



Research Paper

PETROL ENGINE EXHAUST VALVE DESIGN, ANALYSIS AND MANUFACTURING PROCESSES

B Seshagiri Rao^{1*} and D Gopi Chandu¹

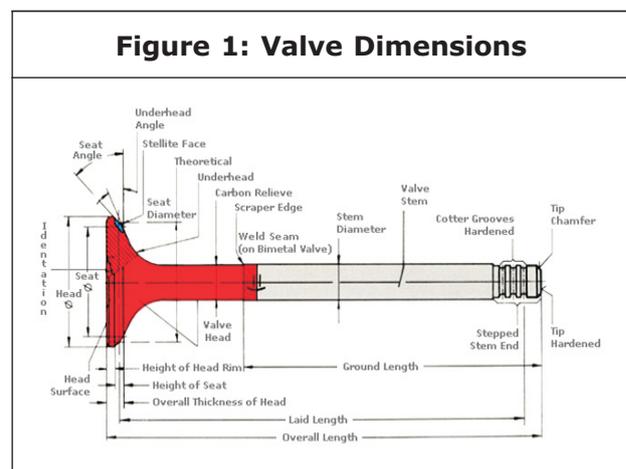
*Corresponding Author: **B Seshagiri Rao** ✉ seshu.308@gmail.com

The aim of this paper is to design an exhaust valve for a four wheeler petrol engine using theoretical calculations. Manufacturing process that is 2D drawings is drafted from the calculations and 3D model and transient thermal analysis is to be done on the exhaust valve when valve is open and closed. Analysis is done in ANSYS. Analysis will be conduct when the study state condition is attained. Study state condition is attained at 5000 cycles at the time of when valve is closed is 127.651 sec valve is opened 127.659 sec. The material used for exhaust valve is EN52 steel. We are doing material optimization by doing analysis on both materials EN52 and EN59. Static Modal analysis the exhaust valve to determine mode shapes of the valve for number of modes.

Keywords: Petrol Engine, Exhaust Valve Design, Analysis, Manufacturing Processes

INTRODUCTION

The valves used in the IC engines are of three types: Poppet, mushroom valve, Sleeve valve or Rotary valve. Of these three types, Poppet valve is most commonly used. Since both the inlet and exhaust valves are subjected to high temperatures of 1930°C to 2200°C during the power stroke, therefore, it is necessary that the materials of the valves should withstand these temperatures. The temperature at the inlet valve is less compared to exhaust valve. Thus the inlet valve is generally made of nickel chromium alloy steel and exhaust valve is made of silchrome steel.



About Valves

Engine Valve is one of the main parts which are used in all IC Engines. Each cylinder in

¹ Mechanical Engineering Department, Mother Teresa Institute of Science and Technology, Khammam, Telangana-507 303.

the engine has one inlet and one exhaust valve. Now a days engine are designed with multi valves viz., two inlet and one exhaust or Two inlet and Two exhaust valves which prevents air pollution and improves engine efficiency.

Function of Inlet Valve

The inlet which operates by the action of Tappet movement, allows air and fuel mixture into the cylinder.

