OPTIMIZATION OF INLET VALVE OF IC ENGINE USING FEA

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Abstract - *Internal combustion engine valves are precision engine components. The valve should be optimally designed so as to avoid an abnormal valve movement, such as valve jumping or bounce up to the maximum engine speed. There are different types of valves used by the manufactures; some common types of valves being poppet valves, slide valves, rotary valves and sleeve valve. This work considered the stress induced in a valve due to high pressure inside the combustion chamber, spring force and cam force for the optimization of fillet radius of inlet valve. For modelling CATIA V5 R21 is to be used and to analyze the valve ANSYS 14.0 is used as the tool. Static Structural analysis are to be performed on the different valve materials and on the different fillet radius of the inlet valve. A static analysis calculates the effect of steady loading condition on a structure.*

Key Words: **Inlet valve ,CatiaV5, Ansys14.0**

1. INTRODUCTION

Poppet valves are used in most piston engines to open and close the intake and exhaust ports in the cylinder head. The valve is usually a flat disk of metal with a long rod known as the valve stem attached to one side of valve and this portion fillet is given . Following fig.1 shows the fillet portion of the inlet valve.

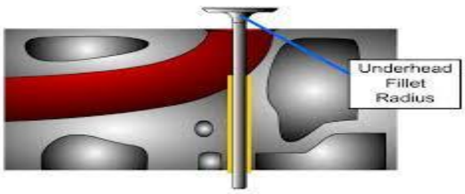

Fig. I Fillet

Design of this valve is depends on many parameters like behaviour of material at high temperature, vibrations, oxidization characteristics of valve material and exhaust gas, fatigue strength of valve material, configuration of the cylinder head, coolant flow and the shape of the port. The basic nomenclature used for valves is as shown in Fig.2 Out of these valve poppet valve is selected for optimization because of the following advantages:

1. Simplicity of construction
2. Self centering
3. Free to rotate about stem to the new position.
4. Maintening of sealing efficiency is relatively easier.

Inlet valves are larger than the exhaust valves because the velocity of incoming charge is less than the velocity of exhaust gases which leave under pressure.

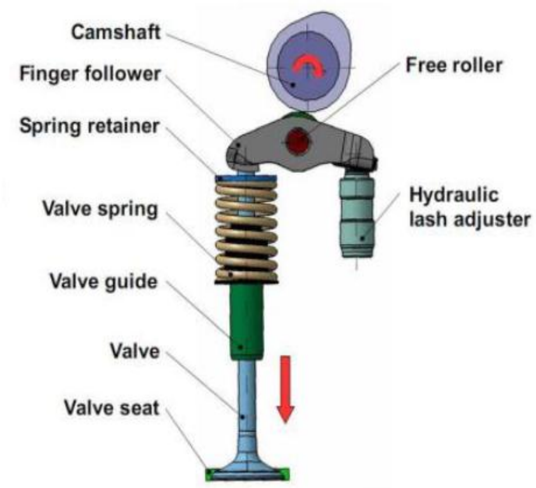

Fig. 2: Engine valve mechanism [5]

2. LITRATURE SURVEY

1] Yuvraj K Lavhale "Overview of Failure Trend of Inlet & Exhaust Valve" In this review it is observed that valve failures occur due to mechanical fatigue, thermal fatigue, thermo mechanical fatigue which is due to cyclic load, cyclic stresses. Fatigue failure occurs at stresses that are well below the yield point of the material.

2]Sanoj T. has performed "Thermo Mechanical Analysis of Engine Valve with different material. In this review it is observed that the for both valve materials, it has been concluded that the displacement value for Nimonic105A is very less than the values of other material for the same thermal and structural loads.

3]Snehal S.Gawale1, Dr.S.N.Shelke2 Design Of Stationary Ic Engine's Exhaust Valve and Optimization Based on Finite Element Analysis In this work, stress concentration on valve can be further reduced using suitable filet radius through optimization based on finite element analysis andexperimental validation on UTM to increase working life of exhaust valve. Design of valve is done based on given specifications with study of valves and its failure modes.

4] Goli Udaya Kumar has discussed "Failure Analysis of Internal Combustion Engine Valves by using ANSYS" Analysis is done with two conditions as valve, valve with seat and fin segments by varying two materials. Two different valve materials used – Aluminium and Magnesium alloy Coupled field analysis (combined analysis of static and thermal) is done on valve, valve with seat and fin segments by varying two materials. Fatigue analysis is done on valve for life calculation on ANSYS. The outcome of litrature survey is Studied various *materials used* for valve design, Forces acting modes of failure studied several of IC engine valves, Got idea about on valve i.e. Cam pressure, spring force and engine pressure.

5] A. S. More has discussed Analysis of Valve Mechanism – A Review In this review it is observed that dynamic model of valve train mechanism developed by using software can be used for the dynamic analysis of a valve train for the different camshaft speeds. The dynamic behaviour of the system is mainly induced by the cam profile with its specific displacements and acceleration.

