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**ORIGINAL ARTICLE**

# Diesel Engine Exhaust Valve Design, Analysis And Manufacturing Processes

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**Abstract:**
*The aim of this paper is to design an exhaust valve for a four wheeler diesel 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:** Diesel Engine; Exhaust Valve Design; Analysis ; Manufacturing Processes

## 1.0 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.
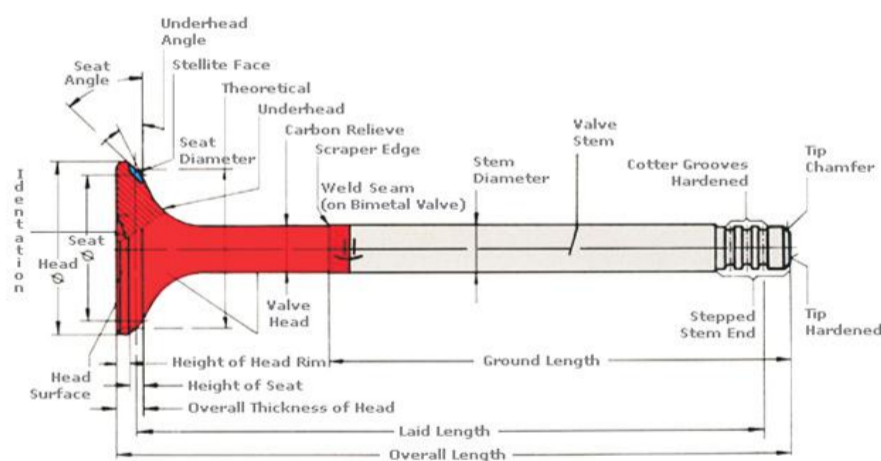


**Figure.1: Valve Dimensions**

**About Valves**

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

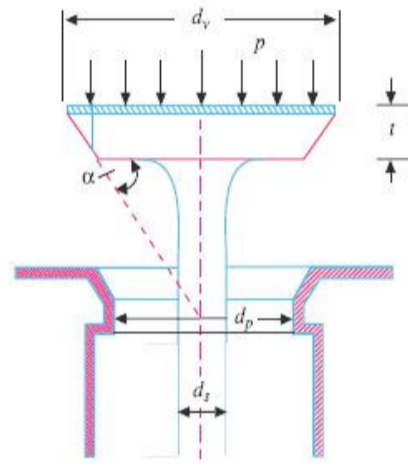**2.0 Design Calculations of Exhaust Valve**



**Figure.2: Exhaust Valve**

a. size of valve port

$$a_p \, v_p = aV$$

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

$$a_p = \frac{3302.66 \times 10933.33}{90000} = 462mm$$

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

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

B .thickness of valve disc

$$t = Kd_p\sqrt{\frac{p}{\sigma_b}}$$

$$t = 0.42 \times 24.25\sqrt{\frac{10.936}{100}} = 3.36mm$$

C. maximum lift of the valve:

$$h = \text{lift of the valve}$$

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

D. valve steam diameter:

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

$$d_s - 3.03 + 6.35$$

$$d_s - 9.38 \ (or) \ 1403mm$$

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

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

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

### 2.1 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.
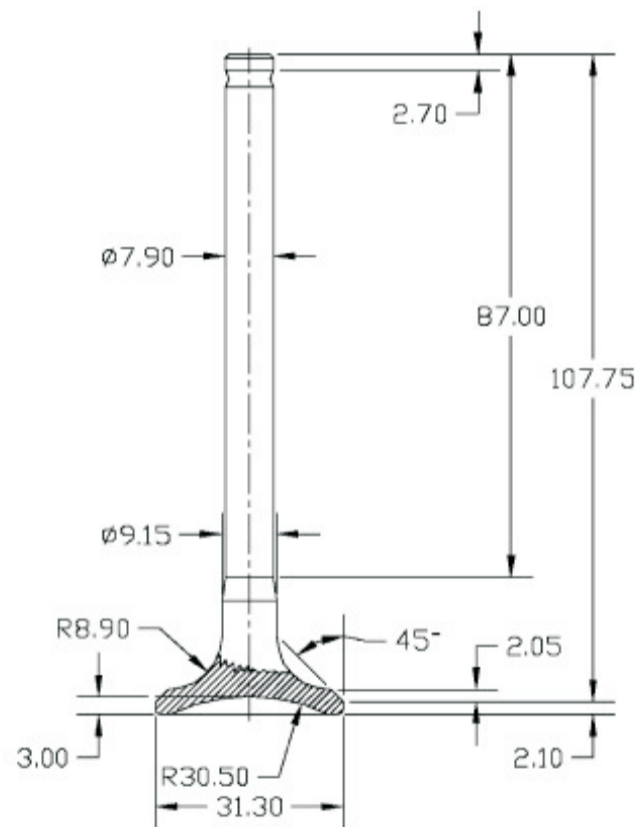
**Figure.3: Description of the Physical System**

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 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.