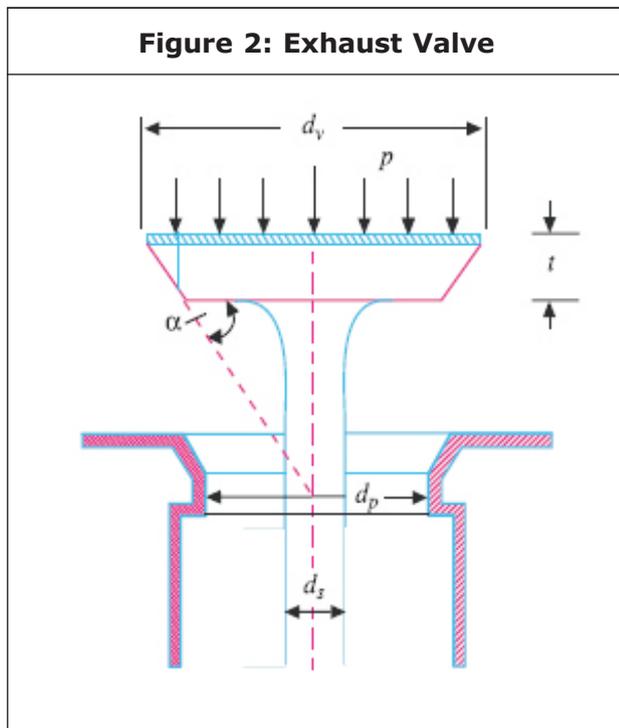
Function of Exhaust Valve

The exhaust valve allows burnt gases to escape from the cylinder to atmosphere.

Valve Efficiency

Depends on the following characteristics like Hardness, Face roundness and sliding properties capable to withstand high temperature etc.

Design Calculations of Exhaust Valve



a. size of valve port

$$a_p v_p = aV$$

$$V = 90m/s = 90000mm/s$$

$$a_p = \frac{3302.66 \times 10^3 \times 3.33}{90000} = 462mm$$

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

$$(d_p)^2 = \frac{462 \times 4}{\pi} = 588.53 \Rightarrow d_p = 24.25mm$$

B. thickness of valve disc

$$t = K d_p \sqrt{\frac{p}{\sigma_s}}$$

$$t = 0.42 \times 24.25 \sqrt{\frac{10.336}{100}} = 3.36mm$$

C. maximum lift of the valve:

h = lift of the valve

$$h = \frac{d_p}{4 \cos \alpha} - \frac{24.25}{4 \cos 30^\circ} = \frac{24.25}{3.46} = 7mm$$

D. valve stem diameter:

$$d_s = \frac{24.25}{8} + 6.35 \text{ or}$$

$$d_s = 3.03 + 6.35$$

$$d_s = 9.38 \text{ (or) } 1403mm$$

$$\tan \alpha = \frac{2(h+t)}{\left(\frac{d_p}{2}\right)} = \frac{2(h+t)}{d_p}$$

$$\tan 30 = \frac{2(3.36+7)}{d_p}$$

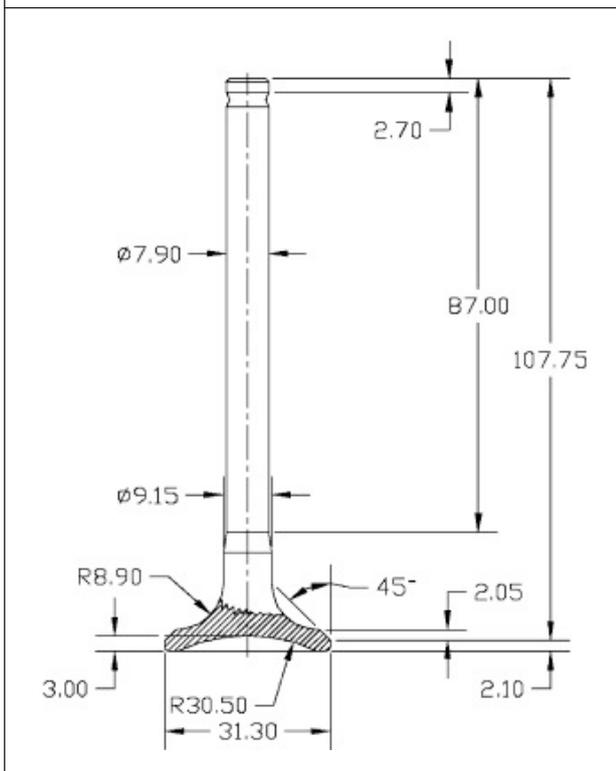
$$d_s = \frac{20.72}{0.577} = 35.9mm = 36mm$$

Description of the Physical System

The geometry of the exhaust valve is shown in Figure 3. The exhaust valve sits on the cylinder head of a combustion chamber. The engine coolant liquid passes around the cylinder liner and the water passages in the cylinder head. The valve pops up and down to let the exhaust gases leave the combustion chamber.

