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Design and Transient Thermal Analysis of a Diesel Engineout let Bi Metal Valve for Open and Closed conditions

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Abstract:

The valves used in the IC engines are of three types: Poppet or mushroom valve or 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 to2200°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. The aim of the project is to design an exhaust valve for a four wheeler diesel engine using theoretical calculations. 2D drawings are drafted from the calculations and 3D model is done in Pro/Engineer. 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 conducted when the study state condition is attained. Steady state condition is attained at 5000 cycles at the time of when valve is closed is 127.651 sec and valve is opened 127.659 sec. The materials used for exhaust valve is EN52 steel for valve seat Austenitic Stainless Steel for valve tip. Pro/ENGINEER is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design. ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system Into very small pieces (of user-designated size)called elements.

1. INTRODUCTION TO IC ENGINE VALVE:

Valves Train Components for Internal Combustions Engines, which include

1. Inlet and Exhaust Valves
2. Valve Guides
3. Tappets
4. Camshafts

1.1 What does an engine do?

• It generates the power required for moving the vehicle or any other specific purpose.

•It converts the energy contained in fuel to useful mechanical energy, by burning the fuel inside a combustion chamber.

•An engine contains number of parts like Valves and other Valve train components, Piston, camshaft, Connecting rod, Cylinder block, Cylinder head etc., from which REVL supplying some of the valve train components to engine manufacturers .

1.2 Types of Engines

•From the basic concept there are 2 major types of engine which are subdivided further based on their working principle.

1. Internal Combustion Engines (IC Engines)
a) 2 Stroke Engines
b) 4 Stroke Engines
2. External combustion Engines (EC Engines)
a) Steam engines (E.g. Locomotives)
b) Turbine engines (E.g. Aircraft)

Types of Engines

➢ Based on the Fuel Used, IC Engines can be classified as follows

1. Diesel Engines (CI Engaines)

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a) DI / IDI / CRDI
b) NA / Turbo Charged

2. Petrol Engaines (SI Engines)
   a) Carburetor Engaines
   b) SPFI / MPFI Engaines
3. Gas Engaines
   a) LPG
   b) CNG

- Based on the Application, IC Engines can be classified as follows

1. Automotive Engines
   a) On road Vehicles
   b) Off road Vehicles
   c) Marine Applications
   d) Racing Vehicles
2. Stationary Engines
   a) Generators
   b) Power Plants

1.3 WHAT IS A VALVE TRAIN?

- It is the set of components in a 4-stroke engine, responsible for smooth functioning of the inlet and exhaust valve
- It makes the valve to open and close as per the timing required for the correct functioning of the engine
- The performance of the engine is severely depends proper functioning of valve train. Any malfunctioning in the valve train system could even lead to severe damage to the engine

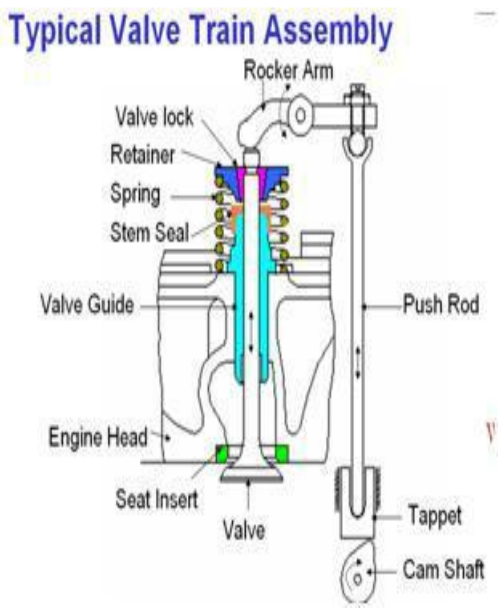

Figure 1.1 typical valve train assembly

1.4 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.

A. Function of Inlet Valve:

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

B. Function of Exhaust valve:

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

C. Valve Efficiency:

Depends on the following characteristics like Hardness, Face roundness and sliding properties capable to withstand high temperature etc. As compared to inlet, exhaust valve operates at high temperature as exhaust gases (around 800 Deg C) escape through it. As it resulting in early ways and gets corrosion, austenitic steel is used for manufacture of exhaust valve and martens tic steel is used for manufacture of inlet valve. The manufacturing process involves upset and forging, heat treatment and machining (turning and grinding) and special processes like TIG welding, Projection Welding, PTA Welding, Friction Welding, Induction Hardening and Nitriding.

