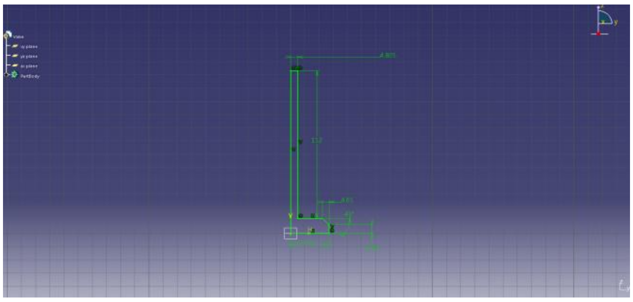

Fig. 4 : Sketch in CATIA

4.1 3D Model of Trapozoidal Section

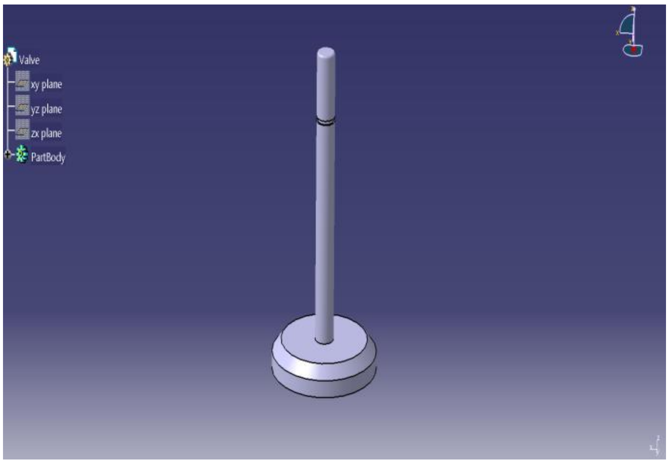

Fig. 5 : CAD Model

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V. PERFORMING VIBRATION ANALYSIS

To perform vibration analysis on exhaust valve we have to go through the model analysis with FEA software. Vibrations set up in valve can be measured in Hz with its maximum deformation values in mm. Model analysis is nothing but an vibration analysis where the vibrations are measured in the form of frequency range set up in valve during vibrations.

Here ANSYS is the FEA package that we are using for performing vibration analysis over exhaust valve.

VI. VALVE MATERIAL

While performing analysis on valve we need to assign initial and boundary conditions of valve. The material properties of valve are the important factors for performing vibration analysis. Due to hardness at room temperature (50 Rockwell C) for Steel alloys with a martensitic grain structure after tempering, properties like strength, wear resistance improve extensively. Such characteristics of valve material are good for long life of valve with efficient performance and high corrosion resistance.

6.1 Material Properties Of Structural Steel

A shank end of crane hook is fixed and a loads are applied on bunch of nodes at lower centre of hook in downward direction. A load of 1ton (9806N) is taken for analysis. First material selected for crane hook is Structural Steel and the properties of material are given below:

Structural Steel > Constants

Density	7850kgm^-3
Coefficient of Thermal Expansion	1.2e-005C^-1
Specific Heat	434Jkg^-1C^-1
Thermal Conductivity	60.5Wm^-1C^-1
Modulus of elasticity	2.5e05Mpa
Poissons Ratio	0.3

Structural Steel>Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+008

Structural Steel > Tensile Ultimate Strength

Tensile Ultimate StrengthPa
4.6e+008

Reference Temperature C
22

Chemical Composition of Structural Steel

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Element	Content (%)
Vanadium,V	0.03-0.08
Carbon, C	0.15-0.30
Phosphorus,P	0.04-0.05
Silicon, S	0.02-0.4
Nickel,N	0.25-1.25
Mangnese, Mn	0.50-1.70

Maximum Nodes = 12180
Maximum Nodes = 7499

VII. MESHING OF EXHAUST VALVE

Meshing is nothing but converting entire object into small number of pieces which are connected to each other by means of connecting points. Each small piece of an object is called as element and the connecting points are called as nodes. It is one of the important step in FEA to carry out required solution. For generation of meshing of exhaust valve we are 3D tetrahedron element. This process is also called discretisation process. Following figure 2 shows the meshed view of an exhaust valve. using Exhaust vale meshing details with respect to nodes and elements.