The up-and-down motion of the valve takes place with the help of a rocker lever which is connected to the push rod. The push rod rests over cams on the camshaft. The valve is spring loaded. The spring keeps the valve connected to the camshaft during its

Figure 3: Description of the Physical System



motion. After the expansion process, the exhaust gases, at high temperature, are purged through the exhaust valve and as a result the temperature of the exhaust valve increases. In order to avoid any damage to the exhaust valve due to this high temperature, heat must be continuously taken away from the valve. This is achieved when the valve is in contact with its seat. As the exhaust valves touch its seat, a significant drop in exhaust valve temperature occurs.

Analysis Results

Result when valve is closed at study state at 5000 cycles, at time 127.651 sec material properties: Thermal Conductivity - 0.22w/mmk.

Specific Heat - 1168 j/kg k

Density - 0.000027 kg/mm3

Figure 4: Contour Plot Thermal Stresses

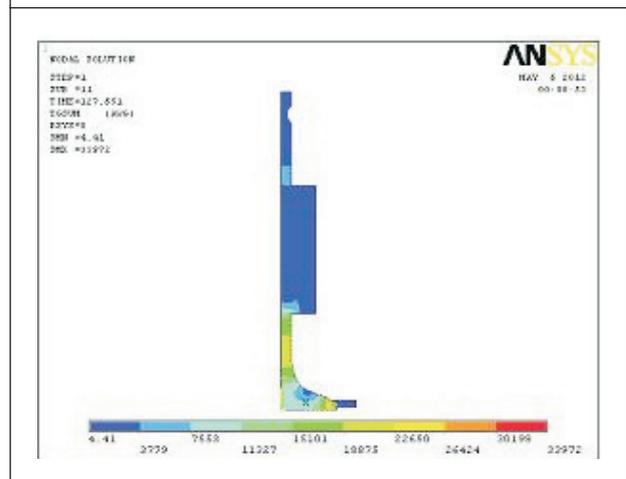


Figure 5: Thermal Flux

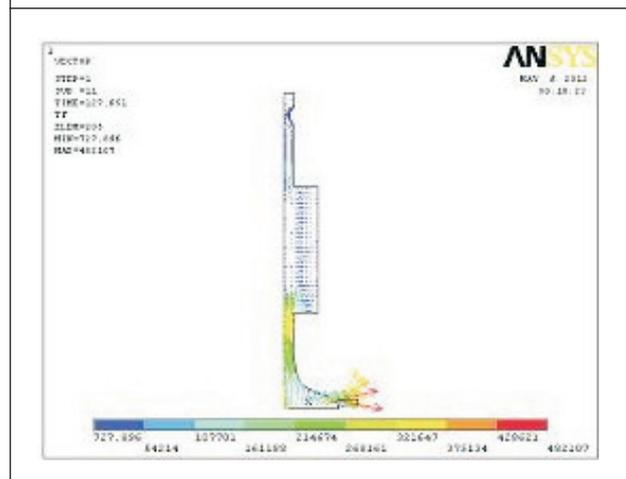


Figure 6: 3D Thermal Stresses