1.5 VALVE DIMENSIONS:

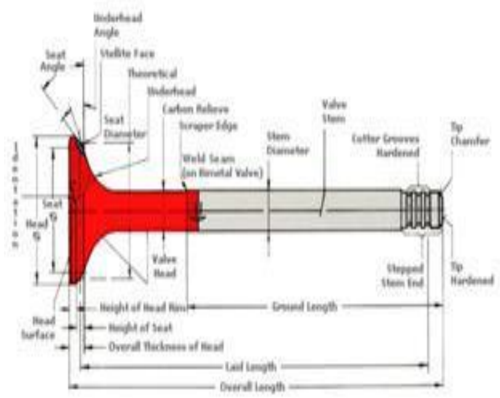

Figure 1.2 dimension of typical valves

1.5.1 Working Requirements for Valves

1. Inlet Valve
   a) Allow incoming charge into the engine
   b) Seal the port with out leak for remaining period
   c) Resistance to wear at the mating surfaces
   d) Good sliding surface for seizure resistance
2. Exhaust Valve
   a) Allow gases go out of the engine
   b) Seal the port with out leak for remaining period
   c) Strength to with stand high temperatures
   d) Resistance to wear at the mating surfaces
   e) Good sliding surface for seizure resistance

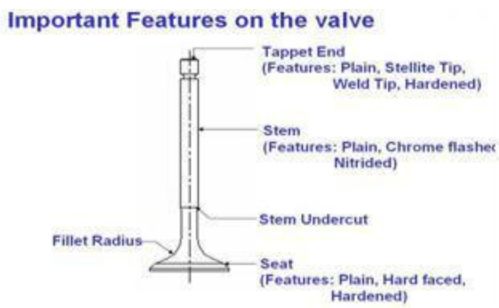

Figure 1.3 Features of typical valves

2. LITERATURE SURVEY

M. I. Karamangil A. Avci and H. Bilal [1] Internal combustion engine valves are precision engine components. They open and close as and when needed. 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. They are also used to seal the working space inside the cylinder against the manifolds.

Naresh Kr. Raghuwanshi, Ajay Pandey, R. K. Mandloi[2] The I.C. Engine valve failures, it is quite evident that a common cause of valve fracture is fatigue. Valves fail due to cyclic loading at high temperatures. High temperature is also responsible for decrease in hardness and yield strength of valve material, and also causes corrosion of exhaust valves. The surface oxidation and fretting / galling on the valve stem occur due to overheating and fatigue strength is decreased due to overheating. The impact loading of the valve face on the valve seat results in removal of material from that portion, which is known as valve recession. Wear failure occurs generally at the seat face of valve and at the stem due to sliding inside the stem guide. The wear rate increases with increase the number of cycles. Failure due to erosion-corrosion of exhaust valves is also a recognized failure mode in internal combustion engine valves.Fatigue failure is the main cause of valve failure. The fatigue strength is significantly decreased with increase of temperature. The combined S-N curve shown in Fig.10 is useful for comparing fatigue failure of the material, corresponding stresses cycles; and for developing a high fatigue strength material even at high temperature. The current focus is on light weight engine valves made up of ceramic materials which can operate without failure at high temperatures and can sustain stress cycles up to 109.

Prashant Rashmikant Pandya1,Amol Bagesar[3] The experiment concluded that the **Speed** is the main factor that is affecting the Burn off Length. Other parameters such as Friction Pressure and Time are contributing but not at a large scale so they can be neglected or can be taken as noise. The results can be very helpful for generating FEA Models for friction welding. Other properties of Bi-metal Poppet Exhaust valves such as tensile strength, toughness, hardness and fatigue properties can be analyzed and can be used for Bi-metal Production of Poppet Exhaust Inlet and outlet valves seal off the combustion chamber and control the charge exchange process in the engine. Valves are thermally and mechanically, highly strained components which are additionally subject to corrosive influences. The mechanical strain is a result of the bending of the valve head under combustion pressure and impact when closing (impact stress). With corresponding construction like strength and shape of the valve head and respective choice of material, these strains are brought to a manageable level.

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The outlet valve is additionally heatedby the passing hot exhaust gases duringoutlet clock opening. The valves are cooleddown mainly by conducting heat via the valve seat insert to the cylinder head. The smaller proportion of the heat is conducted via the valve guide to the cylinder head. Inlet valves reach temperatures of approx. 300 °C to 550 °C, outlet valves can get up to 1,000 °C.

3. GEOMETRIC MODELLING

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems product lifecycle management software suite. CATIA competes in the CAD/CAM/CAE market with Siemens NX, Pro/E, Autodesk Inventor, and Solid Edge as well as many others

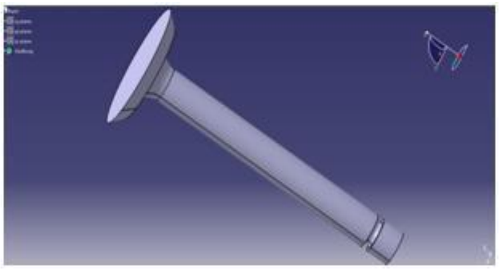

Fig 3.1 CATIA model of valve

Fig 3.2 CATIA model of bi metallic valve

4. INTRODUCTION TO ANSYS:

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyse by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations. ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments. ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping. With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction

Developer(s)	Dassault Systems
Stable release	V6R2011x / November 23, 2010
Operating system	Unix / Windows
Type	CAD software
License	Proprietary
Website	WWW.3ds.com

in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc.

5. Transient Thermal Analysis

5.1. Bi metal valve Transient thermal analysis Result when valve is closed at steady state at 5000 cycles, at time 127.651 sec

5.1. A. Imported model

Figure.5.Imported Model from PRO/E.

