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Design and Analysis of Composite Material Poppet Valve

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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 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 an exhaust valve with a suitable material for a Four-stroke diesel engine by using fem analysis. In poppet valve we have considered three different materials Al_2O_3, Carbon-epoxy, Technetium composite materials. In this we observe the results of original poppet valve as stress, strain and total deformation. These values are compared with the modified poppet valve design. The modified poppet valve design values are shown tremendous change in stress, strain and total deformation of the composite material.
Keywords: *Poppet Valve, FEM analysis, Composite material, Valve.*

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I. 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.

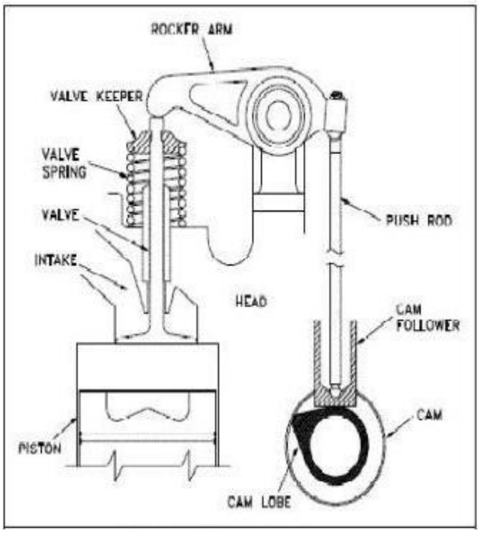


Figure1: Engine Valve

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.

In the operation thermal and mechanical stresses are imposed on inlet and exhaust valve because of high temperature and pressure in the cylinder. At a very early stage in the development of the internal combustion (IC) engine, poppet valves became the standard way of controlling the flow of the fuel/air mixture into the cylinder and the flow of exhaust gases out. Of the two valves, inlet and exhaust, the latter is more susceptible to failure.

1.1. OBJECTIVE

1. The main objective of this project to avoid the reciprocal movement of the valve.
2. To find out the suitable material.
3. To determined better performance, efficiency with low cost materials.
4. To improve strength of valve according to need.

1.2 FOUR STROKE IC ENGINE

In a four stroke engine, the cycle of operations is completed in four strokes of the piston or two revolution of the crankshaft. Each stroke consists of 180 deg. Of crankshaft rotation and hence a four stroke cycle is completed through 720 deg. of crank rotation.

Intake stroke: The first stroke of the internal combustion engine is also known as the suction stroke because the piston moves to the maximum volume position (downward direction in the cylinder). The inlet valve opens as a result of the cam lobe pressing down on the valve stem, and the vaporized fuel mixture enters the combustion chamber. The inlet valve closes at the end of this stroke.

Compression stroke: In this stroke, both valves are closed and the piston starts its movement to the minimum volume position (upward direction in the cylinder) and compresses the fuel mixture. During the compression process, pressure, temperature and the density of the fuel mixture increases.

