DESIGN, MODELING AND STRENGTH ANALYSIS OF EXHAUST VALVE FOR 4 STROKE SINGLE CYLINDER 10 HP (7.35 KW) DIESEL ENGINE

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ABSTRACT

Engine is the heart of automotive and valve mechanism is the heart of engine. There are two types of the valves which are intake valve and exhaust valve. Intake and exhaust valves are very important engine components that are used to control the flow of intake fresh charge and Exhaust flue gases alternatively in Engine. They are used to seal the working space inside cylinder against the manifold and they open and close by means of what is known as the Valve gear mechanism. The loading and unloading of these valves are design by means of spring force and it is subjected to thermal loading due to the high temperature and high pressure inside the cylinder. In order to develop on Exhaust Valve with high thermal so as structural strength, experimental investigations are generally costly and time consuming, lead time as well as dispatch. An alternative approach is to utilize computational approach such as Finite Element Analysis, which provides greater light on temperature distribution across the valve geometry as well as possible deformation. This method somewhat shortens the design cycle by reducing the number of the physical tests. The analysis in present work is done on SIEMENS NX 9 software and Solved by NASTRAN Solver.

Key words: Exhaust Valve, Diesel Engine, SIEMENS NX, NASTRAN

I. INTRODUCTION

By opening and closing of the exhaust valves in engine, the discharge and exhaust can be maintained within the cylinder. But, due to the extreme pressure and temperature loads, the conventional valves do regularly fails before its life cycle. The present material used in exhaust valves is EN9 which is Steel Based Alloy, but has more strength than stainless steel.10HP (7.35kW) diesel engine is used in Agriculture, Construction Sites, and also used in generators where the 24hr electricity is necessary.

II. RESEARCH OBJECTIVES

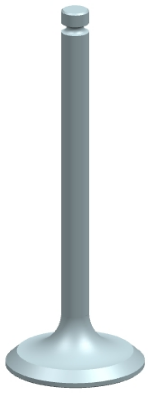

Fig 1: Conventional design of exhaust valve of 10HP diesel engine of EN9

F. Starr has done analysis of design on the Exhaust Valve and got the different results as shown in the figure. As shown in the figure the development in the design is going on since last to 5 to 6 decades [4].
As the design is developing the properties of exhaust valve is also improved.

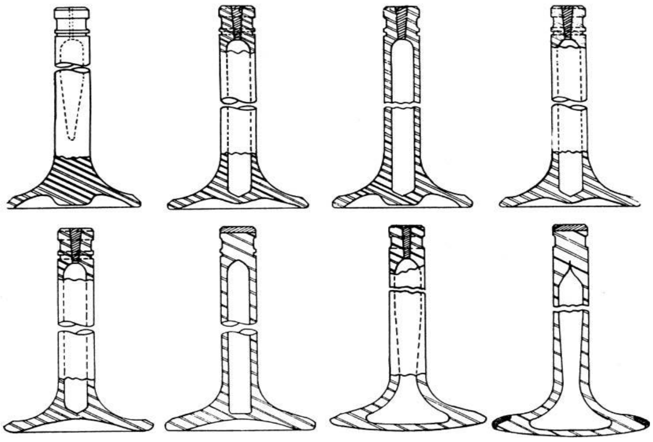

Fig 2: Evolution of Engine valves

On account of operating conditions, the material for exhaust valve should have the following requirements.

a) High strength and hardness to resist tensile loads and stem wear.

b) High hot strength and hardness to combat head cupping and wear of seats.

c) High fatigue and creep resistance.

d) Adequate corrosion resistance.

e) Least coefficient of thermal expansion to avoid excessive thermal stresses in the head.

f) High thermal conductivity for better heat dissipation.

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There are many different types of the material what we can use as the exhaust valve material. These materials are EN9, EN52, Aluminum alloys, Nimonic80A, EN54, EN59, 21-4N, Inconel 751 etc [1].

According to it the best material for the exhaust valve has high corrosion resistance, high fatigue strength, high oxidation resistance, high creep strength, high creep strength etc. out of them EN59 is recently not available.EN54 is expensive to manufacture because of high Nickel contents. Nimonic 80A has good corrosion resistance but its operating temperature range is up to 720 to 750^{o}C. 21-4N can retain the hardness up to temperature of 900^{o}C. It has good creep and impact strength.

High temperature is one of the biggest causes of failure of exhaust valve. Exhaust valves operate at very high temperatures and subjected to cyclic loading, the failure of the conical surface of valve is mainly caused by the elastic and plastic deformation, and fatigue. Exhaust valve stem generally fail by overheating because the temperature of the exhaust valve is about 720 ºC [3].