Maximum Nodes = 18015

Maximum Elements = 87269

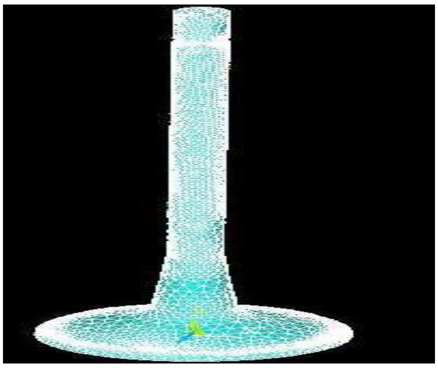

Figure 6: Meshed view of exhaust valve.

VIII. INITIAL AND BOUNDARY CONDITION FOR EXHAUST VALVE

Constraining of valve for vibration analysis is done by applying initial and boundary conditions. Valve geometry is constrained at the top in all directions. In vibration analysis vibration modes can be simulated by applying density value and other property values. Five modes of frequencies are obtained in vibration analysis after applying initial and boundary conditions. Maximum value of frequency will define safer object on vibration point of view.

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IX. GENERATION OF VIBRATION ANALYSIS SOLUTION

Solution for vibration analysis is obtained with five different mode sets and their respective deformations. Each mode specifies the vibration range in the form of frequency and maximum deformation at that frequency level. FEM technique is used to find out these mode frequencies. FEA tool is used for that purpose. Calculated results are studied to obtain conclusions. Maximum deformation is observed in the valve at the fifth mode of vibration. Here the frequency value is also greater than other frequency values in different modes. And this maximum frequency value also called natural frequency of exhaust valve. Exhaust valve may damage due to high vibrations at resonance frequency value which slightly greater than natural frequency of exhaust valve.

X. ANALYSIS RESULTS

The maximum value of frequency is 1511.3 Hz is obtained while performing vibration analysis on exhaust valve. This is the natural frequency value for exhaust valve. Above this value resonance phenomenon will accurse. All the frequency values are tabulated in following table for various modes of frequency.

Table:1 Frequency values and their deformationfor each set

SET	FREQUENCY	LOADSTEP	SUBSTEP
1	139.635 Hz	1	1
2	139.99 Hz	1	2
3	845.76 Hz	1	3
4	1502.2 Hz	1	4
5	15011.3 Hz	1	5

XI. MODES AND VIBRATIONS

11.1 Mode One Vibrations

In this mode the observed frequency value is 139.635 Hz with maximum deformation 128.058mm. The deformation is observed at the bottom side of the valve. But as this portion is placed on valve sheet, this deformation is reduced.

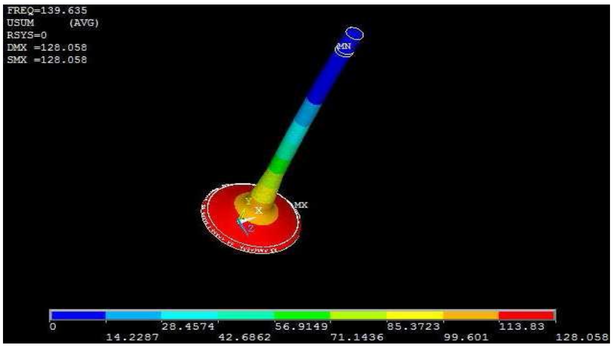

Figure 7: First mode of vibration with possible deformation

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11.2 SECOND MODE OF VIBRATION:

In this mode the deformation is reduced with negligible increment in frequency. The frequency value is observed to 139.986 Hz with deformation 128 mm. This deformation and frequency will not affect performance of valve.

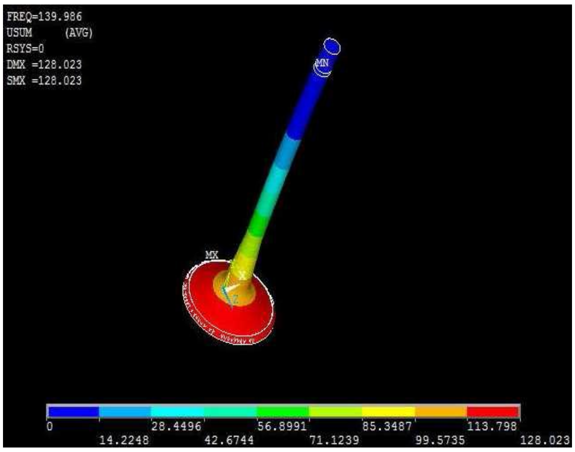

Figure 8: Second mode of vibration with maximum deformation

11.3 Mode Three of Vibration:

In this mode frequency suddenly increases with value 8 45.759 Hz with maximum deformation 218.317 mm. This deformation is large with frequency. But it is maximum allowable deformation. In actual condition there will not be such large deformation because of