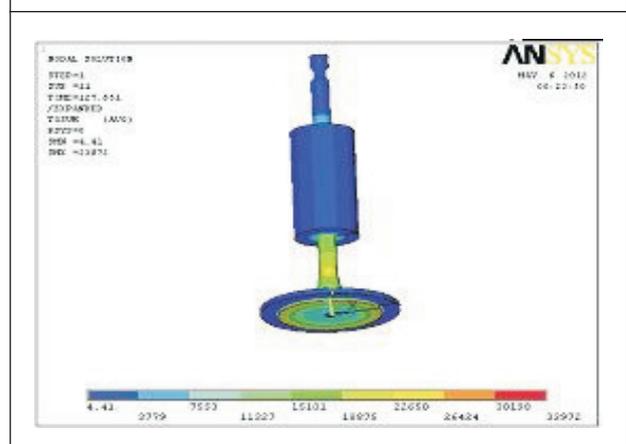


Figure 7: 3D Thermal Flux



Figure 8: Contour Plot Thermal Stresses

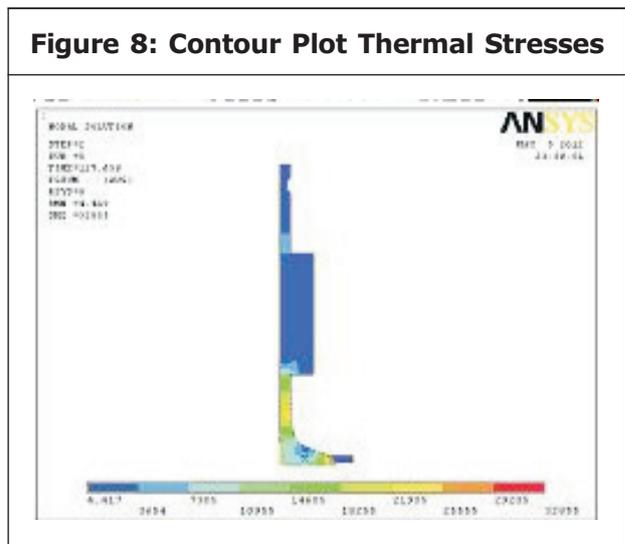
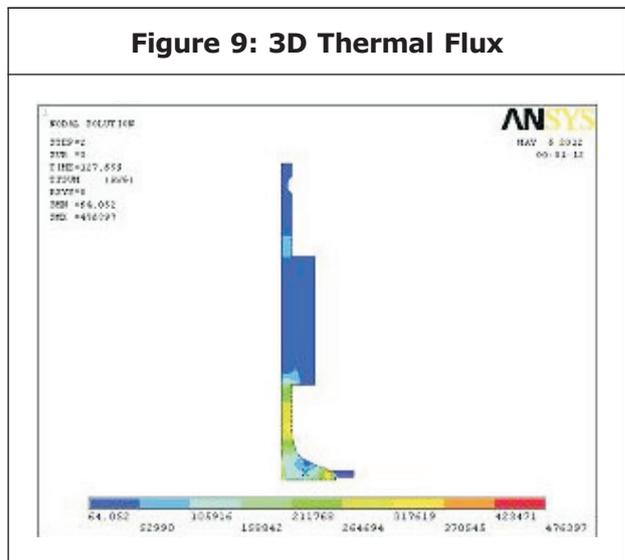


Figure 9: 3D Thermal Flux



Transient Thermal Analysis of rectangular fin body using magnesium alloy

Material Properties: Thermal Conductivity - 0.135w/mmk

Specific Heat - 1233 j/kg k

Density- 0.0000185 kg/mm3

Result when valve is open at study state at 5000 cycles, at time 127.659 Sec.

Table 1: Physical Properties

Material	Hot Forming Temperature	Thermal Conductivity W/(m.K)	Specific Heat Capacity J/Kg. K	Mean coefficient of Thermal Expansion * 10 exp(-6)
214N (349S52)	1150-950 Deg C	14.5	500	100 Deg C 15.5 300 Deg C 17.5 500 Deg C 18.5 700 Deg C 18.8
1.4882	1150-950 Deg C	14.5	500	100 Deg C 15.5 300 Deg C 17.5 500 Deg C 18.5 700 Deg C 18.8
EN24 (817M40)		37.7	460	
EN52 (401S45)	1100- 900 DegC	21	500	100 Deg C 10.9 300 Deg C 11.2 500 Deg C 11.5 700 Deg C 11.8
EN59 (443S65)				
Nimonic (80A)	1150-1050 DegC	13	460	100 Deg C 11.9 300 Deg C 13.1 500 Deg C 13.7 700 Deg C 14.5
StelliteNo. 6			0.101 cal/g. C	50 - 600 Deg C 15.3
StelliteNo. 12			0.098 cal/g. C	50 - 600 Deg C 14.1

