Design and Analysis of IC Engine Poppet Valve with Varied Geometrical Parameters

Review Article

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***Abstract*: Poppet valve is important component of the engine. The pair of inlet and exhaust valve is called as poppet valves or Mushroom valve. Exhaust valve is used to bypass the burnt gases out from the engine through exhaust port after power stroke. as it belong to continuously come into very high temperature and pressure region so that there is more possibility of exhaust valve failure hence we need to take care of exhaust valve we trying to optimize the result by varying geometrical parameters of the valve like fillet radius, chamfer angle, Diameter of the valve head.**

Keywords: Exhaust valve, geometric parameters, Design, Analysis, CATIA v5, ANSYS 19.

I. INTRODUCTION

Mainly three types of valve used in internal combustion engine are as following.

1. Poppet valve or mushroom valve
2. Sleeve valve
3. Rotary valve

Out of three valve poppet vale is more and widely use due to their special advantages compared to other two. The main advantages are.

1) Simplicity in design
2) Self centering
3) Free to rotate about the stem to the new position
4) Maintenance of sealing efficiency is relatively easier.

Engine valves is precision component of the internal combustion engine the rate of exhaust valve failure is more than inlet valve. Because the inlet valve is generally cooled by the fresh air from the inlet port. exhaust valve is the type of valve used to bypass the burnt gases from the exhaust port as we know the temperature inside the combustion chamber is very high nearly equal to above 600ºC which can cause the exhaust valve to damage by the high temperature and pressure inside the combustion chamber rather than the inlet valve hence rate of exhaust valve failure is more compared to inlet valve.

II. LITERATURE REVIEW

Yuvraj K Lavhale et al (2014) They are focused on different type of failure related to inlet and exhaust valve. They found Failure take place on inlet and exhaust valves in four different manners like due to fatigue, thermal loading, wear corrosion and erosion which leads to loss mechanical property of material and engine performance [1].

Deepak Bhargav et al (2016) They have analysed the thermal effect like total heat flux, von Mises stresses Total deformation of the Exhaust valves. They are considered the exhaust valve by applying Thermal barrier coating on the exhaust valve. Coating material is stabilized magnesia-zirconia (MgZrO3) and bond coat powder used is NiCrAl used. In their current work performance of engine valve is evaluated for uncoated and coated engine valve with and without the application of bond coat and analysis has been carried out using FEA [2].

Sagar Deshpande et al (2015) They have studied Stress concentration factor with different geometrical parameters of valve is considered. After studying the most appropriate design is suggested based on analysis of engine valve for stress concentration which is validated with analysis software [3].

Ram M S (2014) He modified the exhaust valve by varying its position, size and shape with particular thermal and structural considerations which helps in increasing the rate of heat transfer from the seat portion of the exhaust valve there by reducing the possibility of knocking. Increased size of the exhaust valve pushes large amount of exhaust gas outside through the manifold which reduces the amount of unburnt mixture/charge which increases the power with less consumption of fuel which increases the fuel efficiency [4].

Vidyadhar C.kale et al (2014) They have been studied based on the parameter they tried to calculate the equivalent elastic strain, equivalent stress acting on the valve. They are considered three types of material Inconel 625, Ti-4.5Al-3V-2Fe-2Moz, Ni-Cr-Mo steel SAE8640_361_QT with the three main varying parameters like Valve Angle, Diameter of valve head, Thickness of valve Disk [5].

III. EXPERIMENTATION AND OBSERVATION

As we all know without reason there is nothing bad similarly the different mode of failure of the exhaust valve should be studied to know the reason of exhaust valve failures. Yuvraj K Lavhale is tried to investigate the mode of failure of the valve like.

1. Failure Due to Fatigue
2. Failure Due to High Temp
3. Failure of valve Due to Erosion-corrosion
4. Failure Due to wear

Looking towards the mode and root causes of intake and exhaust valve failures, while designing the valve important factors should be taken into account. These important factors are Chemical composition of valve material, engineering dimensions and tolerances, operating temperatures, duty cycle, equipment applications, atmospheric condition, HP rating, pick torque rating, RPM rating. Besides of design parameter, operation and maintenance plays very important role for the failure of valves. For cause of fatigue failure, care should be taken likewise over speeding of the engine, foreign material entry during induction, hydraulic locks etc. For thermal loading engine operating temperature is the key factor so intake & exhaust gas temperature should be controlled by tracking of overloading, fuel quality and cooling system performance. In case of wear failure valve adjustment and cleanliness of fresh air is most important. Dust entry in intake port is greatest enemy which causes early wear. Poor compression, scale formation, are the prime sources of valve failure due to corrosion erosion.

