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Design and Analysis of Poppet Valve Using Composite Materials

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Abstract
Poppet valve is a precision engine component which blocks gas flow ports and controls the exchange of gases in internal combustion engines. Intake and exhaust valves are known as "poppet" valves. Poppet valves have a round head that blocks a Hole (the "port") the "stem" attached to the back of this "valve head" pushes the valve up and away from the port, allowing air/fuel to flow through the gap between the valve head and valve seat and into the combustion chamber. Poppet valves work well in engines because the pressure inside the combustion chamber pushes the valve against the seat, sealing the chamber and preventing leaks during this cycle poppet valves are exposed to high temperature and pressure which will affect the life and performance of the engine. The aim of the project is to design and analysis of poppet valve with a suitable material using Finite element Method. 3D model is done in CATIA and Analysis is done in ANSYS. Thermal and structural analysis is to be done on the poppet valve when valve is closed.
Key Words: *Poppet valve, Composite Materials, Finite Element Method, CATIA, ANSYS.*

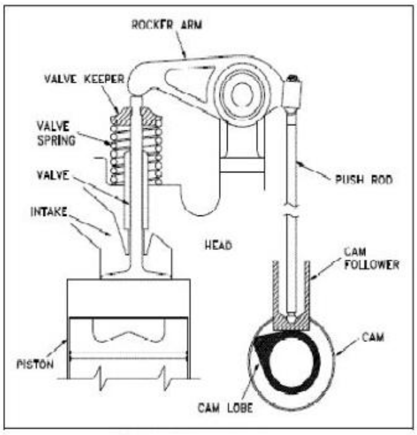
1. INTRODUCTION

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.

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. 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. Any type of valve failure affects the engine performance thus making it mandatory to give due importance to temperature and stress analysis of IC valves.

Valve mechanism is the arrangement of different components which controls the intake and exhaust process.

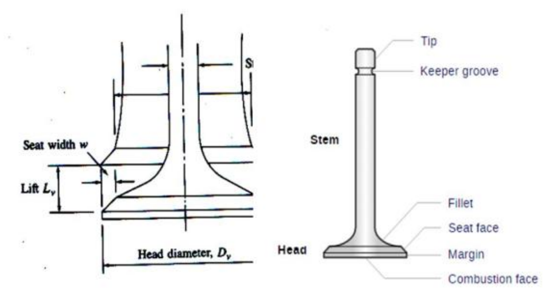
Exhaust and inlet valve are vital components of an IC engine and which are controlling the flow of fresh air and burnt gases in and out of engine cylinders.



1.1 Engine Valve

In the operation thermal and mechanical stresses are imposed on inlet and exhaust valve because of high temperature and pressure in the cylinder.

Geometrical Nomenclature for Valves



The instantaneous valve flow area depends on valve lift and the geometrical details of the valve head, seat and stem.

1.2 Nomenclature for poppet valve

2. POPPET VALVE

A poppet valve is a type of check valve often associated with kill and choke lines or pressure-control equipment. A poppet valve is a directional control valve and is typically characterized as being a high flow, fast acting design due to the large flow paths through the main body of the valve. Usually, the poppet valve can be opened relatively quickly.

The inlet valves are made from plain nickel, nickel chrome or chrome molybdenum. Whereas exhaust valves are made from nickel chrome, silicon chrome steel, high speed steel, stainless steel, high nickel chrome, tungsten steel and cobalt chrome steel.

With the help of these parts, valve performs it's operation very accurately in internal combustion engine. The valve spring, keeps the valve pressed against its seat and ensure a leakage proof operation and also bring back the valve very quickly during its closing. When the engine is started, it gets heated up gradually thereby causing the valve stem to expands. The clearance provided in exhaust valve is slightly more than that of inlet valve. This is due to slightly more expansion in exhaust valve because of higher temperature of hot exhaust gases produced during combustion.

Valves are the most important part of every engines, So due care must be taken in selection and maintenance of valve.

3. SELECTION OF MATERIALS

In reaction to increasing worldwide competition and developing concern for environment, the auto manufacturers have already been encouraged to meet up the conflicting demands of increased power and performance, lower fuel consumption, lower pollution emission and reduced vibration and noise. To be able to fulfill these newer and emerging needs, the automobile industry has acknowledged the necessity for materials substitution.