Specific Heat - is the ratio of heat required to raise the temperature of a certain weight of material by 1 Deg C to that required to raise the temperature of the same weight of water by 1 Deg C, Coefficients of Thermal Expansion for Valve Guide Material (between 0 and 200 Deg C, in $10 \exp(-6).K(-1)$). Cast Iron 11, Phosphor Bronze 18, Aluminum Bronze 18

*Note - To find the expansion at 300 Deg C of a valve with a stem diameter of 0.275" in 214N material. (Assuming the stem diameter was measured at 20 Deg. C), the temperature difference is (300 Deg C - 20 Deg C) = 280 Deg C. Stem diameter x temperature difference x coefficient of thermal expansion = Expansion of Valve

$$le: 0.275 \times 280 \times 0.0000175 = 0.0013$$

6.0 PTA Deposition Plasma Transferred Arc Process (PTA Process) is used to fuse a metallic coating to a substrate in order to improve its resistance against wear and/or corrosion. This technique is called hardfacing, wear surfacing, or more commonly wear facing. During the process, metal powder is fed into a molten weld puddle (fusion bath) generated by the plasma arc at high temperature (up to 20,000 °C). All welding parameters, including powder feed, power input, plasma gas and shielding gas, as well as torch and workpiece movement are automatized and computer controlled in PLASMA TEAM equipment. PTA hardfacing is a true welding process, with a metallic bond between the substrate and deposit. Deposit thickness can range from 0.6 to 6.0 mm, width from 3 to 10 mm when using a single pass; multipass welding reaches deposit

thickness up to 20 mm and width over 30 mm. The core of PTA process is PLASMA. The plasma (a gas sufficiently ionized to be electrically conductive) can be viewed as the natural state of matter (the so called fourth state of matter), with the other states existing only as variants to the normal. Plasma state constitutes more than 99.9% of all matter in the universe. Thermal plasma describes a gas which is at least 1% ionized, with a temperature greater than 13,000 °C, and is a good electrical conductor.

Product Parameters

Table 2: Product Parameters

PARAMETERS & CHARACTERISTICS	SPECIFICATION/TOLERANCE	VERIFICATION EQUIPMENT	SAMPLE SIZE & FREQ. OF INSP.
Bar length valve length(OL) after friction	Spec. as per route card with tolerance of ±0.50	Vendor fixture-HS with dial gauge	1 per 100 Nos. FOA (5 Nos.)
welding Runout	0.4mm TIR Max.	Fixture-STR with 0.01 dial gauge	5 Nos. per 100 Nos. 5 Nos. at FOA
Tensile test	For all parts At weld joint: 92 Kgf/mm ² Min For Deutz parts At weld joint: 92 Kgf/mm ² Min On Head: 97 Kgf/mm ² Min On Stem: 112 Kgf/mm ² Min For Cummins part No. 41435 At weld joint: 700 N/mm ² Min	Universal Testing Machine (UTM)	1 No. at the time of setting 1 No. at the end of the batch For Deutz 1 No. at setting shift beginning and thereafter 1 No. after lunch and 1 No. at shift end bath completion 1 No. at the time of setting
Visual inspection	No flash allowed after de-flash	Visual	1 No. at the time of setting or at the time of tip indexing change

Observations

- Improper bonding may take place leading to the reduced strength of the component and as a result the component will tend to fail
 - If the upset force is less then also the strength of the weld will be less thereby increasing the tendency of the component to fail.
- 8.0 Manufacturing Results

Valve Process Flow with Head to Pin Friction Welding

1. One halve of the bar is upsetted and then forged.
2. Now the forged head is welded to another bar by friction welding.
3. Deburring is done to remove the flash generated in friction welding
4. The valves obtained are straightened and given as input to rough centreless Grinding operation..