From the experimentation and analysis Deepak Bhargav suggested that the Total heat flux and Total deformation of uncoated engine valve is more compared to coated engine valve.

Table-1.0 summation of results

Analysis	Valve condition	Uncoated engine valve	Coated engine valve with bond coat	Coated engine valve without bond coat
Total Heat Flux W/m^2 x 10^6	Open	4.32	1	5.32
	Close	2.48	1.211	0.80
Von Mises Stress GPa	Open	4.47	3.39	5.03
	Close	0.242	0.5	0.12
Total Deformation mx10^{-3}	Open	0.495	0.4	0.51
	Close	0.1	0.078	0.10

They explained and found the result mentioned in Table1.0. The considerable decrease in heat flux, mechanical stress and total deformation the with coated engine valve with bond coat while increase in stress is observed in coated engine valve without bond coat. The better performance of coated engine valve with bond coat thus gives the applicability of surface coating technology on engine valve for long life and reliability without using costly material for valve body also it provides better wear and corrosion resistance.

As we all know Exhaust valve is vital component of internal combustion engine. Exhaust valve is belongs to continuously at high temperature and thermal stressed region. Hence it is need to evaluate the stress concentration. Sir Sagar S Deshpande try to evaluate the effect of stress concentration factor based on varying Neck radius and valve Head diameter. He obtained the following graphs1.0, 1.1 and Table1.1.

Table-1.1 Theoretical Stress Concentration Factor for Geometric Parameter

Sr no	Diameter of valve head (mm)	Theoretical stress concentration factor
1	31	0.8812
2	24	0.8791
3	22	0.8899
Sr.no	**Neck Radius**	**Theoretical stress concentration factor**
1	15.5	0.8812
2	20.5	0.8336
3	25.5	0.8006

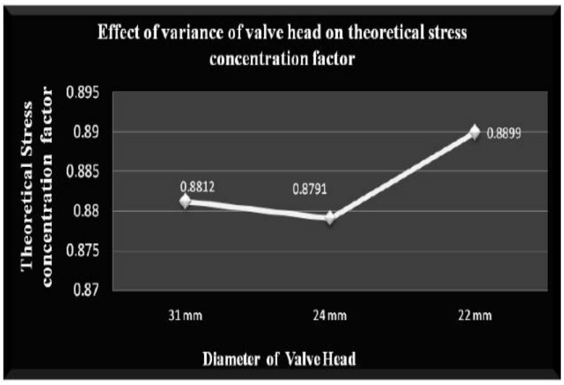

Fig 1.0 Effect of Variance of Valve Head On Theoretical Stress Concentration Factor

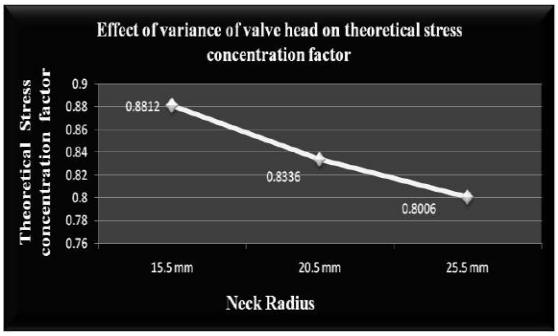

Fig 1.1 Effect of Variance of Neck Radius on Theoretical Stress Concentration Factor

It can be seen that geometric parameters affect stress concentration factor, where respective parameter differ in sensitivity. Sensitivity for the theoretical stress concentration factor of diameter of valve head is 2.84%, whereas sensitivity of neck radius is 5.68%. Change in Neck radius is more sensitive to stress concentration in comparison to change in diameter of valve head. Stress concentration factor should be least to improve fatigue strength, as a result based on above result it can be deduced that neck radius should be larger to extent permissible and diameter of valve head should be least to extent permissible. Engine valve with 15.5mm as neck radius and 24mm as diameter of valve head will result into improved fatigue strength over with conventional design of engine valve.

More That Engine valve is also depends on the size, position and orientation on the internal combustion engine. Ram MS Reviewed the Exhaust valve he modify the position and diameter of the exhaust valve in order to reduce the probability of knocking which will increase the engine efficiency.