**3.0 Analysis Results**

3.1 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
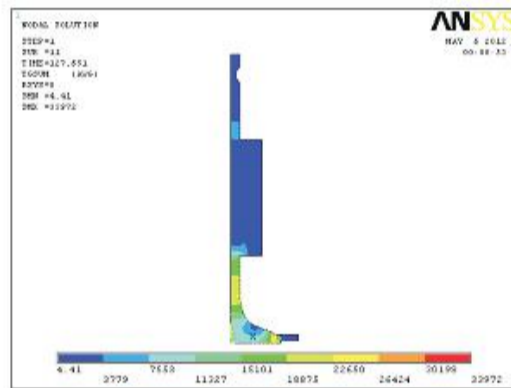Density - 0.0000027 kg/mm3
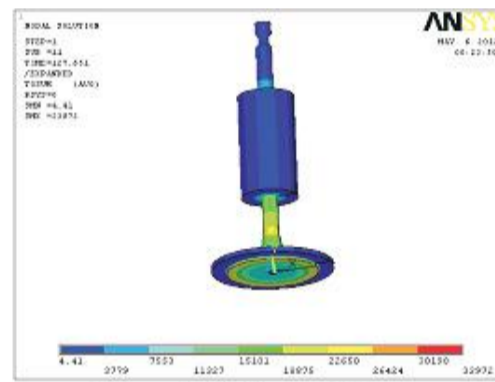


Figure.4: Contour Plot Thermal Stresses


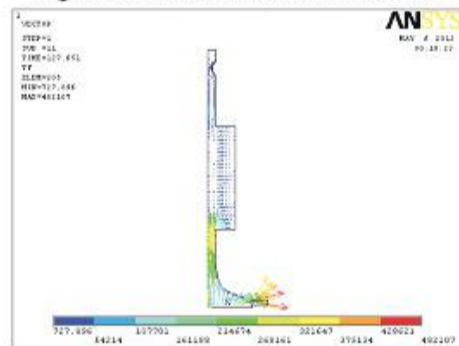
Figure.6: 3D Thermal Stresses
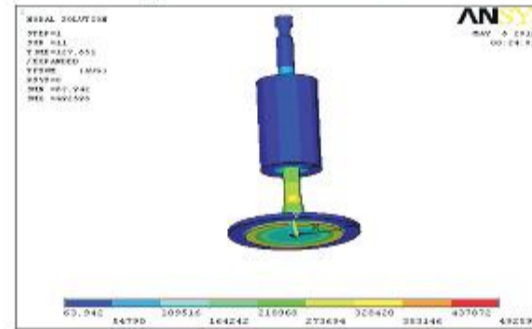


Figure.5: Thermal Flux



Figure.7: 3D Thermal Flux

**4.0 Transient Thermal Analysis of rectangular fin body using magnesium alloy**
Material Properties: Thermal Conductivity – 0.135w/mmk
Specific Heat – 1233 j/kg k
        Density - 0.00000185 kg/mm3
4.1 Result When Valve Is Open At Study State At 5000 Cycles, At Time 127.659 Sec
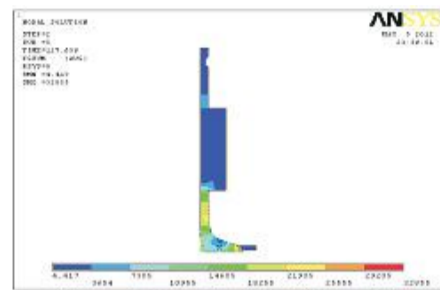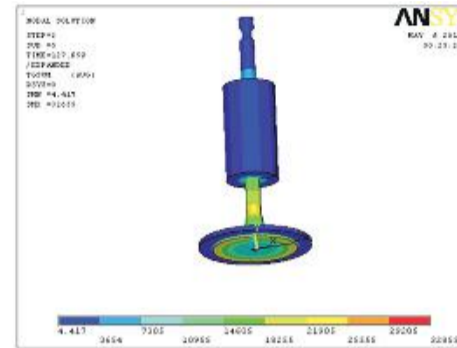
Figure.8: Contour Plot Thermal Stresses
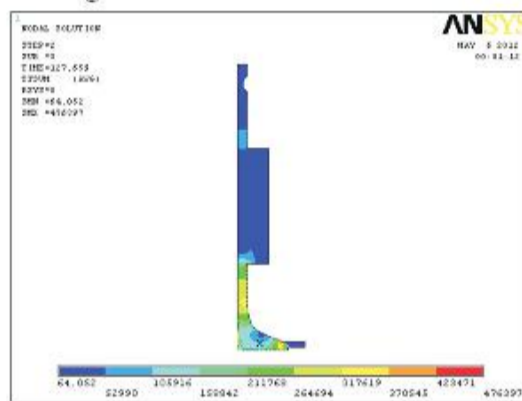