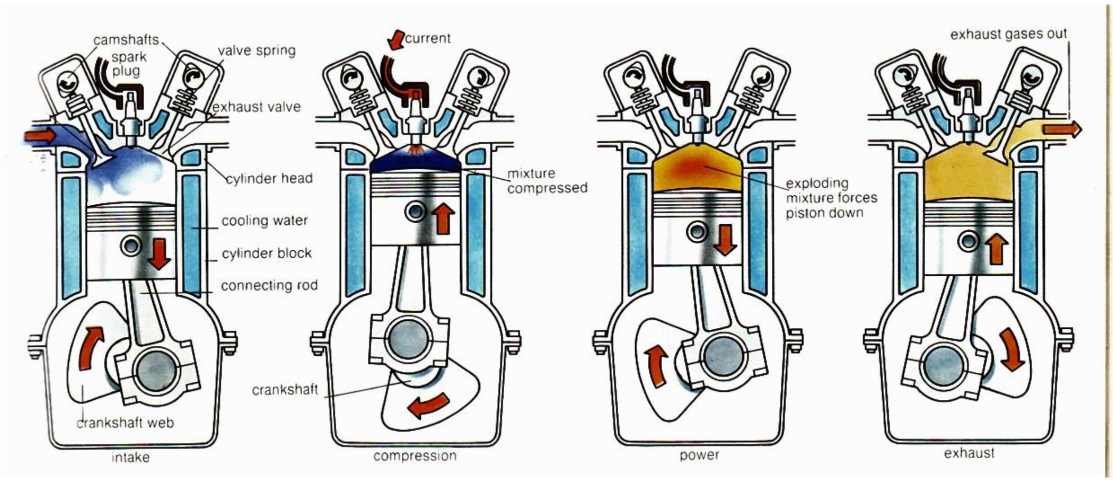


Figure2: stroke engine mechanism

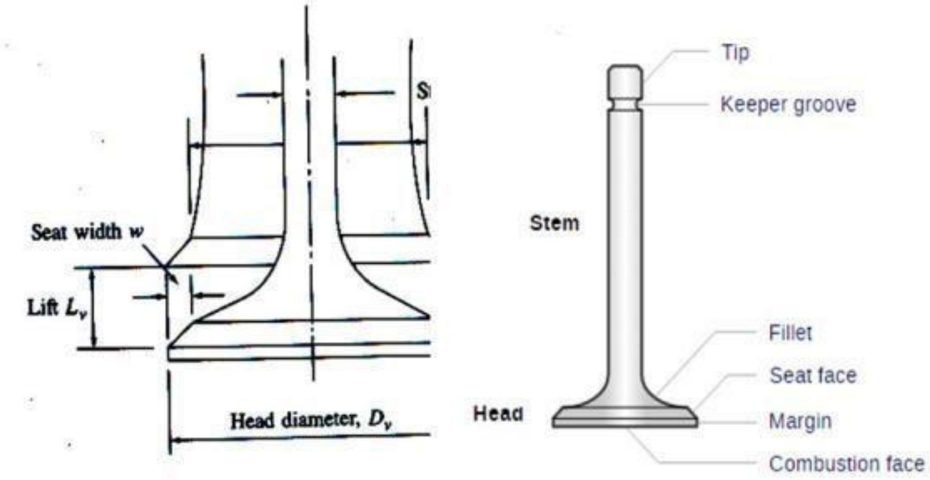
A Power stroke: When the piston reaches a point just before top dead centre, the spark plug ignites the fuel mixture. The point at which the fuel ignites varies by engine; typically it is about 10 degrees before top dead centre. This expansion of gases caused by ignition of the fuel produces the power that is transmitted to the crank shaft mechanism.

Exhaust stroke: In the end of the power stroke, the exhaust valve opens. During this stroke, the piston starts its movement in the maximum volume position. The open exhaust valve allows the exhaust gases to escape the cylinder. At the end of this stroke, the exhaust valve closes, the inlet valve opens, and the sequence repeats in the next cycle. Four-stroke engines require two revolutions.

1.3 POPPET VALVE:

A poppet valve (also called mushroom valve) is a valve typically used to control the timing and quantity of gas or vapor flow into an engine. It consists of a hole or open-ended chamber, usually round or oval in cross-section, and a plug, usually a disk shape on the end of a shaft known as a valve stem. The working end of this plug, the valve face, is typically ground at a 45° bevel to seal against a corresponding valve seat ground into the rim of the chamber being sealed. The shaft travels through a valve guide to maintain its alignment. A pressure differential on either side of the valve can assist or impair its performance. In exhaust applications higher pressure against the valve helps to seal it, and in intake applications lower pressure helps open it.

A poppet valve consists of a disc of metal with a coaxial stem on one side which closes a circular opening in a wall separating two chambers, against which wall it is drawn by a spring. To open the valve, a force must be applied to it in a direction contrary to that of the spring pressure. Poppet valves are lifted from their seats by means of cams, and are closed by springs. The rate at which the valve is opened and closed depends on the cam outline and on the type and size of cam follower employed. From the standpoint of gas flow it is, of course, desirable that the valve should open and close very quickly, and remain fully open for the



greatest possible length of time

Figure3: Geometric Nomenclature Of Valve

Poppet valve has following main parts, Cam Shaft, Cam, Cam Follower, Tappet, Adjusting Screw, Washer, Valve Spring, Valve Stem, Guide valve face. With the help of these parts, valve performs its operation very accurately in internal combustion engine. The cam actuates the movement of the valve through the tappet. The replaceable valve stem moves up and down in the valve stem guide. This movement is obtained by rotation of camshaft and cam, which generally runs at the half the engine speed. . The valve spring, keeps the valve pressed against its seat and ensures a leakage proof operation and also brings back the valve very quickly during its closing. When the engine is started, it gets heated up gradually there by causing the valve stem to expand. A valve tappet clearance is always provided to allow the expansion of valve stem and other parts. This clearance value depends upon the length of the valve, its material and the operating temperature of the engine. The tappet valve clearance can be adjusted by rotating the adjusting screw. Where adjusting screw is not provided to vary the clearance, it can be increased by grinding the bottom of the valve stem and face or by using longer valve. Due care must be taken because even a slightly insufficient clearance may lead to the valve not properly resting against its seat as the engine gets heated causing increased noise level and loss of power. 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.