Past research and experiences had indicated that during the operation of the internal combustion engine, the maximum stress concentration is developed at the junction area of valve stem and valve head [2].Current problems that are found in 10HP are the objectives of this research

a) Failure of valve head happens due to large Hoop Stress

b) Sudden failure and fatigue cracks produce due to improper distribution of thermal and mechanical load on the valve face.

c) Stem of valve damages due to the higher tension and compression load on it at top and bottom end of the valve.

d) Fatigue due to high temperature

e) Failure of valve due to erosion and corrosion.

f) Design modification & change in material

III. DESIGN MODIFICATION AND ANALYSIS OF VALVE

The specifications of Engine are described as:

Parameters	Values and Specifications	Units
Engine type	4-stroke diesel engine.	--
No. of Cylinders	1	nos
Cooling System	Air cooled	--
Bore / Stroke	102 / 116	mm
Cubic Capacity	948	cc
Compression Ratio	1:16	--
Max. Power	7.35 / 10	KW / H.P
Max. Explosion Pressure	4.5	N/mm2
Total Engine Weight	194	kg
Rated Speed	1500	r.p.m.
Starting	Hand start	--
Fuel tank Capacity	11.5	Ltr.
Type of Fuel injection	Direct injection	--

Table 1 : Specifications of Engine

Design Calculations:

Size of the valve port:

Diameter of piston D = 102 mm

RPM N = 1500 rpm

Length of the piston L = 116 mm

V = Mean velocity of piston

= 2 L N / 60

= 23×116×1500 / 1000 × 60

= 5.8 m/s

V_p= 100 m/s (given)

A_p= Area of the piston

$A_p = \frac{\pi}{4}(d_p)^2$ mm^2

$A_p V_p$ = AV

$0.00817 \times 5.8 = \frac{\pi}{4}(d_p)^2$

d_p = 34.7372 mm

d_p = 35 mm

Diameter of valve d_v,

$d_v = d_p + 2w$

= 35 + 2(2.1)

= 39.2 mm

Thickness of the valve disc:

$$t = k.d_p \sqrt{\frac{p}{\sigma_b}}$$

Here,

σ_b = safe bending stress = 46 MPa

P = maximum gas pressure = 4 N/mm^2

t = 0.42 × 35 × (4/46)$^{1/2}$

= 4.3 mm

= 4.5 mm

Maximum lift of the valve:

h = Lift of the valve

$\pi d_p \cdot h \cos \alpha = \frac{\pi}{4} (d_p)^2$

$h = d_p/4\cos \alpha$

= 35 (cos 30) / 4

= 10.10 mm

Valve stem diameter:

The valve stem diameter (d_s) is given by,

$d_s = d_p / 8 + 6.35$

= 35/8 + 6.35

= 10.725 mm

$d_s = d_p / 8 + 11$

= 35/8 +11

= 15.375 mm

Diameter of stem d_s= 15 mm

Port diameter (dp)	35 mm
Valve diameter(dv)	39 mm
Thickness of valve disc(t)	4.5 mm
Stem diameter(ds)	15 mm
Max. lift of the valve(h)	10.10 mm

Table 2: Result table of dimensions of valve by Calculations

The 2D drafting is done in SIEMENS NX 9 and Modified Valve is drafted

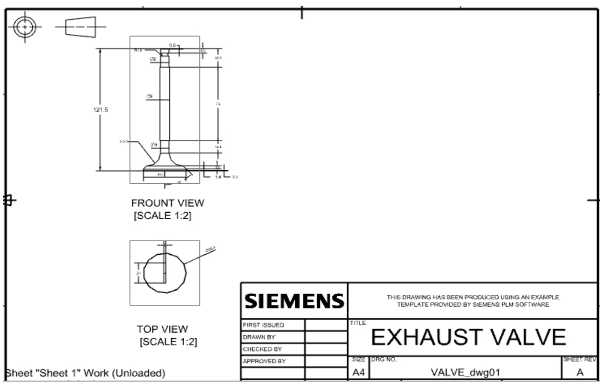

Fig 3: 2D Drafting of Modified Design of Exhaust Valve

The design modifications and calculations are strictly concentrating upon objectives and data. To check whether the data is safe or not, various strength analyses are done on the modified valve. To do so, 3D Model of modified design is created by commands in SIEMENS NX 9.After meshing of exhaust valve; analyses are

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performed over assigned material as EN9. By applying constrains and loads acting on the exhaust valve, accurate results can be get. However we have considered the exhaust blow pressure as the Load in Static condition and all other forces are neglected.

