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Analysis Of Stress Concentration Factor For Engine Valve Designs For Improved Fatigue Strength

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Abstract— Engine valve is precision component of engine which is susceptible to fatigue failure in its operational life. Fatigue strength is affected by concentration of stress in critical section of engine valve which can be analyzed by evaluation of stress concentration factor for different engine valve design under consideration. In this paper attempt is made to explore into stress concentration factor with analytical approach with variation in geometrical parameters with essential assumptions. Most appropriate design is suggested based on analysis of engine valve for stress concentration which is validated with analysis software.

Keywords- Engine valve, Stress concentration factor, Fatigue strength.

I. INTRODUCTION

The elementary stress formulas used in the design of structural members are based on the concept that members are having constant section or a section with gradual change of contour. Such conditions, however, are hardly ever attained throughout the highly stressed region of actual machine parts or structural members. The presence of non continuously varying results in modifications of the simple stress distributions, this leads to localized high stresses, which are highly undesirable. [2]

This localization of high stress is known as stress concentration, measured by the stress concentration factor. The stress concentration factor K can be defined as the ratio of the peak stress in the body (or stress in the perturbed region) to some other stress (or stress like quantity) taken as a reference stress: Mathematically, [2]

$$K_t = \frac{\sigma\, max}{\sigma\, nom}$$

Where the stresses : σ_{max} represent the maximum stresses to be expected in the member under the actual loads and the nominal stresses σ_{nom} are reference normal and shear stresses. The subscript t indicates that the stress concentration factor is a theoretical factor. That is to say, the peak stress in the body is based on the theory of elasticity, or it is derived from a laboratory stress analysis experiment.

The definitions of the reference stresses depend on the problem at hand. It is very important to properly identify the reference stress for the stress concentration factor of interest.

Stress concentration factors are obtained analytically from the elasticity theory, computationally from the finite element method, and experimentally using methods such as photo elasticity or strain gages. [2]

Use of stress concentration factors in analysis and design is not on as firm a foundation as the theoretical basis for determining the factors. The theory of elasticity solutions are based on formulations that include such assumptions as that the material must be isotropic and homogeneous. However, in actuality materials may be neither uniform nor homogeneous, and may even have defects. More data are necessary because, for the required precision in material tests, statistical procedures are often necessary. As always, existing information must be reviewed and judgment used in developing reasonable approximate procedures for design, tending toward the safe side in doubtful cases.[4]

Engine valves are continuously in reciprocating motion, sliding in valve guide whose motion is directed by valve timing diagram actuated by Rocker Arm Mechanism. As a result of which engine valve is subjected to fluctuating stresses leading to fatigue failure in longer run. Thus consideration of fatigue strength is essential from design point of view.

Consider basic design of poppet engine valve based on standard design procedure,

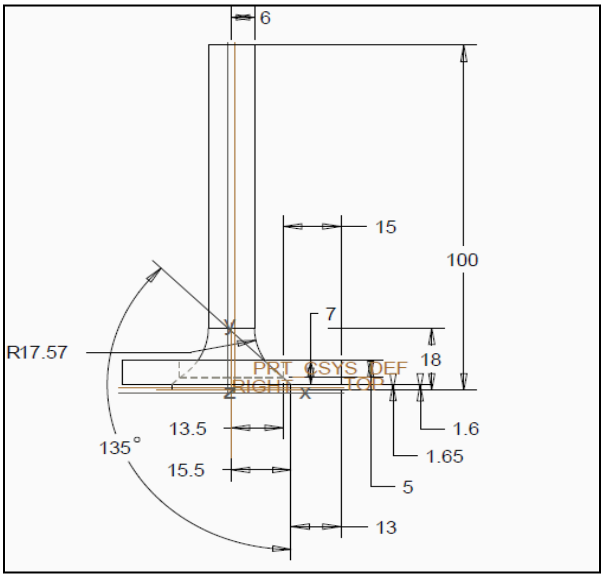

Fig 1: Dimensions of Poppet Valve and Valve Seat

Above figure shows poppet engine valve where all dimension are in mm.

Specification of Engine for which the poppet valve is designed,

Table 1: Specification of Engine

Sr.No	Parameter	Mangnitude
1.	Bore Diameter D	73.5 mm
2.	Length of stroke L	73.5 mm
3.	Engine Speed N	5500 rpm
4.	Break horse power (bhp) @ 5500 rpm	37 Bhp

Table 2: Specification of Poppet Engine Valve

Sr.No	Parameter	Mangnitude
1.	Diameter of valve port (D_p)	27 mm
2.	Width of valve (W)	2mm
3.	Valve angle (θ)	45 degree
4.	Diameter of valve head (D_v)	31 mm
5.	Thickness of valve disk (t)	2 mm
6.	Margin (M)	1.6 mm
7.	Diameter of valve stem (D_s)	12 mm
8.	Maximum valve lift (h_{max})	10 mm

II. ANALYTICAL APPROACH

Analytical approach is based on evaluation of stress concentration factor for different engine valve designs under consideration. Diameter of valve head and valve neck is considered as geometric parameter for analysis of effect of stress concentration factor,

Table 3: Range of Geometric Parameter

Sr.no	Geometric parameter	Range of magnitude
1.	Diameter of Valve Head	31mm, 24 mm, 22 mm
2.	Neck Radius	15.5 mm, 20.5 mm, 25.5mm

Theoretical Stress concentration factor for engine valve is analytically given as,[2]

$$K_t = 0.493 + 0.48\left(\frac{D}{d}\right)^{-2.43} + \left(\frac{r}{d}\right)^{-.48*\frac{\sqrt{3.43-3.41(D/d)^2-0.0232(D/d)\,4}}{\sqrt{1-8.85(D/d)^2-0.078(D/d)\,4}}}$$

Where Kt theoretical stress concentration factor,
D = Diameter of valve head (mm)
d = Diameter of valve stem (mm)
r = Radius of valve neck.