1.4 WORKING PROCEDURE:

Important parts used in valve mechanism are camshaft, cams, valve lifters, pushrods, rocker arms, valve springs, valve stem, and valve seat. Cams are present on the camshaft of an engine. Camshaft rotates with half speed of crankshaft, when the valve lifter touches the cam cone portion then there is some lifting moment in the valve lifter, this motion is transformed to push rods which are used to give moment to the rocker arms. Rocker arm is used to apply the force on valve stem to open the manifolds and when the force released valve closes automatically because of valve spring expansion.

Valves are subjected to:

- Longitudinal cyclic stresses due to the return spring load and the inertia response of the valve assembly.
- Thermal stresses in the circumferential and longitudinal directions due to the large temperature gradient from the Centre of the head to its periphery and from the crown to the stem.
- Creep conditions due to operation at very high temperatures, particularly in case of valve head and corrosion conditions.

1.5 SELECTION OF MATERIALS:
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.

1.6 PROBLEMS WITH AVAILABLE ENGINE:
A poppet valve used in a valve operating system of a usual internal combustion engine is currently employed in most of internal combustion engines because of its good sealing property. When an improvement in performance of the internal combustion engine is intended to be provided, however, the use of the poppet valve is accompanied by the various disadvantages:

- The presence of a valve stems and valve head in a passage results in a resistance to the passing of a gas to cause degradation in intake and exhaust efficiencies.
- Because of the poppet valve have the valve stem and the valve head, intake and exhaust passages are curved in the vicinity of the valve, resulting in degradation in intake and exhaust efficiencies.
- Because of the valve is reciprocally moved by the valve stem, a space elongated in the direction of such reciprocal movement is required, resulting in a large sized engine.
- Because the opening and closing of the valve are conducted by the reciprocal movement of the valve stem, a shock noise is generated during closing of the valve.
- Frictional losses are also present due to more number of mating parts in valve mechanism.
- Due to more components material cost and manufacturing cost of material is increased. And lubricating losses are also increased.

1.7 CATIA DRAWINGS:
By using CATIA V5 mechanical design software we designed new oscillatory valve mechanism system parts. Dimensions are approximately same to the present single cylinder internal combustion engine.

1.7.1 VALVE DESIGN

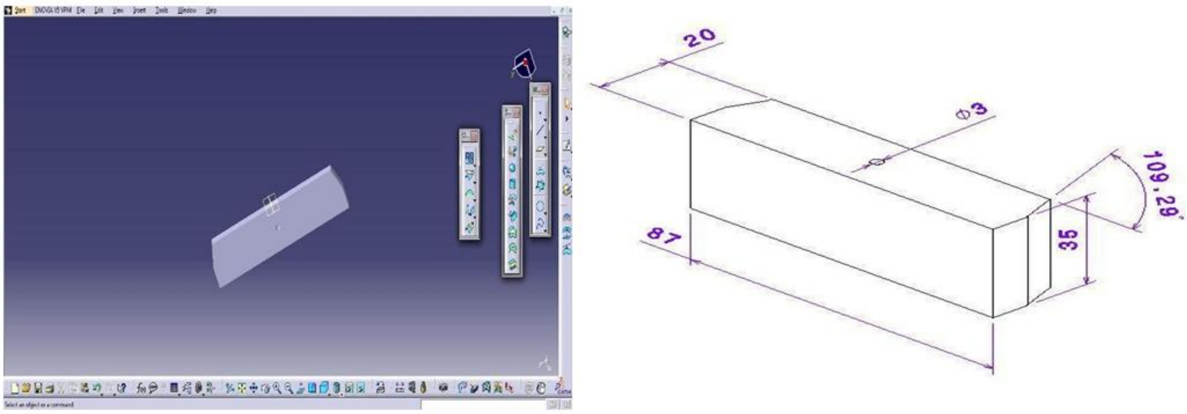


Figure4: Valve Design

This isometric view of valve shows the complete design. Length of valve is 87mm, height is 20mm, width is 35mm, and 3mm diameter hole is used to fix the valve with valve head by using a screw. Valve is curved at the end portions, because of it, valve oscillations are very easy inside the cylinder. NIMONIC 80A is used to manufacture the oscillatory valve. Because valve must contain some properties those are:

- Hot strength and hardness to resist tensile loads.
- Least coefficient of thermal expansion to avoid excessive thermal stresses in the valve.
- High thermal conductivity for better heat dissipation.
- High corrosion resistance.

