ENGINE VALVE OPTIMIZATION USING FEA

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ABSTRACT

Intake and exhaust valves are very important engine components that are used to control the flow and exchange of gases in internal combustion engines. They are used to seal the working space inside the cylinder against the manifolds; and are opened and closed by means of what is known as the valve train mechanism. Such valves are loaded by spring forces and subjected to thermal loading due to high temperature and pressure inside the cylinder. Design of the valve depends on many parameters like behaviour of material at high temperature, vibrations, fluid dynamics of exhaust gas, 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. This project deals with the stress induced in a valve due to high pressure inside the combustion chamber, spring force and cam force at high temperature conditions. For modelling CATIA is to be used and to analyze the valve ANSYS will be used as the tool. Structural analyses are to be performed on the valve.

Keyword: - *Valve, Engine, Crack, Failure.*

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1. INTRODUCTION:

Internal combustion engine valves are precision engine components. The valve train system is one of the major parts of internal combustion engine, which controls the amount of air-fuel mixture to be drawn into the cylinder and exhaust gas to be discharged. The fresh charge (air - fuel mixture in Spark Ignition Engines and air alone in Compression Ignition Engines) is induced through inlet valves and the products of combustion get discharged to atmosphere through exhaust valves. This seals the working space inside the cylinder against the manifolds. So design of valve lift profiles and valve train components is most important for the engine performance, valve train durability, and NVH. Therefore valve train system 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. The basic nomenclature used for valves is as shown in Fig.

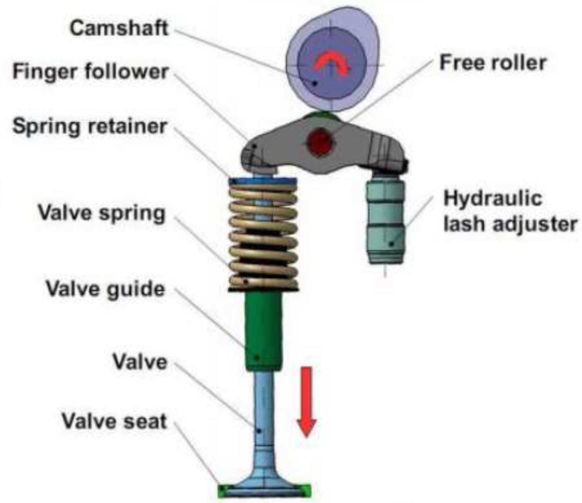

Fig 1: Engine Valve Mechanism

1.1 Purpose of Valves:

The purpose of the valve in the cylinder of the engine is to admit the air-fuel mixture and to force out the exhaust gases. The inlet valve also known as intake valve admits the charge into the cylinder and exhaust valves are used to send the exhaust gases out of the cylinder. In a 4-stroke engine the inlet valve and exhaust valve operate once in two revolution of the crankshaft. Each of the valves must operate once in one turn and this is done by a camshaft, which turns at half speed of the crankshaft. The firing order of cylinder establishes the sequence in which the valves opening and closing. The main components of the mechanism are valves, rocker arm, valve spring, push rod, cam and camshaft. The fuel is admitted to the engine by the inlet valve and the burnt gases are escaped through the exhaust valve. The cam moving on the rotating cam shaft pushes the cam follower and push rod up wards, there by transmitting the cam action to rocker arm. When one end of the rocker arm is pushed up by the push rod, the other end moves downwards. This pushes down the valve stem causing the valve to move down, there by opening the port. When the cam follower moves over the circular portion of the cam, the pushing action of the rocker arm on the valve is released and the valve returns to its seat and closes it by the action of valve spring.

1.2 Valves Materials

The materials used for inlet and exhaust valves are generally different because of the different operating conditions to which these are subjected. The material for exhaust valve must the following mechanical properties which to operate in more severe conditions.

- Sufficient strength and hardness to resist tensile forces and wear
- Adequate fatigue strength
- High creep strength
- Resistance to corrosion
- Resistance to oxidation at the high operating temperatures
- Small coefficient of thermal expansion to avoid excessive thermal stresses
- High thermal conductivity for good heat dissipation

At the inlet valve the temperature attained by it in service is always considerably lower. Two types of low alloy steel are used extensively for inlet valves. Nos. 3140 and 8645. The former is a chrome-nickel steel- containing 1.0 to 1.5 percent of nickel and 0.50-0.80 percent chromium (besides 0.37-0.45 per cent carbon and 0.60-0.95 per cent manganese); the latter a chromium-nickel-molybdenum steel containing 0.35-0.75 percent nickel, 0.35-0.65 per cent chromium, and 0.12- 0.25 per cent molybdenum, besides normal amounts of carbon and manganese. Some-use has been made of a medium-alloy chrome nickel- silicon steel-with (8 to 9 per cent nickel, 12 to 13 per cent chromium, and 2.5 to3 per cent silicon. This CNS steel, which has low carbon and manganese contents, is said to be immune to the corrosive influences of tetra-ethyl lead.

2. MODES OF FAILURES:

Following are different types of failure and their causes of inlet & exhaust valve.