Mr Vidyadhar.C.Kale and Sagar.S.Deshpande has been presented Design and Analysis of Poppet Engine Valve for Enhanced Mechanical Properties with Varied Geometric Parameters and Materials. They are tried to present how geometric parameters and mechanical properties is effective for designing an Exhaust valve after analysis and experimentation they made following observation. With a view to analyse the effect of Geometric parameters and materials on mechanical properties of poppet engine valve, specially to improve fatigue strength following geometric parameters and Materials are considered for purpose of analysis Which form the scope of this research paper.

Geometric parameters under consideration,

1. Valve angle
2. Diameter of valve head
3. Thickness of valve disk

Materials selected under consideration,

1. Inconel 625
2. Ti-4.5Al-3V-2Fe-2Moz
3. Ni - Cr - Mo Steel SAE8640_361_QT

After their experimentation and analysis on exhaust valve design with the varying geometrical and mechanical parameters. They made the following Range of magnitude of geometric parameters to obtain the results as on Table 1.2.

Table-1.2 Range of geometric parameters

Sr.no	Geometric parameters	Range of magnitude
1	Valve angle (degrees)	30,34,38,40,42,48
2	Diameter of valve head(mm)	22,25,28,34,37,40
3	Thickness of valve disk(mm)	1,2,3,4,5,6

Transient structural analysis was used in Ansys workbench 14.5 to obtain following results,

Variation of Equivalent elastic stain and Equivalent stress with variation of diameter of valve head for material under consideration as experimented in Table 1.3. The FEA Analysis of the 3d poppet valve by varying the diameter of valve head is show in Fig 1.2.

Table-1.3 diameter of valve head with corresponding stresses and materials

Material	Diameter of valve head(mm)	Equivalent elastic strain	Equivalent stress (MPa)
Inconel 625	22	0.00011607	21.865
	25	0.000131	24.794
	28	0.00012379	24.441
	31	**0.00013111**	**26.085**
	34	0.00011723	22.697
	37	0.00012573	23.446
	40	0.00012278	23.285
Ti-4.5Al-3V-2Fe-2Mo	22	0.00010658	11.492
	25	0.00012019	13.019
	28	0.00011221	12.632
	31	**0.00011888**	**13.46**
	34	0.00010643	11.775
	37	0.00011463	12.23
	40	0.00011156	12.115
Ni-Cr-Mo-steel SAE8640_361_QT	22	0.00010793	20.347
	25	0.00012182	23.072
	28	0.000011511	22.744
	31	**0.00012192**	**24.273**

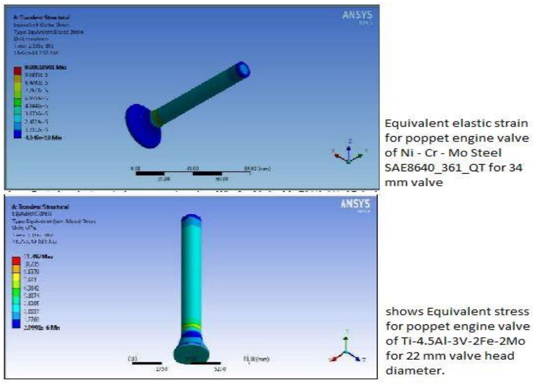

Fig 1.2 Equivalent elastic strain for poppet engine valve of corresponding valve head and parameters.

The variation of Equivalent elastic stain and Equivalent stress with variation of Valve angle for material under consideration is experimented in Table 1.4. The FEA Analysis of the 3d poppet valve by varying valve angle is show in Fig 1.3.

Table-1.4 valve angle with corresponding stresses and materials

Material	Valve angle (mm)	Equivalent elastic strain	Equivalent stress (MPa)
Inconel 625	30	0.0001303	24.81
	34	0.00011733	22.286
	38	0.00089712	172.68
	40	0.000125	23.077
	42	0.000010929	21.117
	45	**0.000012526**	**23.337**
Ti-4.5Al-3V-2Fe-2Mo	30	0.000011931	13.006
	34	0.00010711	11.65
	38	0.0001039	11.599
	40	0.00011429	12.059
	42	1.9E-05	10.988
	45	**0.00011465**	**12.22**
Ni-Cr-Mo-steel SAE8640_361_QT	30	0.00012116	23.087
	34	0.0001091	20.739
	38	0.00010677	20.856
	40	0.000011623	21.475
	42	0.00010163	19.65
	45	**0.00011647**	**21.717**