1.7.2 VALVE HEAD

Valve head is used to control the oscillatory motion of valve. Half of part is inside the combustion chamber and another half is outside of combustion chamber. Valve head having a 3mm diameter hole which is used to fix the oscillatory valve inside the combustion chamber. Valve head is fixed to the cylinder head by a fixed joint. Valve head must contain high strength, high corrosive resistance, high thermal conductivity.

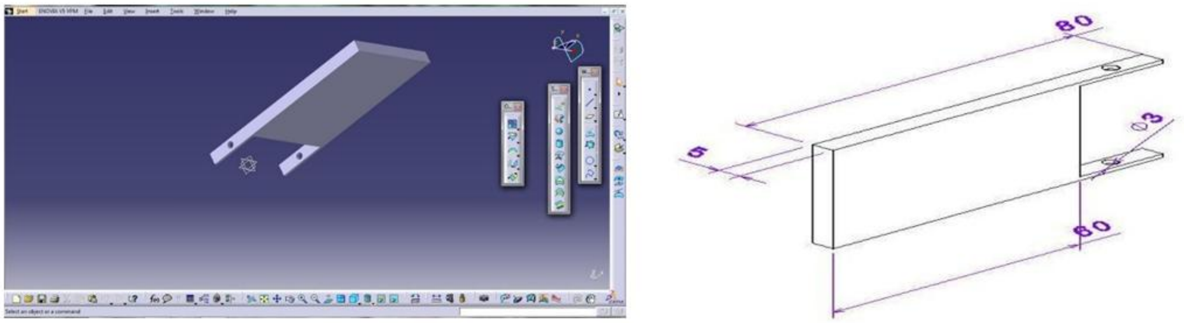


Figure5: Valve Head Design

1.7.3 CYLINDER HEAD

Cylinder head design is completely different from the present IC engine cylinder head. Cylinder head having two manifolds which are inlet and exhaust manifolds. one rectangle slot is used to insert valve head into the combustion chamber. Another 3mm diameter hole is used to join connecting rod and oscillatory valve end. Gray cast iron is used to manufacture cylinder head.

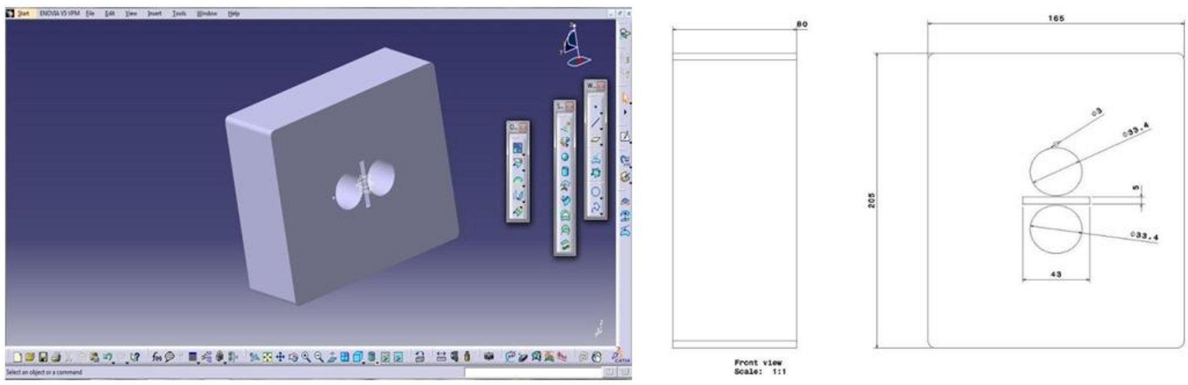


Figure 6: Cylinder Head

1.7.4 CONNECTING ROD

In this oscillatory valve mechanism two connecting rods are used to transform the motion from follower to engine valve. Two fulcrums, valve heads and valve springs are replaced by two connecting rods only. Connecting rods arrangement is to convert translator motion into oscillatory motion.