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.

Now a day's steel and nickel alloys used for poppet valve. Heat generation will be more during power stroke in the combustion chamber. So it is essential that the material of poppet valve has to withstand the high temperature. Composite materials play vital role in selection of materials because of their low weight, high strength,, etc. Selected material should have high thermal conductivity for better heat dissipation. Here we used composite materials such as, SUH1 Steel, Alumina/Alumina composite, Carbon/Carbon composite and Carbon/Carbide composite for further analysis.

Material selection for poppet valve should have the following requirements,

- High strength and hardness to resist tensile loads and stem wear.
- High hot strength and hardness to combat head cupping and wear of seats.
- High fatigue and creep resistance.
- Adequate corrosion resistance.

- Least coefficient of thermal expansion to avoid excessive thermal stresses in the head.
- High thermal conductivity for better heat dissipation.

Though poppet valves are relatively small compared to other equipment components, they play an essential role in effective operation. When poppet valves fail, fluid can be blocked or allowed to flow freely throughout a system, which can cause serious problems within the equipment and damage related upstream and downstream equipment.

When choosing the right material for an application, thoroughly understand the nature of the fluid and conditions within the equipment. Weigh the application characteristics against the material type. Resist the urge to decide based solely on cost and choose the material most appropriate for the application.

There are several factors to consider when deciding on the right poppet valve material. Such factors include:

- Temperature
- Chemical or substance exposure
- Corrosion
- Fatigue
- Strength
- Cost
- Maintenance

Though most poppet valve materials are manufactured for high temperature applications, it is important to measure or gauge the temperature range of the application to ensure that the maximum temperature does not exceed the melting point of the material. It is also important to understand the characteristics of the fluid passing through the valve to ensure that the material can resist wear, degradation and absorption during exposure.

Table 1: Properties of different types of composite materials

MATERIAL	SUH 1 STEEL	ALUMINA/ALUMINA COMPOSITE	CARBON/CARBON COMPOSITE	CARBON/SILICON CARBIDE COMPOSITE
DENSITY (g/cc)	7.7	3.69	2.9	2.4
YOUNG'S MODULUS (Gpa)	200	215	64.5	150
POISSON RATIO	0.265	0.21	0.22	0.4
SPECIFIC HEAT (J/kg-k)	502.416	880	800	750
THERMAL CONDUCTIVITY (W/m-k)	23	18	20	120
COEFFICIENT OF THERMAL EXPANSION (m/m-k) or (k^{-1})	$1.20e^{-09}$	$8.10e^{-09}$	$6.00e^{-09}$	$2.50e^{-09}$

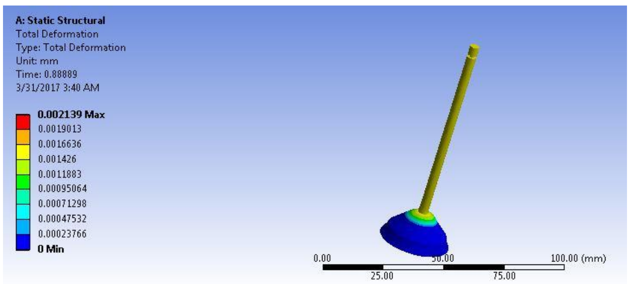
PEEK polymer and nylon tend to be the materials of choice for compressors and chemical transfer applications. These plastics are favored because of their resistance to corrosion when exposed to harsh chemicals, less mass and low thermal conductivity. They can handle a wide range of environments with less fatigue and wear, which allows them to last longer. The longer a poppet valve lasts, the less costs accrue over time due to less maintenance and repairs.