Valve tip – Austenitic Stainless Steel
Material Properties:
Thermal Conductivity – 0.03W/mm K
Specific Heat – 620 J/Kg K
Density - 0.00000901 Kg/mm3
Valve seat – EN52 steel
Material Properties:
Thermal Conductivity – 0.03W/mmK
Specific Heat – 506 J/Kg K Density - 0.00000789 Kg/mm3

5.1. B. Meshed Image

Figure.5.2.Meshed Model in ANSYS.

5.1. C. Temperature = 550 K

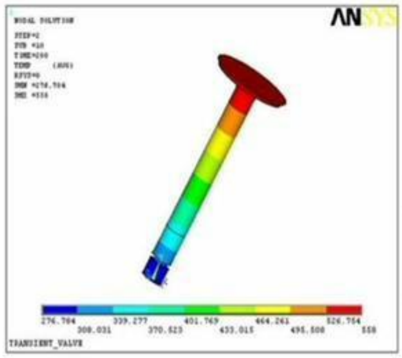

Figure.5.3.Temperature in ANSYS.

5.1. D. Thermal Gradient = 13.029 K/mm

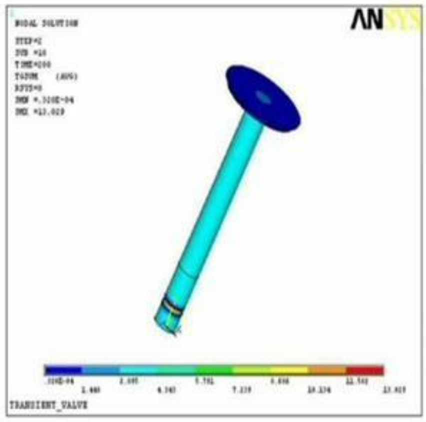

Figure.5.4.Thermal Gradient result in ANSYS.

5.2. E. Thermal Flux = 0.607174 W/mm2

Figure.5.5.Thermal Flux results in ANSYS.

6. Thermal Analysis

6.1. A. Temperature = 550 K

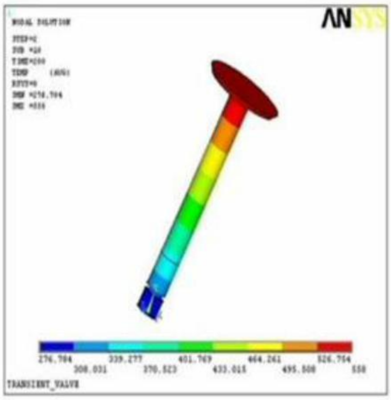

Figure.6.1.Temperature in ANSYS.

6.1. B. Thermal Flux = 0.607174 W/mm2

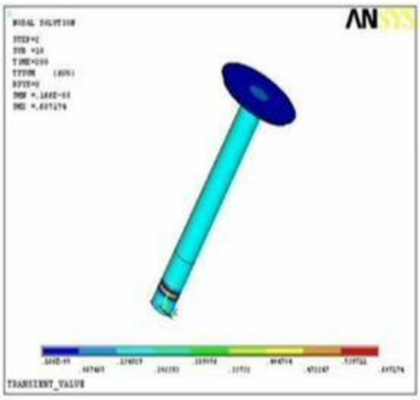

Figure.6.2.Thermal Flux results in ANSYS

6.1. C. Thermal Gradient

Figure.6.3.Thermal Flux results in ANSYS.

7. RESULTS

7.1. Transient Thermal Analysis

		Nodal Temperature (C)	Thermal Gradient (K/mm)	Thermal Flux (W/mm²)
BI METAL VALVE	CLOSED	558	13.029	0.607174
	OPEN	578	10.775	0.502
SINGLE METAL VALVE	CLOSED	558	13.029	0.607174
	OPEN	578	10.775	0.502

Table.7.1. Results for Transient Thermal Analysis.

7.2. Thermal Analysis

		Nodal Temperature (C)	Thermal Gradient (K/mm)	Thermal Flux (W/mm²)
BI METAL VALVE	CLOSED	558	13.029	0.607174
	OPEN	560	81.52	2.446
SINGLE METAL VALVE	CLOSED	558	13.029	0.607174
	OPEN	558	208.687	6.261

Figure.7.2.Table of Results for Thermal Analysis.

8. CONCLUSION:

We designed the diesel engine exhaust valve by using the formulas. We have done the model for the designed model by using Pro/Engineer software. We conducted Transient thermal analysis at closing and opening condition using Bimetal and Single metal for the valve. We have also conducted thermal analysis. Thermal analysis of the exhaust valve shows that the maximum temperature of the exhaust valve occurs at the stem of the valve. By observing the transient thermal analysis results, the results are same for closed and open conditions using Bimetal and Single metal. By comparing the closed and open conditions, the heat transfer rate is good in the closed condition than in open condition. By observing the thermal analysis results, the results are same in closed condition for both Bimetal and Single metal valve as in transient thermal analysis.

But in open condition the results have changed, theheat transfer rate is good for single metal valve thanBimetal valve.

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