*International Journal of Research in Advent Technology, Vol.2, No.2, February 2014*

*E-ISSN: 2321-9637*

# 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 rapid movement of engine valves may creates vibrations during working condition of valve. If the working temperature of valve is above 150 0C, then vibrations may bend it permanently. 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.

***Index Terms***- Finite Element Technique, IC Engine, Exhaust valve.

## 1. INTRODUCTION

Exhaust valve always works under a huge amount of temperature and pressure with mechanical loading. Due to this failure of valve accurse and it gate damaged before completing its lifespan. But it is also observed that vibrations at a particular temperature also damage the valve. Some failures of valve are discussed bellow.

During working of IC engine exhaust valve thermal and mechanical stresses affects the valve and may failure accurse. Wearing, fatigue and corrosion are the possible defects on the valve. These defects affect the proper working of valve. As the exhaust valve undergoes the high thermal and mechanical stresses, it should withstand to those stresses and allow exhaust gasses to go out. Proper functioning of exhaust valve increases the power efficiency of the engine also the knocking resistance. While investigation of exhaust valve using several experimental tests including optical emission spectroscopy, optical microscopy, scanning electron microscopy SEM and EDX it is found that there is change in their metallurgical properties. Here failure of valve accurse before stipulated life time. [1]

In IC engines valves are used to control the flow and exchange of gases with the environment. These valves are spring loaded and always are in spring tension. When these valves work under high temperature and pressure, its hardness, yield strength affected and failure may accurse. A combined S-N (max. stress v/s number of cycles) curve can illustrate the material behavior under thermal or mechanical loading condition of valve. The overall objective of doing investigation is to predict the failure of valves. Results obtained by this analysis are helps to predict the failure and improves the life of the valve. [2]

Sometimes due to the overloading of engines, it is observed that valves are getting damaged as it undergoes huge thermal and mechanical loading. Example is Subaru EJ25 engines, which are currently mounted in passenger cars such as Subaru Impreza. The valves are tested for thermal loads and accordingly conclusions are drawn. [3]

Some studies are done to find out temperature difference, thermal gradient, thermal stresses in the exhaust valve. For this purpose finite element method is used and results are drawn with specific conclusion. Due to the combustion process in the chamber the layer of carbon is deposited on the exhaust valve which affects the metallurgical properties of valve material and there is possibility of valve failure. [4]

Above studies are carried out on exhaust valve with thermal loadings. There are also few studies are available on intake valve which provides extra knowledge for understanding valve problems.

Due to the misalignment of valve shaft the failure of valve accurse. While endurance test of failed valve no defects are observed in the microstructure of valve

material. There was no change in the hardness of the valve material. Valve was placed by misalignment and due to the thermal loading it gets deformed. Proper alignment of valve also plays important role for valve failure. The cracks are observed on the valve shaft and hence it was one more cause of failure. [5]

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. [6]

From above investigations we also understand the causes of failure of exhaust valve. But there is very less information available on vibration effects on exhaust valve. This may be the causes of failure. 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.

## 1. VALVE MODELING PROCESS IN CAD SOFTWARE

There are several CAD software are available for 3D modeling. To model the exhaust valve we have chosen Pro-E. Because it contain better neutral file format conversion properties. Also the modeling is very simple in part module of Pro-E. Pro-E 5.0 creo element is the latest version that we have used for modeling. Various required dimensions are taken by reverse engineering method from exhaust valve. Further this CAD model is converted into IGES (Initial Graphics Exchange Specification) format. The detailed CAD model view is as shown in figure 1.
To model exhaust valve a simple commands are used. It exactly simulates the actual exhaust valve with respect to dimensions. After conversion into IGES format that is in neutral file format, converted file can be used to perform vibration analysis.

### *1.1 VIBRATION ANALYSIS*

Simulation of behavior of an object during vibrating condition with possible deformations in all direction is called as Vibration Analysis. As we know the exhaust valve operates at high temperature and high structural stresses, there are possibilities of vibrations during working. To study the behavior of valve during vibrations, vibration analysis must be carried out.

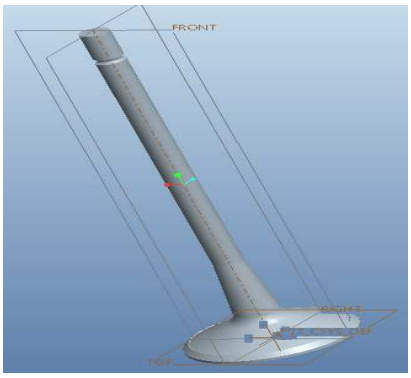


Figure 1: CAD model of exhaust valve in Pro-E software.

### *1.2 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.

### *1.3 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. There are several properties of valve material are available. Few of those are used for analysis. We know that for exhaust valve Steel alloys with a martensitic grain structure are commonly used as a valve material. Several properties of this alloy like density, Poisson's ratio, young's modulus etc are implemented while 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.

### *1.4 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 using

3D tetrahedron element. This process is also called discretisation process.
Following figure 2 shows the meshed view of an exhaust valve.

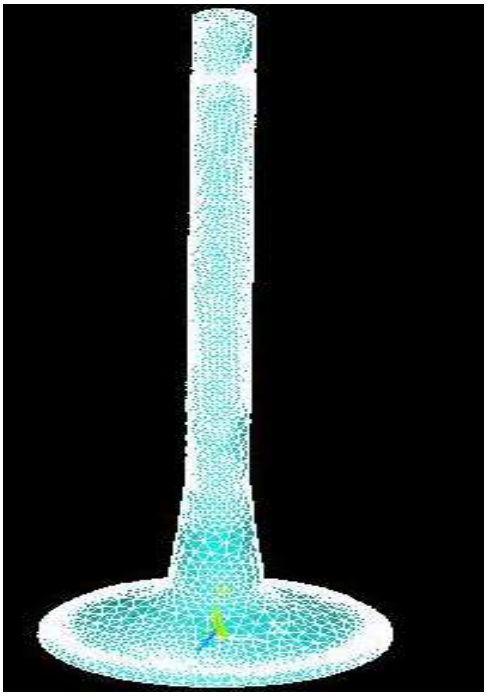

Figure 2: Meshed view of exhaust valve.