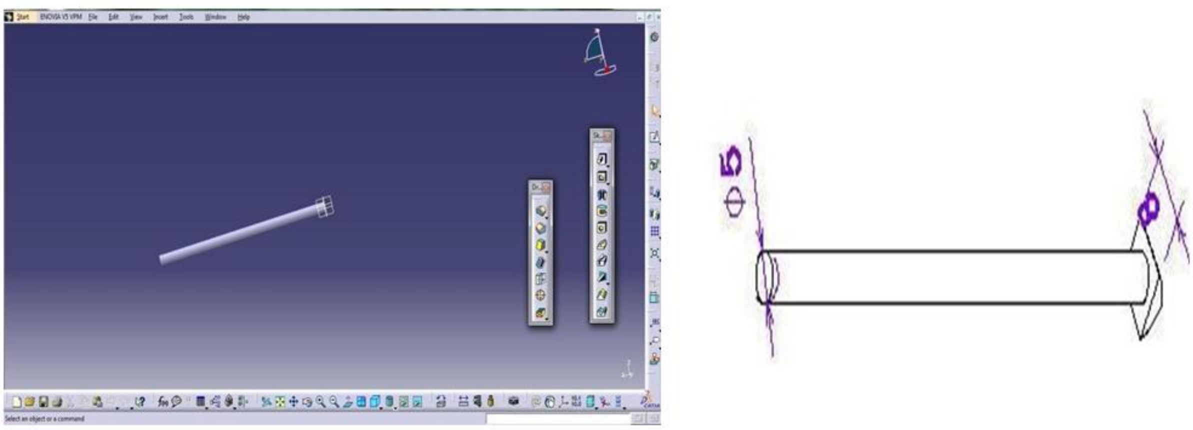


Figure 7: Connecting Rod

1.7.5 COMPLETE ASSEMBLY OF NEW VALVE MECHANISM:

1. Valve head
2. Oscillatory valve
3. Cylinder head
4. Connecting rod1
5. Connecting rod2
6. Follower
7. Cam
8. Camshaft
9. Piston.

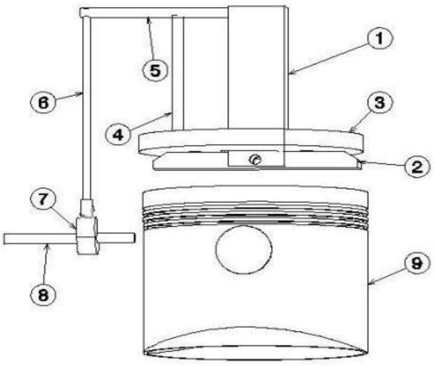


Figure 8: Complete Assembly Of Valve

1.8 DESIGN CALCULATION

1.8.1 SPECIFICATION OF ENGINE
Bore Diameter D = 73.5 mm
Length of stroke L = 73.5 mm
Engine Speed N = 5500 rpm
Break horse power (BHP) at 5500 rpm = 37

1.8.2 SPECIFICATION OF POPPET ENGINE VALVE
Diameter of valve port (D_P) = 27 mm
Width of valve (W) = 2mm
Valve angle (θ) = 45
Diameter of valve head (D_V) = 31 mm
Thickness of valve disk (t) = 2 mm
Margin (M) = 1.6 mm
Diameter of valve stem (D_S) = 12 mm
Maximum valve lift (h_{max}) = 10 mm

Kinematic motion of poppet engine valve is governed by valve actuating mechanism generally push rod mechanism. This mechanism is driven by motion of crankshaft of engine and as a result of which poppet engine valve continuously open and closes the ports which control the flow of gas through ports. Poppet engine valve is opened by valve actuating mechanism just before the beginning of exhaust stroke so that exhaust gases are blown out and it is loosed by compressed spring just after the beginning of suction stroke. Thus poppet engine valve is continuously under tension and compression alternatively which lead to fatigue failure alternatively which lead to fatigue failure.

