FATIGUE ANALYSIS AND LIFE ESTIMATION OF AN OUTLET VALVE FOR DIESEL ENGINE

Guguloth Ravi¹, Banoth Shankar², and Thokala Vikram³

¹,²Department of Mechanical Engineering, Swarana Bharathi Institute of Science and Technology
³Department of Mechanical Engineering, Sreekavitha Engineering College

Abstract—The valves used in the IC engines are of three types: Poppet or mushroom valve or Sleeve valve or Rotary valve. Of these three types, Poppet valve is most commonly used. Since both the inlet and exhaust valves are subjected to high temperatures of 1930°C to 2200°C during the power stroke, therefore, it is necessary that the materials of the valves should withstand these temperatures. In this project, we have taken the materials EN 24, titanium and nickel chromium alloy steel instead of steel. The aim of the project is to design exhaust valve using the theoretical calculations for a 150cc engine. 2D drawings of the valve are drafted and 3D model is drawn in parametric software Pro/Engineer. To validate the strength of the valve which is designed according to calculations, structural analysis is done on them by applying forces. In structural analysis the ultimate stress limit for the design is found. Modal analysis is done on the valve to validate the mode shapes for number of modes. Frequency analysis is done to determine the natural frequencies. Fatigue analysis is also done to determine life, damage and safety factor. Analysis is done using ANSYS

Index Terms—Poppet, mushroom valve, Sleeve valve, Rotary valve, EN 24, titanium and nickel chromium alloy steel, Fatigue analysis.

I. INTRODUCTION

All four-stroke internal combustion engines employ valves to control the admittance of fuel and air into the combustion chamber. Two-stroke engines use ports in the cylinder bore, covered and uncovered by the piston, though there have been variations such as exhaust valves. In piston engines, the valves are grouped into 'inlet valves' which admit the entrance of fuel and air and 'outlet valves' which allow the exhaust gases to escape. Each valve opens once per cycle and the ones that are subject to extreme accelerations are held closed by springs that are typically opened by rods running on a camshaft rotating with the engines' crankshaft. Continuous combustion engines—as well as piston engines—usually have valves that open and close to admit the fuel and/or air at the startup and shutdown. Some valves feather to adjust the flow to control power or engine speed as well. A poppet valve is a valve consisting of a hole, usually round or oval, and a tapered plug, usually a disk shape on the end of a shaft also called a valve stem. The shaft guides the plug portion by sliding through a valve guide. In most applications a pressure differential helps to seal the valve and in some applications also open it.

Design Calculations Of Outlet Valve

Design of outlet valve

Material: Silchrome steel

A. size of valve port

\[ a_p \cdot v_p = aV \]

\[ V_p = 90\text{m/s} = 90000\text{mm/s} \]

\[ a_p = \frac{(2550.465 \times 11720)}{90000} \]

\[ d_p = \frac{\pi}{4} \left( \frac{d_p}{a} \right)^2 \]

\[ d_p = 20.56\text{mm} \]

B. thickness of valve disc

\[ t = Kd_p \sqrt{\left( \frac{p}{\sigma_b} \right)} \]

\[ t = .42 \times 20.56 \sqrt{\left( \frac{10.93615.454}{100} \right)} = 3.39\text{mm} = 3.4\text{mm} \]

C. maximum lift of the valve:

\[ h = \text{lift of the valve} \]

\[ a = 30^0 \]

\[ h = d_p (4 \cos a) = 20.56/4 \times 30^0 = 20.56/3.46 = 7\text{mm} \]

D. valve steam diameter:

\[ ds = 24.25/8 + 6.35 \text{ or} \]

\[ ds = 3.03 + 6.35 \]

\[ ds = 9.38 \text{ (or) 1403mm} \]

\[ \tan a = (2h+t)/(\text{dv/s}) = (2h+t)/d_v \]

\[ \tan 30 = (2(3.367])/d_v \]

\[ d_v = 20.72/0.577 = 35.9\text{mm} = 36\text{mm} \]
II. LITERATURE SURVEY

In four stroke engines with flexible valve actuation, there are several strategies for internal EGR. One is the rebred a thing strategy of [Law et al2001] where the exhaust valve remains open throughout the intake stroke; another is the exhaust recompression strategy [Zhao et al., 2002].[Milovanovic et al.2004] demonstrated that the variable valve timing strategy has a strong influence on the gas exchange process, which in turn influences the engine parameters and the cylinder charge properties, hence the control of the HCCI process. The EVC timing has the strongest effect followed by the IVO timing, while the EVO and IVC timing have the minor effects. [Caton et al.2005] showed that the best combination of load range, efficiency, and emissions may be achieved using a rein diction strategy with variable intake lift instead of variable valve timing. However, no strategy is able to obtain satisfactory HCCI combustion at near idle loads. Also, under high levels of internal EGR the emissions are rein gested in the engine and have an extra chance to be burned in the next cycle.

