

Investigations on Valve Recession of a Commercial Vehicle Engine

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ABSTRACT

Investigations on valve recession of a commercial vehicle engine inlet valve are done. Failure analysis of inlet valve of a six cylinder commercial vehicle engine developing power of 155 BHP is carried out using the software tools IDEAS and TYCON. Failed engine valves are investigated and concluded that the mode of failure of most of them is valve recession, the possible factors responsible for the valve failure are analyzed including the metallurgical properties of the valve. Combustion force, impact force during closure of the valve are the major factors responsible for valve recession. The valve seat angle is considered in the analysis to find if the change in this angle is helpful in increasing the life of the valve. The prevailing wear mechanism has been shown related to the critical operating conditions such as valve closing velocity, combustion load, valve misalignment relative to the seat insert and seat insert material choice. Besides this, the wear volume of the valve face was found to change with valve material, engine operation conditions, geometries, and dynamics changed. Besides adhesion, abrasion, and corrosion associated wear mechanisms, shear strain was found to be additional major wear mechanism. After detailed analysis, it has been noticed the change in valve seat angle, valve material and plasma coatings on the valve improve the life of the valve.

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INTRODUCTION

Despite the great strides forward that have been made in technology, failures continue to occur, often accompanied by great human and economic loss. One of such problems related with engine valve train is the failure of engine valves. There are three common modes of failure in conjunction with engine valves, they are valve recession, valve guttering and torching [1]. The present work in this paper discussed is related to the valve recession problem occurs due to the wear of valve in the valve face. Engine with six cylinders placed in-line with bore 97 mm and stroke 100 mm is considered for the analysis. The average life of the inlet valve is found to be 30000 km run of vehicle. The valve recession is due to the forces on the valve face resulting in wear shown in the [Figure 1](#). Valve recession is caused due to wear of valve over valve-seat area.

Forces on the valve, wear volume are analytically calculated and experimental model is built based on predefined models already existed [2].

The wear occurs by metal abrasion, high temperature corrosion, frictional sliding, and adhesion mechanisms. Valve

recession gradually increases over a large number of cycles during operation. The following mechanisms are ascertained for the valve recession, Impact wear, sliding, abrasion, adhesion and high temperature corrosion. Frictional sliding between the valve-seating face and the seat insert has been cited as a major cause of valve recession [3].



Figure 1. Valve recession

1. INLET VALVE

The inlet valves considered for the analysis are made of EN52 steel (5Cr9Si3), they are operated in a harsh

environment under high temperatures. They are subjected to an impact force on closing followed by a much higher load imposed during combustion in the cylinder, forcing the valve into the seat insert. Seating may occur under dry conditions, the valve seating faces may reach temperature up to (600 to 700) degrees centigrade. These temperatures can cause cylinder distortion. The valves are encouraged to rotate by off-setting the cams on the followers and using free rotating collets. This is to even out wear and help grind away deposits to prevent hot spots forming. The valve seat angle considered in this work is 45°.

1.1. Causes of Valve Recession

Frictional sliding

The contact area between the valve and valve seat-insert undergoes micro deformation of material due to the heavy force which is in the order of 20,000 N developed in the combustion chamber. The forces at different speeds of the engine are calculated and finite element analysis is carried out using IDEAS.

Impact velocity

The impact of the valve on the valve-seat is due to high closing velocity of the valve. The valve should be opened and closed within the prescribed time in correspondence to the speed of the engine. This velocity depends on the profile of the cam and the stiffness of the springs. However the intermediate components between valve and cam are also responsible for the seat force.

Other factors that contribute to the valve recession are as follows [4].

1. Fuel gas combustion characteristics (antiknock rating) or contamination (dirt, e.g. silicondioxide).
2. Combustion air contamination (dirt, e.g. silicondioxide)
3. Metallurgy of the valve-seats and valve-faces (non-uniform and insufficient hardness). There can be fundamental material incompatibility between the valve facing and seat insert.
4. Engine design (head and valve stiffness, valve and seat angles, seat and guide cooling, valve-spring tension, and valve rotators).
5. Engine operating conditions (high combustion chamber temperatures, excessive engine speed, excessive engine load, excessive engine coolant temperature, ebullient cooling with two coolant phases).