Calculation for forces acting on poppet engine valve
Force required to open the valve

$F_{open} = F_i + F_l + F_g$ ……………(1)

Where,
F_i = Initial spring force
F_l= Force required to lift the valve
F_g= Gas force

Mathematically,

$F_i = (\frac{\pi}{4})\ D_v{}^2 X\ P_s$ ………………..(2)

Where,
P_s = Suction pressure = 0.002 to 0.004 N/mm^2

$F_l = k\ X\ h_{max}$…………………(3)

Where,
K= spring stiffness = 10 N/ mm

$$F_g = \left(\frac{\pi}{4}\right) D_v^{\,2} X\, P_g \ldots\ldots\ldots\ldots(4)$$

Where,

Pg = gas pressure = 0.35 to 0.45 N/mm^2

Substituting equation (2),(3) and (4) in equation (1),

F_{open} = 379.11 N

F_l = 15.08 N

Calculation for valve timing of poppet engine valve

Engine under consideration is high speed engine and as a result of which the exhaust valve will open 55 before Bottom dead center and will close 20 after top dead center. This being true theoretically but will deviate from it under practical situation whose consideration is beyond the scope of this research paper. Total angle of rotation of crank shaft when exhaust valve is open is,

θ_1 = 55 + 180 + 20 = 255

Total angle of rotation of camshaft when exhaust valve is open

θ_1 = 255/2 = 127.5 = 2.224 radians

Speed of camshaft is given by,

N_{cs} = 5500/ 2 = 2750 rpm

Number of rotation of camshaft per second,

$N_{ps} = N_{cs}/ 60$ = 2750 /60 = 45.83 seconds

Time required by camshaft to complete one rotation,

T_{1r} = 1

N_{ps} = 1/ 45.83 = 0.0218 sec

Time required by camshaft to complete rotation of one degree,

$T_{1d} = T_{1r}$ /360 = 0.0218/ 360 = 6.06×10^{-5} seconds

Time for which the exhaust valve is open is given by,

Topen = θ_1 × T1d

= 255 × 6.06×10^{-5}

= 15.453×10^{-3} seconds

Cycle time for poppet engine valve to once open and close is given by,

$T_{total} = 360 \times T_{1d}$

= 360 × 6.06×10^{-5} seconds

= 21.86×10^{-3} seconds

Where,

Ttotal = Topen + Tidle

Where,

T_{idle} = Time for which valve is closed and is in idle state which means that it neither opens nor close during this time.

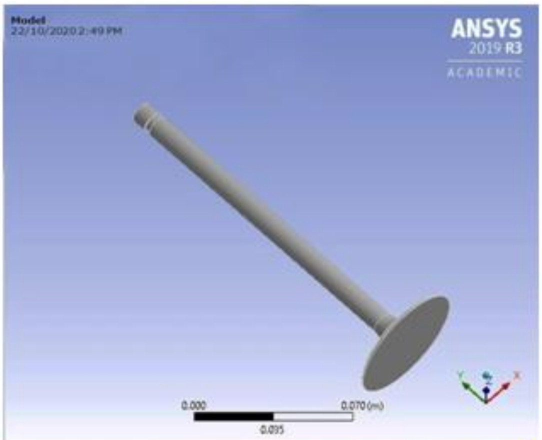
Therefore,

Tidle = Ttotal – Topen

Substituting values in above equation we get,

$T_{idle} = 21.86\times 10^{-3} - 15.453\times 10^{-3}$ = 6.416× 10-3 seconds.