Friction Welding Operation in “Head to Pin” Process.



Figure 10: Head Pin

TENSILE STRENGTH

Friction welding operation was carried with Head to pin and some checks were conducted to know the mechanical properties of the welded joint.

Tensile strength for different diameter bars after friction welding

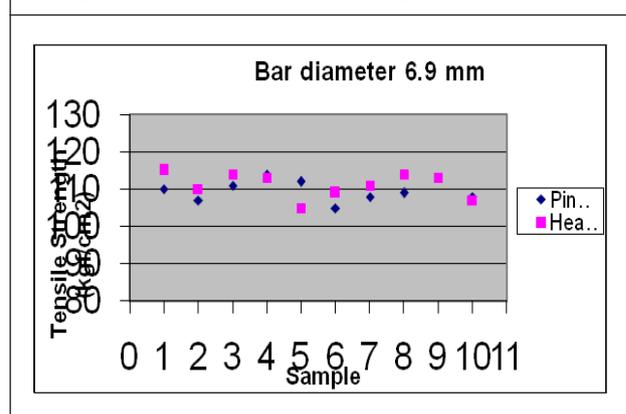
Bar diameter = 6.90 mm

Required tensile strength = 89-134 kgf/mm2

Table 3: Tensile Strength of 6.9 mm

Sample No.	Tensile strength (kgf/mm2) (Pin to Pin)	Tensile strength (kgf/mm2) (Head to Pin)
1	110	115
2	107	110
3	111	114
4	114	113
5	112	105
6	105	109
7	108	111
8	109	114
9	113	113
10	108	107

Figure 11: Tensile Strength of 6.9mm



CONCLUSION

1. Material Saving:
 1. 45665 - Rs. 2.59 Valve
 2. 40574 - Rs. 1.46Valve
 3. 40579 - Rs. 1.40Valve
2. Grinding Cost Saving :
 1. 45665 - Rs. 0.99 Valve
 2. 40574 - Rs. 0.65Valve
 3. 40579 - Rs. 0.65Valve
3. Totally four operations eliminated for these part nos.
4. Total savings per annum - Rs.20.0 lakhs

5. In-direct benefit: This becomes a Poke-Yoke to avoid reverse material forging which is one of the critical customer complaint.
6. Lead time reduced by 2 days.

REFERENCES

1. Avinash Kumar Agrawl, Shravan Kumar Singh, Shailendra Sinha and Mritunjay Kumar Shukla (2004), "Effect of EGR on the Exhaust Gas Temperature and Exhaust Opacity in Compression Ignition Engines", *Sadhana*, Vol. 29, No. 3, pp. 275-284.
 2. G Brecq 1 and O Le Corre (2005), "Modeling of in - Cylinder Pressure Oscillations Under Knocking Condition :Interodiction to Pressure Envelope curve SAE2005".
 3. Hirt C W, Amsden A A and Cock J L (1974), "Journal of Computational Physics", Vol. 14.
 4. J B Heywood (1988), "Internal Combustion Engine Fundamentals", *McGraw -Hill, New York*.
 5. Leppard W R (1982), "Individual-cylinder Knock Occurrence and Intensity in Multi Cylinder Engine", *SAE Technical Paper N 820074*.
 6. Lu (2009), "C,Q: Multi-dimensional Numerical Simulation for Combustion Process of CA6DL1- 30 Petrol Engine .Jiangsu University", Jiangsu.
 7. R K Rajput (2008), "A Text Book of Internal Combustion Engine", *2nd Edition Laxmi publications Pvt. Ltd.*
-