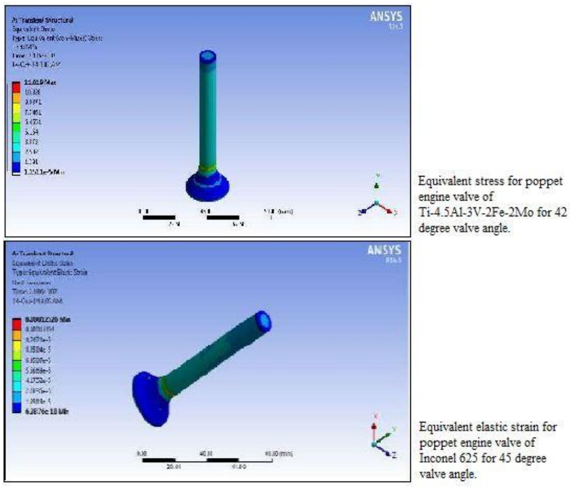

Fig 1.3 Equivalent elastic strain for poppet engine valve of corresponding Angle and parameters

The variation of Equivalent elastic stain and Equivalent stress with variation of Thickness of valve disk for material under consideration Table 1.5.

Table-1.5 Thickness of valve disk with corresponding stresses and materials

Material	Thickness of valve disk (mm)	Equivalent elastic strain	Equivalent stress (MPa)
Inconel 625	1	0.00010658	20.47
	2	**0.00012526**	**23.337**
	3	0.00011973	23.093
	4	0.00011998	23.125
	5	0.00012139	23.5
	6	0.00011717	22.251
Ti-4.5Al-3V-2Fe-2Mo	1	9.72E-05	10.689
	2	**0.00011465**	**12.22**
	3	0.00011097	11.933
	4	0.00010844	11.981
	5	1.10E-04	12.175
	6	1.07E-04	11.619
Ni-Cr-Mo-steel SAE8640_361_QT	1	9.91E-05	13.049
	2	**0.00011647**	**21.717**
	3	0.0001131	21.276
	4	0.0001091	20.739
	5	0.00011287	21.868
	6	0.000010895	20.706

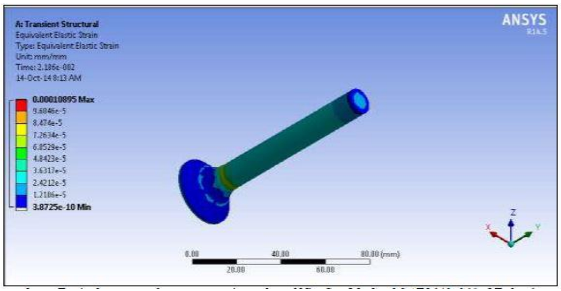

Fig 1.4 Equivalent stress for poppet engine valve of Ni - Cr - Mo Steel SAE8640_361_QT for 6 mm valve disk thickness

Fatigue load is continuously acting at the head section of the valve. The experimented and evaluated results is summarised on Table 1.6. The variation of fatigue life along with variation of geometric parameter and materials.

Table 1.6 variation of fatigue life with variation of geometric parameter and materials,

Material	Fatigue
Inconel 625	1.00E+06
Ti-4.5Al-3V-2Fe-2Mo	1.00E+07
Ni-Cr-Mo-steel SAE8640_361_QT	1.00E+11

Based on results obtained by transient structural analysis following conclusion are made**.**

(1) Least equivalent elastic strain is obtained for Ni - Cr -Mo steel SAE8640_361_QT as 0.000010901 for 34 mm head diameter which is most desirous.

(2) Least equivalent stress is obtained for Ti-4.5Al-3V-2Fe-2Mo as 11.492 Mpa for 22 mm valve head diameter which is most desirous.

(3) Least equivalent elastic strain is obtained for Inconel as 0.000010901 for 45 degree.

(4) Least equivalent stress is obtained for Ti-4.5Al-3V-2Fe-2Mo as 10.988 Mpa at 42 degree valve angle.

(5) Least equivalent elastic strain is obtained for Ni - Cr - Mo steel SAE8640_361_QT as 0.000010895 at 6 mm valve disk thickness.

(6) Fatigue life remains almost unaffected by change in geometrical parameters but is altered by change in material. After comparing Ni - Cr - Mo SteelSAE8640_361_QT has highest fatigue for all values of geometrical parameters as 1.00E+11 which is most desirous.

IV. CONCLUSION

From the review made by the respective authors all are belong and tried to minimize the failure of exhaust valve due to high temperature and thermal stress induced in the combustion chamber which directly effect on the exhaust valve during exhaust cycle. Many of authors considered material properties, stress concentration factor and five of them is only considered the geometrical parameters to minimize valve failure.

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