1.9 FEM ANALYSIS



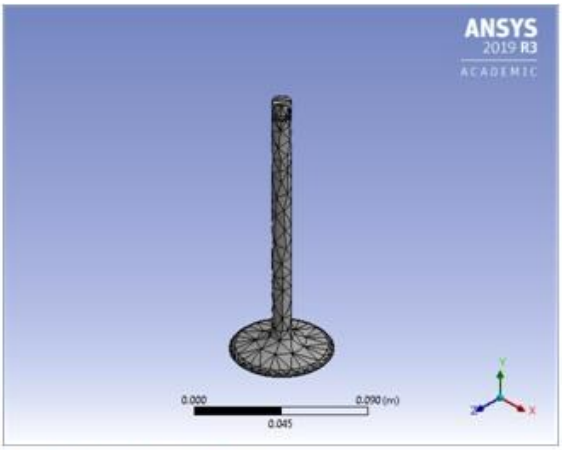


Figure 9: FEM Analysis of Valve Structure

1.9.1 STRESS, STRAIN, TOTAL DEFORMATION ANALYSIS FOR AL_2O_3

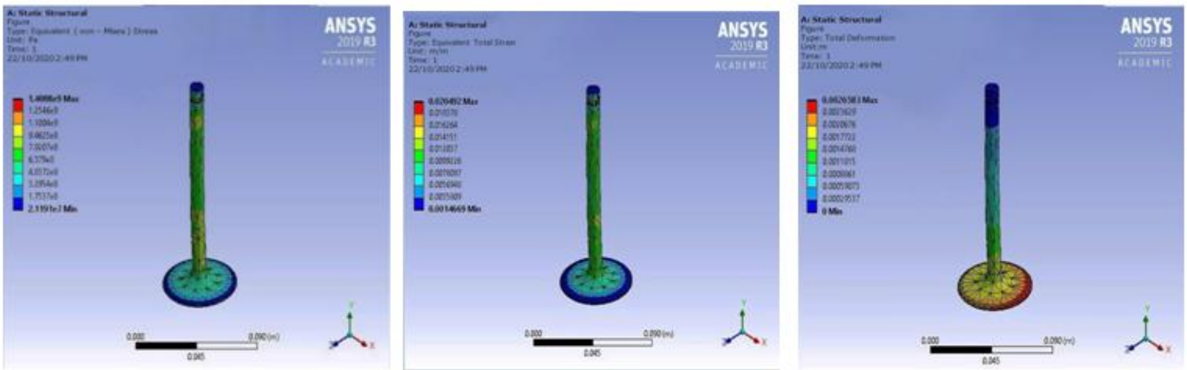


Figure 10: Total Equivalent Stress, strain and Total Deformation for AL_2O_3

AL_2O_3 composite mat.	Minimum	Maximum	Average
Equivalent Stress(Pa)	2.1191e7	1.4088e9	7.149955e8
Equivalent strain(m/m)	1.4669e-003	2.0492e-002	6.0934e-003
Total Deformation(m)	0.	2.6583e-003	1.7552e-003

1.9.2 STRESS, STRAIN, TOTAL DEFORMATION ANALYSIS FOR EPOXY CARBON

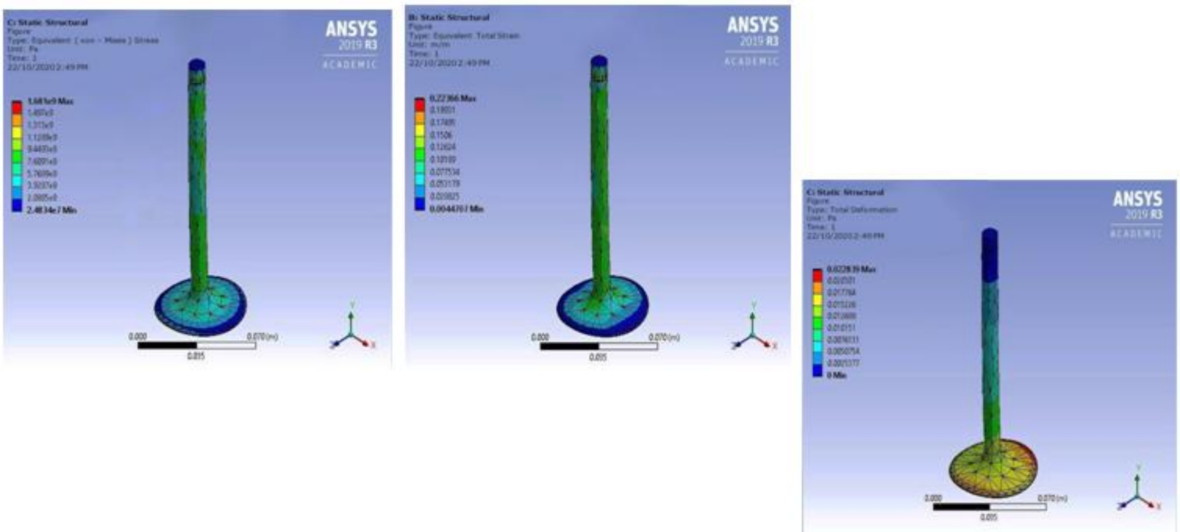


Figure 11: Total Equivalent Stress, strain and Total Deformation for Carbon Epoxy

Epoxy Carbon composite mat.	Minimum	Maximum	Average
Equivalent Stress(Pa)	2.4834e+007	1.681e+009	4.3546e+008
Equivalent strain(m/m)	4.4707e-003	0.22366	5.8575e-002
Total Deformation(m)	0.	2.2839e-002	1.3879e-002