3. METHODOLOGY & DESIGN CALCULATION

1. Litrature Study
2. Analytical Method
3. Finite Element Method (Static Structural Analysis)
4. Experimental Method

A. Design of Intake Valve for Following Specifications:

4-Stroke CI engine-
Allowable Stress 57.5 N/mm² (Carbon Steel), Valve Seat Angle - 45⁰,
Gas Velocity – 2250 m/min Mean Piston Speed - 290 m/min,
Max. Gas Pressure 7.0 N/mm²,
Cylinder Bore Diameter - 125 mm,
Stroke: 150 m ; Engine speed - 1275 rpm
Intake valve Temperature is 680⁰C.
Length = 11.2 cm (Reference Mechanical System Design – by Haidari – Book)

B. Forces on the Valve are due to:

1. Force due to gas pressure on the valve, when it opens. $\mathbf{F_G}$
2. The inertia force, when the valve moves up. $\mathbf{F_A}$
3. The initial spring force to hold the valve in its seat against the suction or negative pressure inside the cylinder. $\mathbf{F_I}$

1) $\mathbf{F_G} = \pi/4\ d_2^2\ p_c$

Where,

F_G = Gas Force when the valve opens

d_2 = Valve head diameter, mm

p_c = Cylinder pressure when intake valve opens, MPa = 0.55 MPa

2) $\mathbf{F_A}$ = mass x acceleration

Where,

Mass = Valve mass, kg

Acceleration = Valve acceleration, m/s²

Acceleration = $\pi^2\ \omega^2\ h\ /\ 2\ \theta_L^2$

ω = Cam Shaft Speed, rad/sec

θ_L = Angle of lift, rad

Cam Shaft Speed = ½ Crank Shaft speed (4 stroke engine)

= ½ * 1275*2 π/60

= 66.76 rad/sec

$\theta_L = ½\ \theta_{cam}$

= 1.272 rad

Valve lift = 15.87 mm

Acceleration = $\pi^2\ \omega^2\ h\ /\ 2\ \theta_L^2$

$= \pi^2 * 66.76^2 * 15.87 \times 10^{-3} / 2\ (1.272)^2$

= 215.73 m/s²

3) $\mathbf{F_I} = \pi/4\ d_2^2\ p_s$

Where,

F_I = Initial Spring force

p_s = Maximum Suction pressure, MPa = 0.03 MPa below atmosphere

$$\mathbf{F_T} = F_G + F_A + F_I$$

F_T = Total Force on valve face, N

1. $\mathbf{F_G} = \pi/4\ d_2^2\ p_c$
   $= \pi/4\ (54.18)^2\ 0.55$
   = 1268.03 N
2. $\mathbf{F_A}$ = mass x acceleration
   = 0.253 x 215.73
   = 54.58 N
3. $\mathbf{F_I} = \pi/4\ d_2^2\ p_s$
   $= \pi/4\ (54.18)^2\ 0.03$
   = 69.17 N