Exhaust vale meshing details with respect to nodes and elements.
Maximum Nodes = 18015
Maximum Elements = 87269

## 2. 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.

### *2.1 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.

### *2.2* ANALYSIS RESULTS WITH DISCUSSION

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 for five modes.

| 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 |

## 3. MODES AND VIBRATIONS

### *3.1 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.

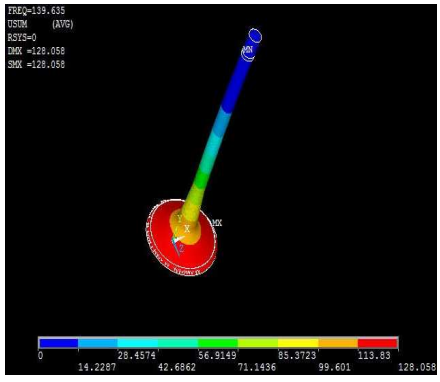


Figure 3: First mode of vibration with possible deformation

### *3.2 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.

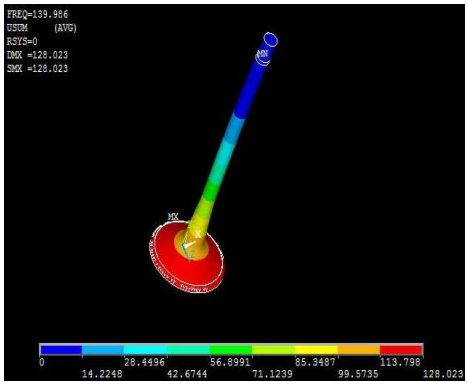


Figure 4: Second mode of vibration with maximum deformation.

### *3.3* MODE THREE OF VIBRATION:

In this mode frequency suddenly increases with value 845.759 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.

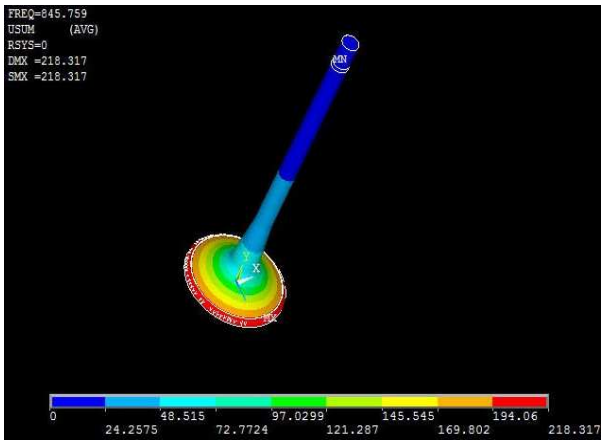


Figure 5: Third mode of vibration with allowable deformation.

### *3.4* 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.

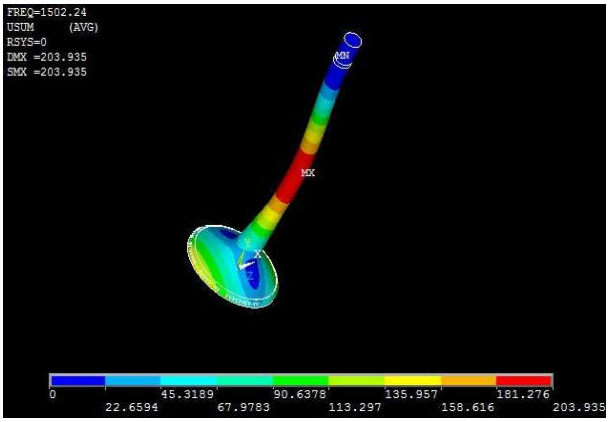


Figure 6: Fourth mode of vibration with frequency and deformation

### *3.5* 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.

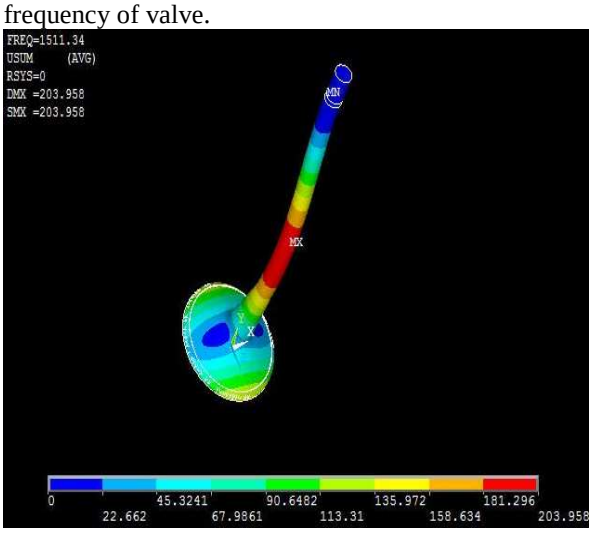


Figure 7: Maximum frequency with maximum deformation.

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

**Table 3: Frequency values and their deformation for each set.**

| SET | FREQUENCY | DEFORMATION |
|---|---|---|
| 1 | 139.63 Hz | 128 mm |
| 2 | 139.98 Hz | 128 mm |
| 3 | 845.75 Hz | 218.31 mm |
| 4 | 1502.24 Hz | 203.93 mm |
| 5 | 1511.34 Hz | 203.95 mm |

## 4. 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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