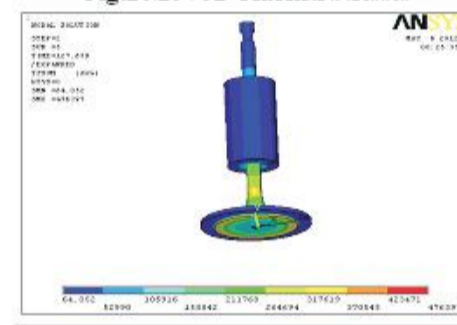Figure.10 : 3D Thermal Stresses


Figure.9: Thermal Flux


Figure.11: 3D Thermal Flux

## 5.0 Material Characteristics
### 5.1 Chemical Composition

The initial assessment of any group of steel is by chemical analysis and the main alloys used in Valve Steels are :--

Chromium: (Cr)

The most valuable element for improving the corrosion and oxidation resistance of steel, particularly against sulphur in any form or in combination with hydrogen or with organic compounds. It is considered that under oxidising conditions,a thin tenacious surface layer of chromium oxide is formed which provides a skin impervious to further oxidation. This protective surface remains constant, preventing any penetration of the general body of the steel. As an alloying element,

chromium has advantages over others, such as silicon and aluminium, both of which improve oxidation resistance but are less satisfactory in the presence of reducing atmospheres and/or sulphur attack..

Nickel: (Ni)

In the higher additions, nickel improves oxidation resistance, especially in the presence of chromium, but has little effect when present at values below 2%. This element has a considerable effect on toughness and depth of hardening of the martensitic steels. High nickel steels are prone to attack by sulphurous atmospheres due to inter granular formation of nickel sulphide.

Silicon: (Si):

This element leads to improvement in strength and resistance to oxidation but is on occasions responsible for manipulation difficulties and brittleness due to grain coarsening. In certain ranges of composition, silicon contributes to lack of uniformity in mechanical properties.

Molybdenum: (Mo)

An element generally regarded as an additive to promote fine grain and to confer an increase in resistance to temper brittleness.It has a beneficial effect on high temperature strength.

Tungsten: (W)

This element has a beneficial effect on high temperature strength and was one of the first elements used for this purpose.

Nitrogen: (N)

This element has a beneficial effect on improving hardness.

Niobium: (Nb)

This element has a beneficially effect on refining the grain size

Physical Properties

Hot Forming Temperature, Thermal Conductivity, Specific Heat Capacity & Coefficient of Thermal Expansion

| Material | Hot Forming Temperature | Thermal Conductivity W/(m.K) | Specific Heat Capacity J/Kg. K | Mean coefficient of Ther Expansion * 10 exp(-( |  |
|---|---|---|---|---|---|
| 214N (349S52) | 1150-950 Deg C | 14.5 | 500 | 100 Deg.C<br>300 Deg.C<br>500 Deg.C<br>700 Deg.C | 15.5<br>17.5<br>18.5<br>18.8 |
| 1.4882 | 1150-950 Deg C | 14.5 | 500 | 100 Deg.C<br>300 Deg C<br>500 Deg C<br>700 Deg C | 15.5<br>17.5<br>18.5<br>18.8 |
| EN24 (817M40) |  | 37.7 | 460 |  |  |
| EN52 (401S45) | 1100- 900 DegC | 21 | 500 | 100 Deg C<br>300 Deg C<br>500 Deg C<br>700 Deg C | 10.9<br>11.2<br>11.5<br>11.8 |
| EN59 (443S65) |  |  |  |  |  |
| Nimonic (80A) | 1150-1050 DegC | 13 | 460 | 100 Deg C<br>300 Deg C<br>500 Deg C<br>700 Deg C | 11.9<br>13.1<br>13.7<br>14.5 |
| Stellite No. 6 |  |  | 0.101 cal/g. C | 50 - 600 Deg C 15.3 |  |
| Stellite No. 12 |  |  | 0.098 cal/g. C | 50 - 600 Deg C 14.1 |  |

**Table.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

Ie: 0.275 x 280 x 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 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.

**7.0 Product Parameters**

| PARAMETERS & CHARACTERISTICS | SPECIFICATION/TOLERANCE | VERIFICATION EQUIPMENT | SAMPLE SIZE & FREQ. OF INSP. |
|---|---|---|---|
| Bar length/valve length(OL) after friction welding | Spec. as per route card with tolerance of ±0.50 | Venier/ fixture-HS with dial gauge | 1 per 100 Nos. |
| | | | FOA (5 Nos.) |
| 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 Duetz 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 | 1No. at the time of setting or at the time of tip indexing/changing. |

Table.2

**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

8.1 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.

**8.2 Valve processing at Friction welding**



**Figure.12**



**Figure.13: Manufacturing process**

**9.0 Conclusion**

The following are the points concluded about this paper

1.       Material Saving:
1.       45665 - Rs. 2.59 / Valve
2.       40574 – Rs. 1.46 / Valve
3.       40579 – Rs. 1.40 / Valve
2.       Grinding Cost Saving :

1.      45665 - Rs. 0.99 / Valve
2.      40574 – Rs. 0.65 / Valve
3.      40579 – Rs. 0.65 / Valve
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

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