1.2. Effects and Observations

The wear scars formed on the valve seating faces appeared uneven. The formation of a brown oxide, characteristic of fretting wear (reciprocating wear caused by very small displacements), was observed as well as debris at the edges of wear scars. Examination of the wear scars of the valves run against cast seat inserts revealed the evidence of

deformation and the presence of the series of ridges and valleys formed circumferentially around the axis of the valve seating face. The observations made indicate that the introduction of the impact caused a bedding in process to occur, improving the uniformity of the valve wear scars and causing them to increase the width. It has also been noticed that the valve has greater wear than a seat insert. The effect of the misalignment (valve relative to seat insert produced a crescent shaped wear scar on the valve seating face. The widest point of the scar was at the point of initial contact with the seat insert. At this point the wear was more severe than was achieved when the valve was aligned.

1.3. Combustion Forces on Valve

The forces due to combustion are calculated (Table 1) from *P-θ diagram* shown in the Figure 2 with respect to the peak pressures developed in the engine at various speeds. These forces are the input for the finite element analysis using 'IDEAS' to find the stress distribution on the valve seat. Also these forces are used to analyze the valve train using the software tool 'TYCON'.

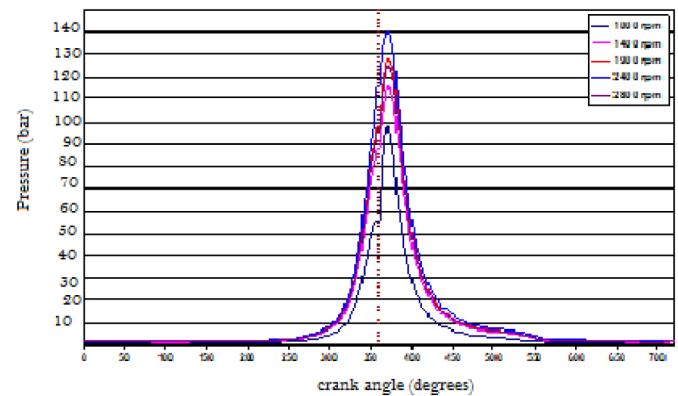


Figure 2. *p-θ diagram at various speeds*

Table 1. *Force on the valve*

ANALYTICAL CALCULATIONS OF COMBUSTION FORCES	
Combustion forces on the inlet valve:	
diameter of the inlet valve (mm)	44
Area of the head $\pi/4 (44^2)$ mm ²	1520.5308
Maximum pressure in the cylinder at 2400 rpm (bar)	140
Force on the valve (N). (area * pressure) $140 * 10^5 * 1520.5308 * 10^{-6}$	21287
Projected area of the valve seating (mm ²) $\pi/4(43.42) - \pi/4(41.5942)$	120.558
Actual area of the seating (mm ²) $120.558/\cos 45$	170.5
Actual force on the valve seat (N).	15052

Similarly at various speeds, the combustion forces are calculated based different peak pressures inside the cylinder at different speeds.

The combustion forces at various speeds are responsible for the micro sliding in the valve seat area. However it is not feasible to reduce these forces on the valve seat as the p-θ diagram cannot be disturbed. But, as there is a possibility to reduce the stress on the seat area by changing the width of the seat, changing the valve seat angle, the geometrical parameters are considered to reduce the valve recession.

2. RESULTS

Considering maximum force developed on the valve at maximum pressure of 140 bar, the normal component of force and the tangential component are resolved.