4. ANALYSIS

INLET VALVE

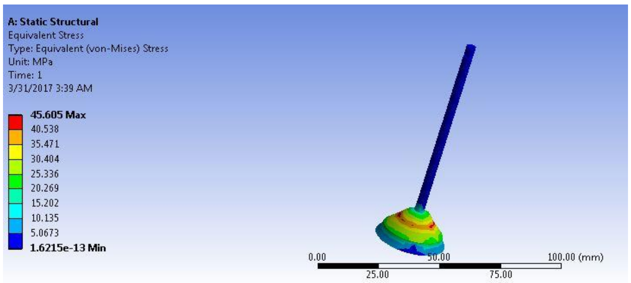
CASE 1: SUH 1 STEEL

DEFORMATION



4.1 Deformation of Poppet Valve for SUH 1 Steel

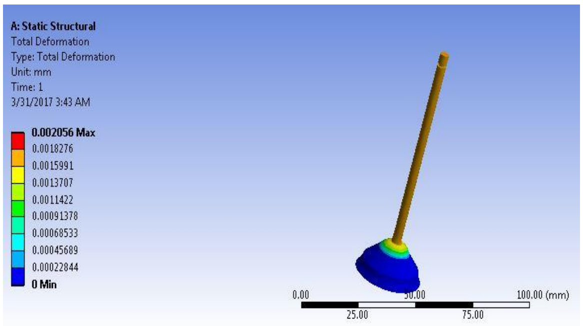
STRESS



4.2 Stress of Poppet Valve for SUH 1 Steel

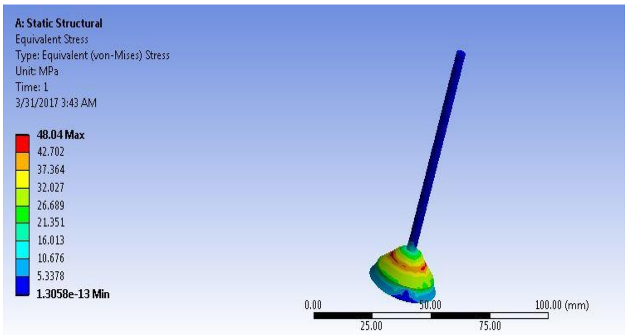
CASE 2: ALUMINA/ALUMINA Composite

DEFORMATION



4.3 Deformation of Poppet Valve for ALUMINA/ALUMINA

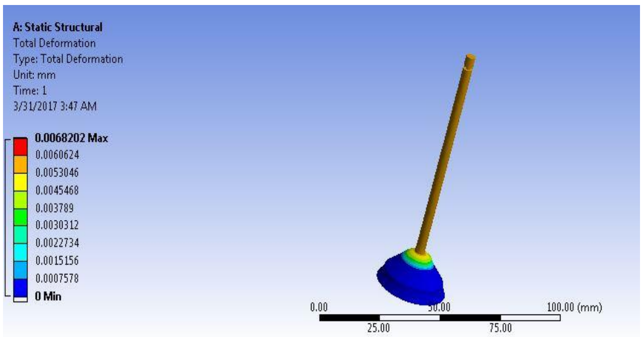
STRESS



4.4 Stress of Poppet Valve for ALUMINA/ALUMINA

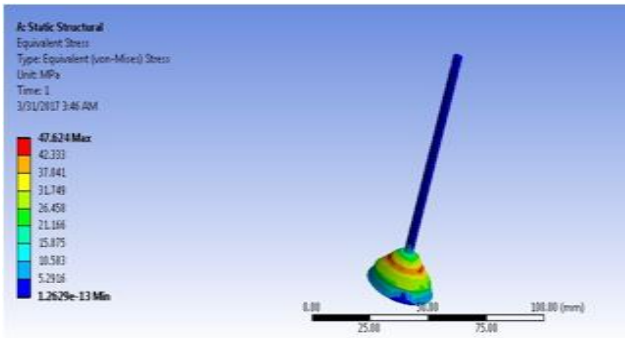
CASE 3: CARBON/CARBON Composite

DEFORMATION



4.5 Deformation of Poppet Valve for CARBON/CARBON

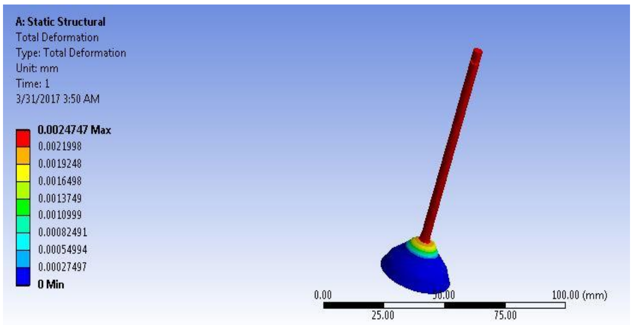
STRESS



4.6 Stress of Poppet Valve for CARBON/ CARBON

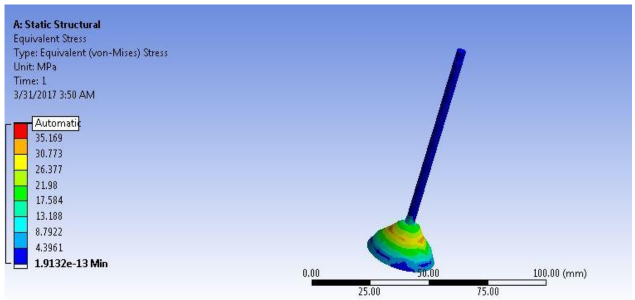
CASE 4 : CARBON/SiC Composite

DEFORMATION



4.7 Deformation of Poppet Valve for CARBON/ SiC

STRESS

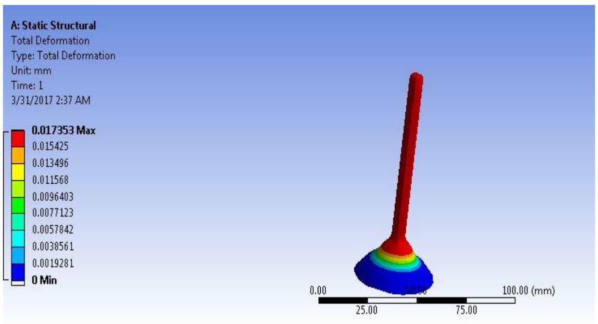