Above stated analytical formula for theoretical stress concentration factor is considered based on assumption that engine valve angle has negligible effect on stress concentration and thus has been neglected for analysis purpose. It should be noted that magnitude of diameter of valve head considered lies on both side of design value.

Following table provide data for Theoretical Stress concentration factor for different geometric parameter under consideration using analytical approach,

Table 4: Theoretical Stress Concentration Factor for Geometric Parameter

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

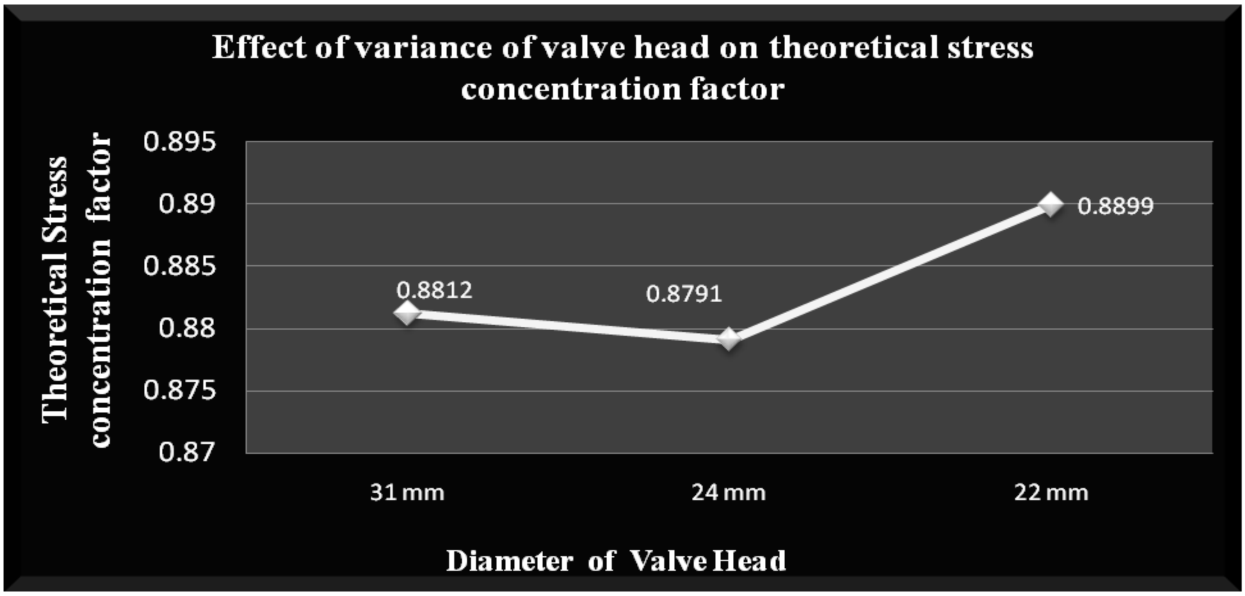

Fig 1: Effect of Variance of Valve Head On Theoretical Stress Concentration Factor

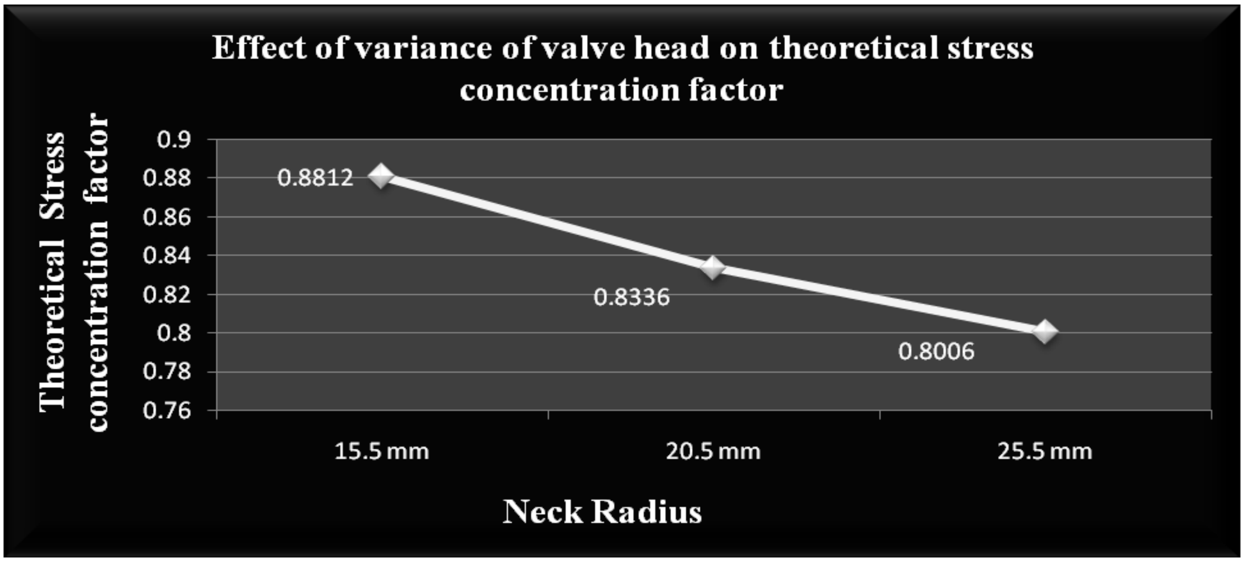

Fig 2: Effect of Variance of Neck Radius on Theoretical Stress Concentration Factor

CONCLUSION

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.

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