2.1 Failure Due to Fatigue

The meaning of word fatigue means "to tire" which is derived from latin word "Fatigue". In engineering language/terminology fatigue failure is a progressive structural damage of the material of the component when the component under goes cyclic loading. There are two important categories of fatigue failure a) Mechanical failure due to fluctuating stresses due to cyclic load at high temperature. b) Thermal fatigue due to cyclic changes in component material temperature.

Fig.2 Valve failure due to fatigue

2.2 Failures Due to High Temperature

Exhaust valves operate at very high temperatures usually above 6000 C and are subjected to cyclic loading. The failure of the conical surface/sealing area of valve is mainly caused by the elastic and plastic deformation. Exhaust valve stem generally fails by overheating because the temperature of the exhaust valve is about 600 ºC. The fracture surface of the valve stem is covered with a black oxide scale formation. Fracture surface in the fatigue area is smooth and is covered with thick oxide or deposits that cannot be removed satisfactorily. In the middle portion of the stem a longitudinal fretting damage is occurred. Some small cracks are initiated and propagated across the section. With high loading, multiple cracks are initiated if the valves are subjected to high temp eratures and, under such operating conditions, it would be logical to expect that failure would occur within a few million cycles.

Fig.3failure due to high temperature

3. MATERIALS OPTIMIZATION FOR VALVE

Materials used:

1. Super Alloy 21-2N Valve Steel (UNS K63017)

Introduction

Super alloys are metallic alloys used at high temperatures above 540ºC (1000ºF) where high surface stability and deformation resistance are mainly required. Three major classes of super alloys include iron-base, nickel-base and cobalt-base alloys. The iron-base super alloys are generally wrought alloys with stainless steel technology. Nickel-base and cobalt-base super alloys may be cast or wrought based on its composition or application. Super alloys are commonly forged, rolled to sheet or produced in various shapes. However, highly alloyed compositions are produced as castings.

The following datasheet provides a detailed description of super alloy 21-2N valve steel.

Chemical Composition

The following table shows the chemical composition of super alloy 21-2N valve steel.

Elements	Content (%)
Chromium, Cr	20.35
Manganese, Mn	8.5
Nickel, Ni	2.13
Carbon, C	0.55
Molybdenum, Mo	0.50 max
Silicon, Si	0.25 max

Physical Properties

The physical properties of super alloy 21-2N valve steel are given in the following table.

Properties	Metric	Imperial
Density	7.60 g/cm³	0.2878 lb/in³

Mechanical Properties

The mechanical properties of super alloy 21-2N valve steel are displayed in the following table.

Properties	Metric	Imperial
Yield strength	440-580 MPa	63816.61-84121.89 psi
Modulus of elasticity	215 GPa	31183 ksi
Elongation	8%	8%
Reduction	10%	10%
Hardness	28	28

2. AISI 1541 Carbon Steel

Introduction:

Carbon steels contain carbon as the specific alloying element. They also contain 1.2% manganese and 0.4% silicon. In addition to carbon, they also contain copper, nickel, molybdenum, and aluminum as residual elements. Sulfur and phosphorous are also present as impurities in these steels.

Chemical Composition

The following table shows the chemical composition of AISI 1541 carbon steel.

Element	Content (%)
Iron, Fe	97.82 - 98.29
Manganese, Mn	1.35 - 1.65
Carbon, C	0.360 - 0.440
Sulfur, S	0.0500
Phosphorous, P	0.0400

Physical Properties

The physical properties of the AISI 1541 carbon steel are tabulated below.

Properties	Metric	Imperial
Density	7.90 g/cm^3	0.278-0.290 lb/in^3

Mechanical Properties

The mechanical properties of AISI 1541 carbon steel are outlined in the following table.

Properties	Metric	Imperial
Elastic modulus	190-210 GPa	27557-30458 ksi
Poisson's ratio	0.27-0.30	0.27-0.30
Tensile Strength, Ultimate	670 to 750 MPa	97 to 109 x 10^3 psi
Yield Strength	380 to 650 MPa	55 to 94 x 10^3 psi
Elongation	12 to 18 %	

Table: Results based on Material (Fillet radius 14.0mm)

Material	Elastic Strain, mm/mm	Von Mises Stress, MPa	Allowable Stress, MPa	Volume, mm^3	Density, kg/m^3	Weight, g
Martensitic steels VV45	**0.0010853**	**216.91**	**233.33**	**29146**	**7500**	**218.6**
21-2N	0.0010702	213.87	293.33	29146	7600	221.5
AISI 1541	0.0011084	221.5	266.67	29146	7900	230.2

From the above result it can be seen that Material 21-2N gives us better result without failure, hence can be used for alternative to existing material.

4. CONCLUSIONS

- Valve radius fillet plays important role in valve failure and should be carefully selected.

-The results we got for valve radius are showing good improvement compare to allowable stresses.

- Valve with fillet radius 14.0 mm shows safe results and is selected for further work.

- Material 21-2N shows less stress (3.44 %) and weight (4.01 %) compare to AISI 1541 with higher allowable stress and hence finally suggested for Valve improvement.

- Overall reduction in stress is 14.34 % and weight is on greater side by 1.32 % (For 21-2N material) and is not a big issue considering stress reduction.

5. REFERENCES:

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