Three dimensional time dependent CFD simulations of auto ignition and emissions were reported for an idealized engine configuration under HCCI like operating conditions [M.diaz et al.,2005]. The emphasis is on NOx emissions. Detailed NOx chemistry is integrated with skeletal auto ignition mechanisms for Neptune and isoctane fuels. A storage/retrieval scheme is used to accelerate the computation of chemical source terms, and turbulence/chemistry interactions were treated using a transported probability density function (PDF) method. Simulations include direct in cylinder fuel injection, and feature direct coupling between the stochastic Lagrangian fuel spray model and the gas phase stochastic Lagrangian PDF method. For the conditions simulated, consideration of turbulence/chemistry interactions is essential. Simulations that ignore these interactions fail to capture global heat release and ignition timing, in addition to emissions. For these lean, low temperature operating conditions, engine out NOx levels are low and NOx pathways other than thermal NO are dominant. Engine out NO2 levels exceed engine out NO levels in some cases. In cylinder in homogeneity and unmixedness must be considered for accurate emissions predictions. These findings are consistent with results that have been reported recently in the HCCI engine literature.

In 2002 a study introduces a modeling approach for investigating the effects of valve events In a model based control strategy, to adapt the injection settings according to the air path dynamics on a Diesel HCCI engine, researcher complements existing air path and fuel path controllers, and aims at accurately controlling the start of combustion [M.Hillion et al, 2011]. For that purpose, start of injection is adjusted based on a Knock Integral Model and intake manifold conditions Experimental results were presented, which stress the relevance of the approach.

Many Numerical and experimental investigations were presented with regard to homogeneous charge compression ignition for different fuels. In one of the dual fuel approach, Neptune and butane were considered for covering an appropriate range of ignition behavior typical for higher hydro carbons [Barroso.G et al., 2005].Starting from detailed chemical mechanisms for both fuels, reaction path analysis was used to derive reduced mechanisms, which were validated in homogeneous reactors and showed a good agreement with the detailed mechanism. The reduced chemistry was coupled with multi zone models (reactors network) and 3D CFD through the Conditional Moment Closure (CMC) approach. Many Numerical and experimental investigations were presented with regard to homogeneous charge compression ignition for different fuels. In one of the dual fuel approach, N heptanes and n butane were considered for covering an appropriate range of ignition behavior typical for higher hydro carbons[Barroso.G et al.,2005].Starting from detailed chemical mechanisms for both fuels, reaction path analysis was used to derive reduced mechanisms, which were validated in homogeneous reactors and showed a good agreement with the detailed mechanism. The reduced chemistry was coupled with multi zone models (reactors network) and 3D-CFD through the Conditional Moment Closure (CMC) approach. HCCI is an alternative and attractive combustion mode for internal combustion engines that offers the potential for high diesel like efficiencies and dramatic reduction in NOx and PM [Sjöberg et al., 2005]. HCCI occurs as the result of spontaneous auto ignition at multiple points throughout the volume of the charge gas and each auto
ignition may or may not produce a flame front. In order to control the energy release rate to acceptable levels the engine must be operated with high levels of dilution, exhaustor extra air, which results in significantly reduced pumping losses for SI engines and lower peak burned gas temperature. With appropriately higher compression ratio and less heat loss due to low combustion temperature; the thermal efficiency approaches the levels of CI engines. The low combustion temperature also dramatically reduces NOx emissions [Dickey et al., 1998]. Unlike conventional diesel combustion, the charge is well mixed, so PM emissions can be very low. With increasingly stringent emissions legislation

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**III. STRUCTURAL ANALYSIS OF OUTLET VALVE**

**A. Material - En24**

![Fig 1: Valve Displacement](image1)

![Fig 2: Total Deformation](image2)

![Fig 3: Von-Mises Stress](image3)

![Fig 4: Von-Mises Strain](image4)

**B. Material - Titanium**

![Fig 5: Total Deformation](image5)

![Fig 6: Von-Mises Stress](image6)
IV. FATIGUE ANALYSIS OF OUTLET VALVE

A. Material - En24

B. Material - Titanium

C. Material - Steel

V. RESULTS TABLES

Static Analysis:

<table>
<thead>
<tr>
<th>Material</th>
<th>Deformation (mm)</th>
<th>Stress (N/m²)</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN24</td>
<td>0.18943</td>
<td>3.193</td>
<td>0.003195</td>
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</table>
Fatigue Analysis:

**Table 2:**

<table>
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<tr>
<th>Material</th>
<th>Life</th>
<th>Damage</th>
<th>Safety Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN24</td>
<td>1E6</td>
<td>2.3524E6</td>
<td>15</td>
</tr>
<tr>
<td>TITANIUM</td>
<td>1E6</td>
<td>1E32</td>
<td>15</td>
</tr>
<tr>
<td>STEEL</td>
<td>1E6</td>
<td>1.844E5</td>
<td>15</td>
</tr>
<tr>
<td>NICKEL</td>
<td>700</td>
<td>1.4441E6</td>
<td>15</td>
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</tbody>
</table>

Graphs
VI. CONCLUSION

To validate the strength of the valve which is designed according to calculations, structural analysis is done on them by applying forces. In structural analysis the ultimate stress limit for the design is found. By observing the materials, the stress values for all materials are less than their respective yield stress values. When compared the values between materials, the deformation and stress values are less for Titanium alloy. Modal analysis is done on the valve to validate the mode shapes for number of modes. Frequency analysis is done to determine the natural frequencies. When compared the values between materials, the deformation and frequency values are less for Nickel alloy. Due to lesser frequencies, vibrations will be less. Fatigue analysis is also done to determine life, damage and safety factor. By observing the results, the life is more when Steels are used. The damage factor is more for Titanium alloy (i.e) the valve will be failed if the applied load is multiplied with the damage value. Since the damage value is more for Titanium alloy, the valve when Titanium alloy is used will fail at very larger loads.

REFERENCES