constraints available

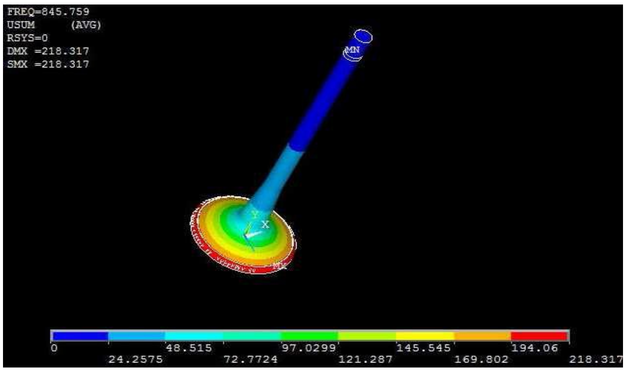

Figure 9: Third mode of vibration with allowable deformation.

11.4 Mode Four Of Vibration:

Here also the frequency value increases. But increment is large with reduction in deformation.

Maximum value of frequency is 1502.24 Hz with deformation of 203.93 mm. In this mode deformation is reduced as compare to third mode.

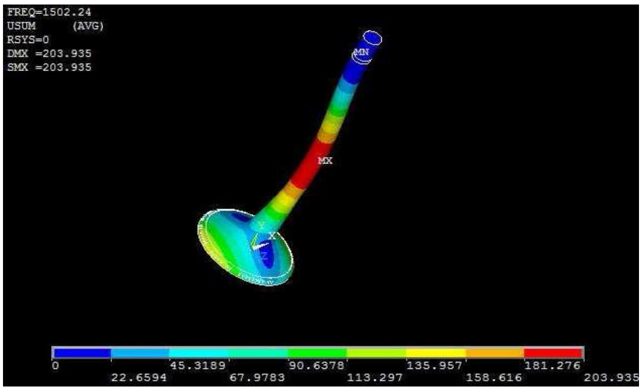

Figure 10: Fourth mode of vibration with frequency and deformation

11.5 Mode Fifth Of Vibration:

In this mode maximum deformation is 203.95 mm with maximum frequency 1511.34 Hz. Above this value valve may damage. Stem of valve is most affected zone. This maximum frequency is natural frequency of valve.

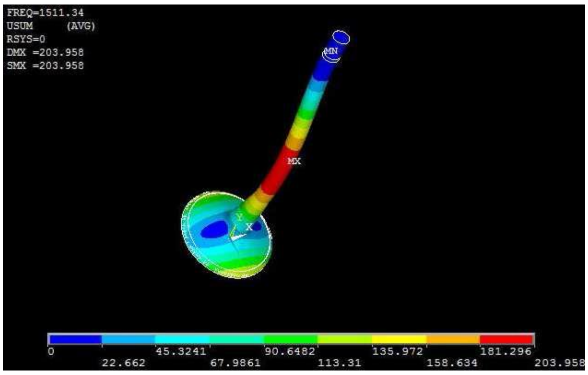

Figure 11: Maximum frequency with maximum deformation

RESULT

SET	FREQUENCY	DEFORMATION
1	139.63 Hz	0.128 mm
2	139.98 Hz	0.128 mm
3	845.75 Hz	0.218 mm
4	1502.24 Hz	0.203 mm
5	1511.34 Hz	0.203 mm

Table 2: Frequency values and their deformationfor each set

Below table have frequency values and deformations for each mode of vibration.

XII. CONCLUSIONS

By studying all five modes of vibrations we can conclude following points.

1. Deformation and frequency value in first and second mode of vibration is approximately same.
2. Deformation is large in all modes of vibration and needs to reduce.
3. Maximum frequency of valve provides better stability.
4. For deformation in each mode, constraints are required.

5. Exhaust valve have a good frequency but deformation needs to reduce.

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