Hence, Total Force acting on Valve is,

$\mathbf{F_T} = F_G + F_A + F_I$

= 1268.03 + 54.58 + 69.17

= **1391.78 N**

C. Existing Valve Drawing:

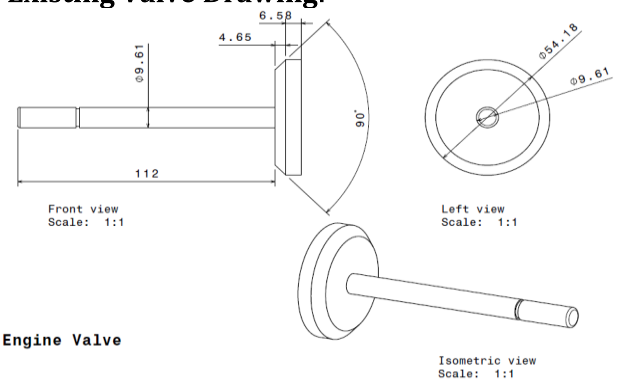

Fig.3 Valve Drawing

A. Existing Valve Modelling

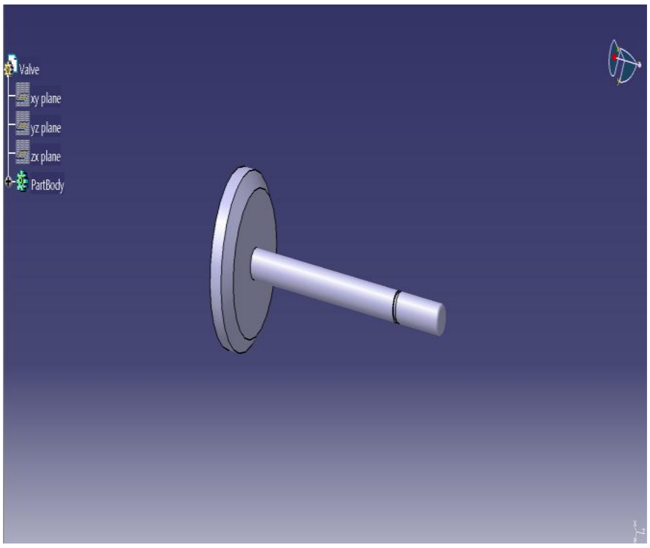

Fig.4 Cad model of existing valve without fillet radius

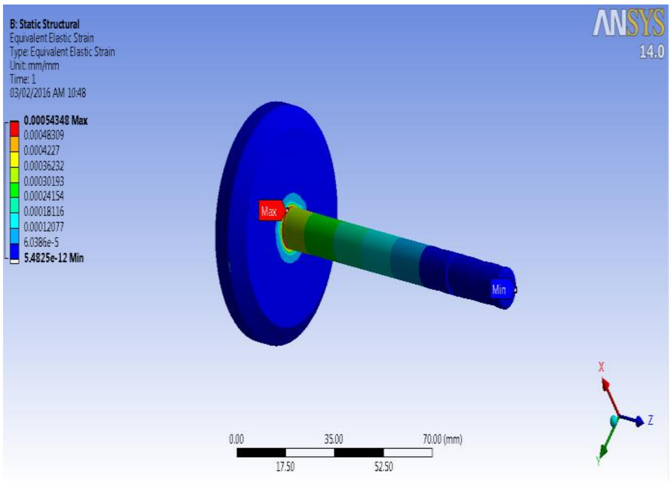

Fig.5 Elastic Strain

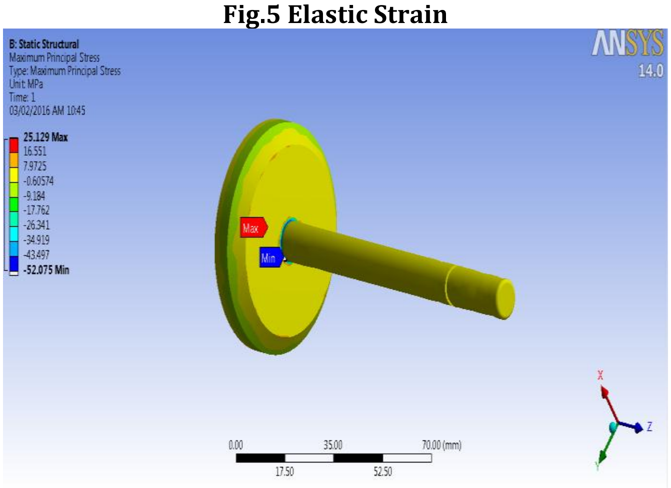

Fig:6 Maximum Principal Stress

4. MODELLING AND ANALYSIS WITH DIFFERENT FILLET RADIUS RESULT

Table.1 Fillet Radius used for optimization

Trial	Radius, mm	Von Mises Stress, MPa	Maximum Principal Stress, MPa	Elastic Strain, mm/mm
0	0	97.865	25.129	0.00054348
1	2	87.362	14.185	0.00043684
2	4	76.722	13.839	0.00038369
3	6	70.072	11.775	0.0003504
4	8	66.675	9.8304	0.00033339
5	10	62.072	6.9085	0.00031036
6	12	57.958	4.6175	0.00028979
7	14	55.563	3.75	0.00027782
8	16	52.432	3.6212	0.0002616
9	18	50.373	3.6255	0.00025187

5. MATERIAL OPTIMIZATION:

Materials to be tested for selected valve radius model (9mm radius):

1. SUPER ALLOY 21-2N VALVE STEEL (UNS K63017)

$\sigma_{all} = 440/6 = 73.33$ MPa

2. AISI 1541 Carbon Steel

$\sigma_{all} = 400/6 = 66.67$ MPa

Table.3 Results based on Material (Fillet radius 12.0mm)

Material	Elastic Strain, mm/mm	Von Mises Stress, MPa	Allowable Stress, MPa
Carbon Steel-70	0.00027782	55.563	57.5
21-2N	0.00037999	75.998	73.33
AISI 1541	0.012128	57.955	66.67

From the above result it can be seen that Material AISI 1541 gives us better result without failure (High allowable stress compare to C70), hence can be used for alternative to existing material.

6. CONCLUSION:

1. The results obtained through Static structural analysis suggest that the optimized value of fillet radius is 14 mm shows safe results and is selected for further work that is for material optimization.
2. The results for selected valve radius are showing good improvement compare to allowable stresses.
3. Material AISI 1541 shows less stress (23.74 %) compare to 21-2N with higher allowable stress and hence finally suggested for Valve improvement.
4. Overall reduction in stress is 40.78 %.

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BIBLOGRAPHY

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