4.8 Stress of Poppet Valve for CARBON/SiC

EXHAUST VALVE

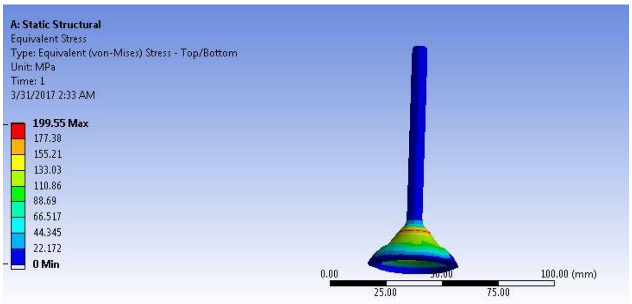
CASE 1: SUH 1 STEEL

DEFORMATION



4.9 Deformation of Poppet Valve for SUH 1 Steel

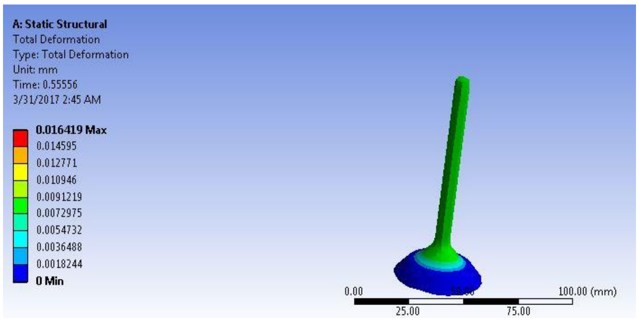
STRESS



4.10 Stress of Poppet Valve for SUH 1 Steel

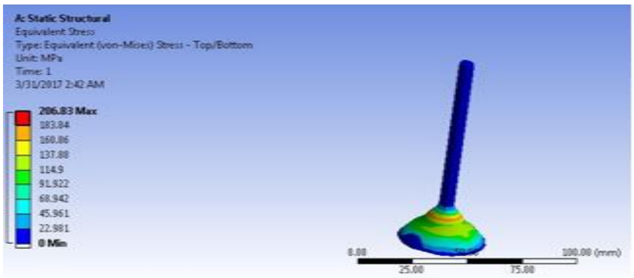
CASE 2: ALUMINA/ALUMINA COMPOSITE

DEFORMATION



4.11 Deformation of Poppet Valve for ALUMINA/ALUMINA

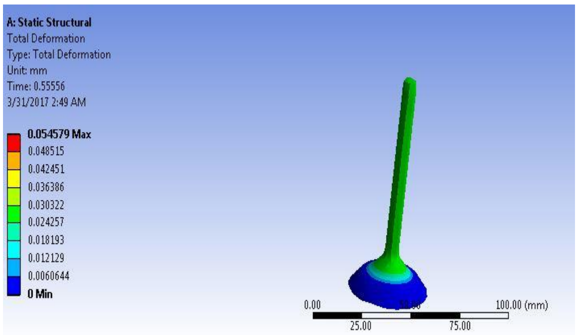
STRESS



4.12 Stress of Poppet Valve for ALUMINA/ALUMINA

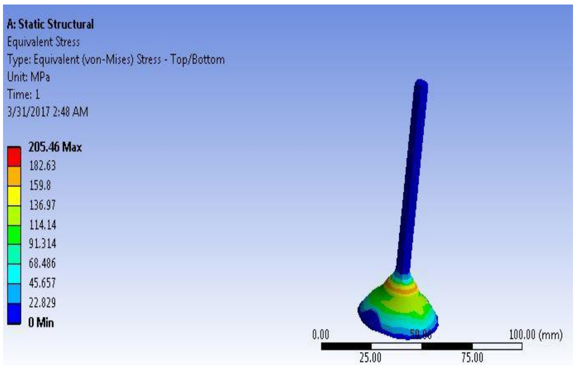
CASE 3: CARBON/CARBON COMPOSITE

DEFORMATION



4.13 Deformation of Poppet Valve for CARBON/CARBON

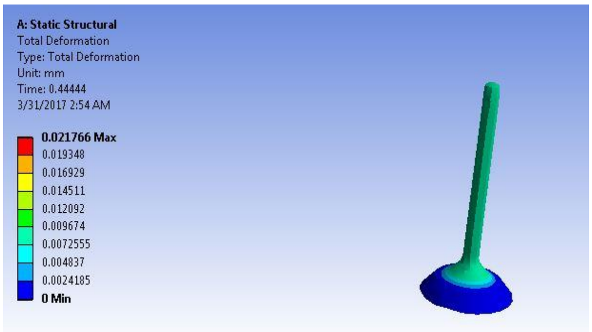
STRESS



4.14 .Stress of Poppet Valve for CARBON/CARBON

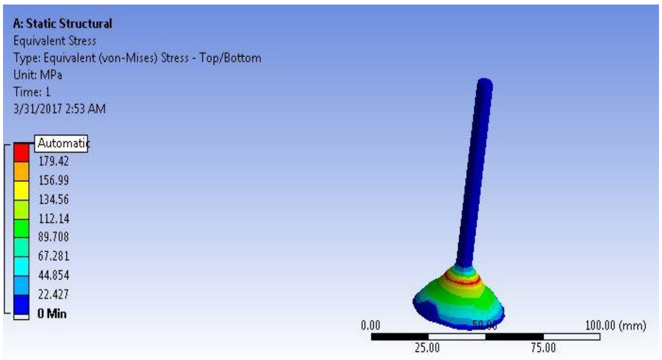
CASE 4 : CARBON/SiC COMPOSITE

DEFORMATION



4.15 Deformation of Carbon/SiC

STRESS



4.16 Stress of poppet Valve for Carbon/SiC

5. RESULTS

Table 2: Deformation and stress values for inlet valve

	SUH 1 STEEL	ALUMINA/ ALUMINA	CARBON/ CARBON	CARBON / SiC
DEFORMATION(mm)	0.8888	0.0020	0.0068	0.0024
STRESS (MPa)	46.60	48.04	47.62	39.56

Table 3: Deformation and stress values for exhaust valve

	SUH 1 STEEL	ALUMINA / ALUMINA	CAN/ CARBON	CARBON / SiC
DEFORMATION(mm)	0.0173	0.0164	0.0545	0.4444
STRESS (MPa)	199.55	206.83	205.46	201.84

6. CONCLUSION

In this study provides a conceptual framework for better understanding on the finite-element simulation of material behavior of inlet and exhaust valves in internal combustion engine.

Four different cases has been done on inlet and exhaust valves. Pressure of 25 Mpa and 30 Mpa has been considered for analysis and the results are observed. From the results we can suggest that Carbon/SiC is better material for inlet valve and SUH 1 STEEL for exhaust valve.

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