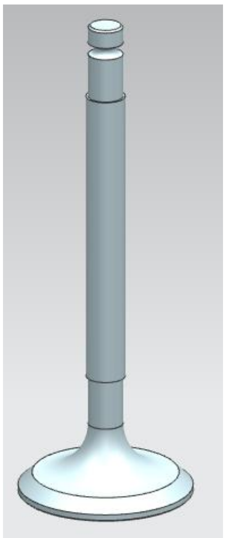

Fig 4: Modified 3D Model of Exhaust Valve

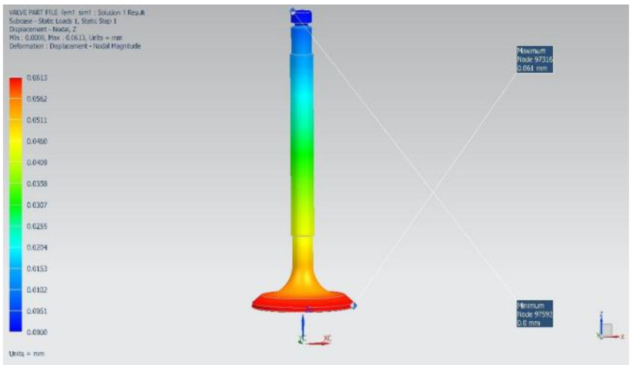

Fig 5: Nodal Displacement Analysis max=0.0613mm

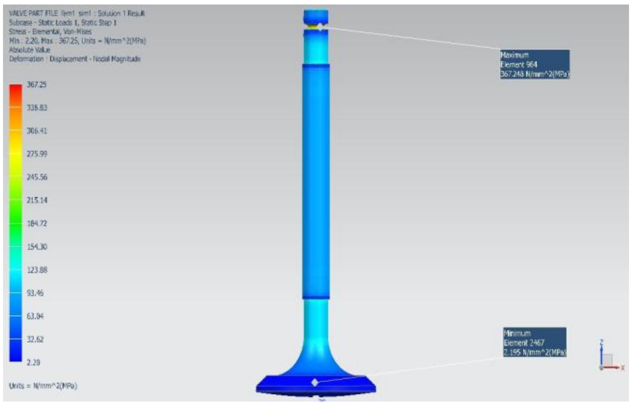

Fig 6: Analysis Stress: Von Mises max=367.25MPa

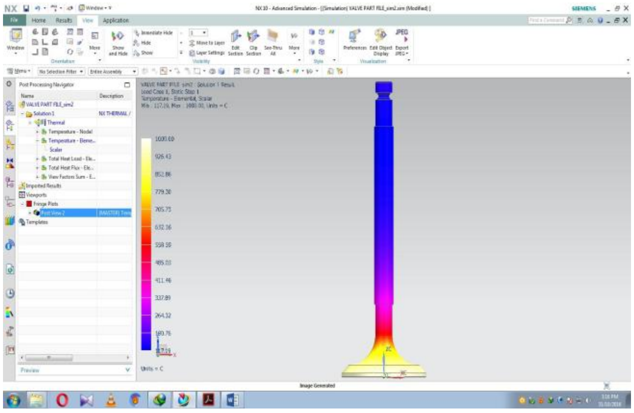

Fig 7: Temperature Change respect to nodes max=1000^{o}C

PROPERTIES	EN 9	ALLUMINIUM ALLOY - 356	ALLUMINIUM ALLOY LM12	EN 52	21 - 4 N
MAX. TENSILE STRESS (MPa)	600-700	500-600	210-500	500	550
DENSITY (g/mm^3)	0.00294	0.00269	0.00294	0.00761	0.0077
SPECIFIC HEAT CAPACITY (J/Kg.K)	910	963	910	500	773
YOUNG'S MODULUS (N/mm^2)	71000	76000	74000	210000	215000
POISION'S RATIO	0.33	0.33	0.33	0.30	0.29
BHN	100	75	85	44-50	201/255
THERMAL CONDUCTIVITY (w/mK)	44.6	151	154	135	14.5

Table 3: Materials and their properties

After the analyses, there is still a need to increase the strength without affecting the properties and cost. Change in material with EN9 doesn't imply the need to fulfill the need, but we can get assurance by comparing the materials. Genetic Analysis is needed to complete the assurance of safe limits as well as high reliability. Comparison of similar properties as well as chemical composition is done in Table 3.

IV. CONCLUSION

As per the C.I. engine specifications and dimensions the manual design calculation of the exhaust valve done based on EN9 materials and the design obtained as a safe design for the cylinder.

After that the 3D model of exhaust valve created in SIEMENS NX as per the calculated dimensions by manual design calculations.

On the basis of design and analysis conclusions imply that:

a) The Vonmises Stress is concentrated on the Keeper's groove and the slot in the face of exhaust valve.

b) The temperature at the valve face and head at its highest causes failures most at all.

c) The temperature gradient is highest at valve seat means change in temperature W.R.T distance is at highest.

d) The existing design can be modified for existing material or by choosing suitable material A/C to its properties as given in table 3.

Although these results are promising, there is still the future scope for this table in GeneticAlgorithm Analysis

V. FUTURE SCOPE

a) Genetic Analysis can be done.

b) Fluid Analysis can be done.

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