Force on the valve face = 21287 N

Tangential component of force = $21287 \cos 45 = 15052 \text{ N}$

Normal component of force = $21287 \sin 45 = 15052 \text{ N}$

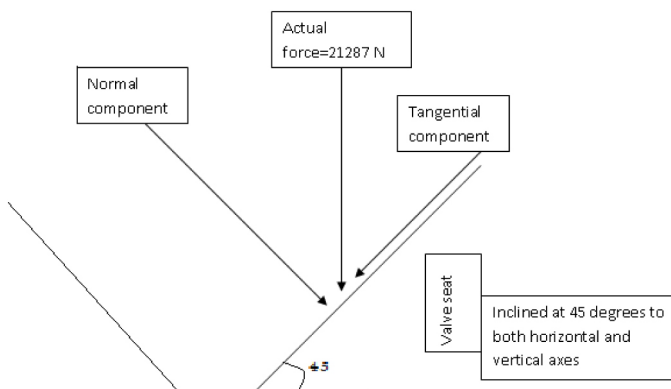


Figure 3. Forces on valve seat face

The valve seat area is inclined at an angle of 45 degrees to both horizontal and vertical axes. These resolved forces are considered to analyze the stress developed in the seat area. The stress developed depends on area of contact and the angle of the seat. Valve seat angle is an important factor to be considered while designing a valve and so the values of both tangential component and normal component of force are calculated.

The seat width of the valve is 2.8 mm.

The normal component of the force is 15052 N.

The area of the valve seat is $\pi.d.w = 3.14 \times 40 \times 2.8 = 351.68 \text{ mm}^2$

The normal component of the force = 15,052 N
The stress on the seat area of the valve = $15052 / 351.68 = 42.8 \text{ N/mm}^2$

When the seat angle is 30 degrees with respect to horizontal axis, the normal and tangential components are different. The valve with 30 degrees seat angle with respect to horizontal axis is also managed to have seat width higher than that of the original valve with seat angle 45 degrees to both horizontal and vertical axes.

The actual force of component is calculated above which is equal to 21287 N

The tangential component of the force is = $21287 \times \sin 30$
Therefore the tangential component = 10643 N

2.1. Finite Element Analysis

The stress analysis of the valves is done using the IDEAS software where the combustion forces are input to analyze the stress distribution on the seat area of the valve. The stress distribution is analyzed at various pressures developed in the engine. The load on the inlet valve is the combustion force which is proportional to the area of the face of the valve. This force makes the valve to slide on the seat insert leading to the valve recession

2.2. Boundary Conditions and Stress Distribution

The valve has only axial movement and can rotate about its axis, no other degree of freedom is available to have any movement. So the valve is constrained on the seat area as shown in the Figure 4. the force is distributed uniformly on the face with total force equal to the combustion force.

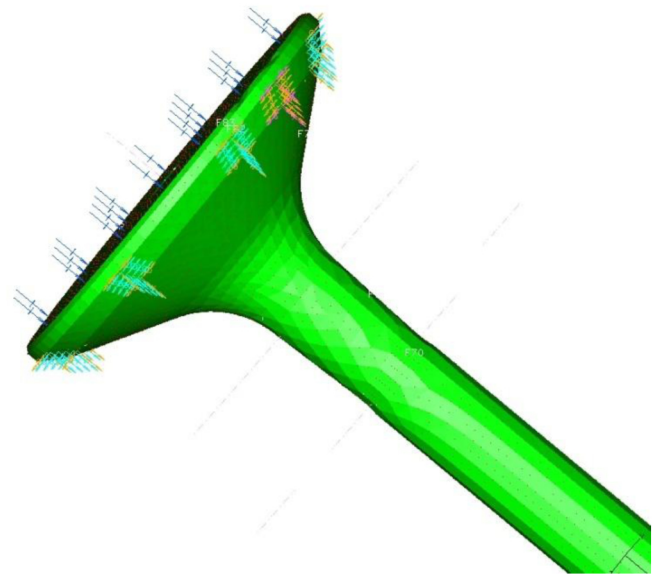


Figure 4. Boundary Conditions on inlet valve

The results are shown in the Figure 5 where the stress is distributed on the seat area. It is noticed that the stress distribution along the inner circumference of the seat area is maximum, minimum in the middle of the valve and slightly increases on the outer circumference of the seat area. This FEA is carried out for both the valves, valve seat angle 45° which is currently used in the vehicle and compared with valve with seat angle 30°. The finite element analysis is carried under the peak pressure of 140 bar generated due to combustion inside the cylinder. Stress distribution on the valves with seat angle of 45° and 30° is analyzed as shown in the Figure 5.