1.9.3 STRESS, STRAIN, TOTAL DEFORMATION ANALYSIS FOR TECHNETIUM

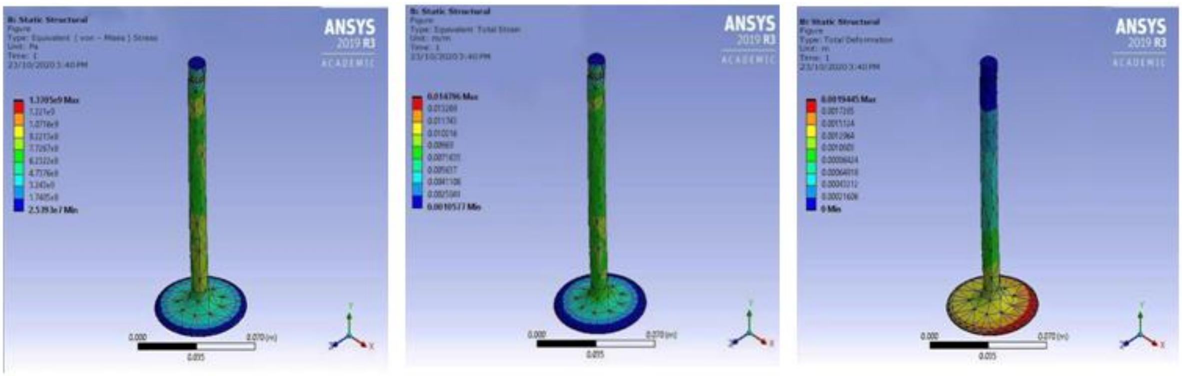
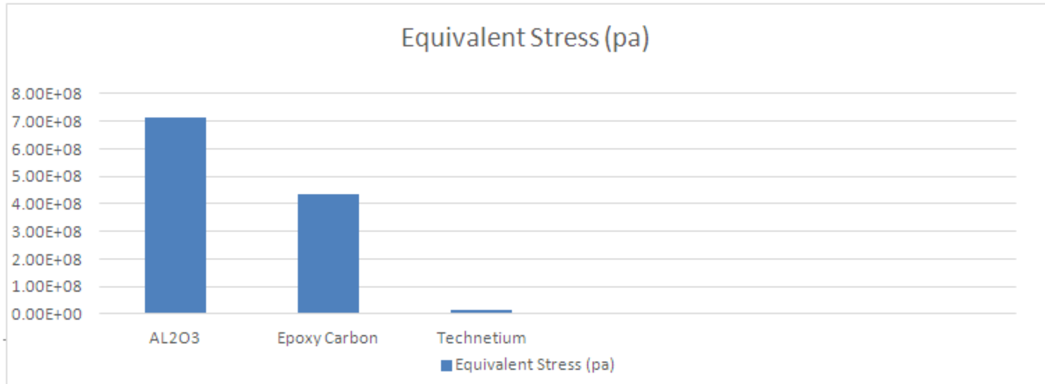


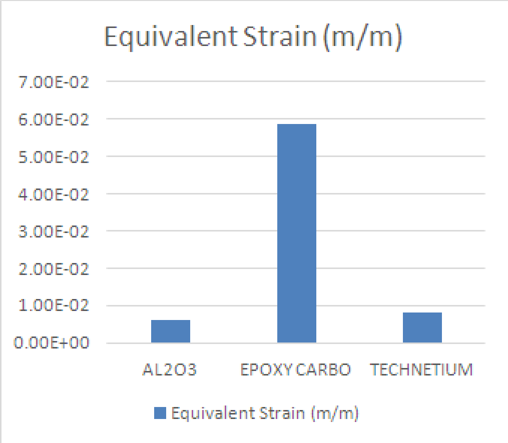
Figure 12: Total Equivalent Stress, strain and Total Deformation for Technetium

Technetium composite mat.	Minimum	Maximum	Average
Equivalent Stress(Pa)	2.5593e7	1.3705e5	1.2865025e7
Equivalent strain(m/m)	0.0010577	0.014796	0.00792685
Total Deformation(m)	0.	1.9445e-003	1.2867e-003

Material	Equivalent Stress (pa)			Equivalent Strain (m/m)			Average Total Deformation (m)
	MI N	MAX	AVG	MIN	MA X	AVG	
AL2O3	2.1191e7	1.4088e9	7.149955e8	1.4669e-003	2.0492e-002	6.0934e-003	1.7552e-003
EPOXY CARBO	2.4834e+007	1.681e+009	4.3546e+008	4.4707e-003	0.22366	5.8575e-002	1.3879e-002
TECHNETIUM	2.5593e7	1.3705e5	1.2865025e7	0.0010577	0.014796	0.00792685	1.2867e-003

II. RESULT AND DISCUSSION





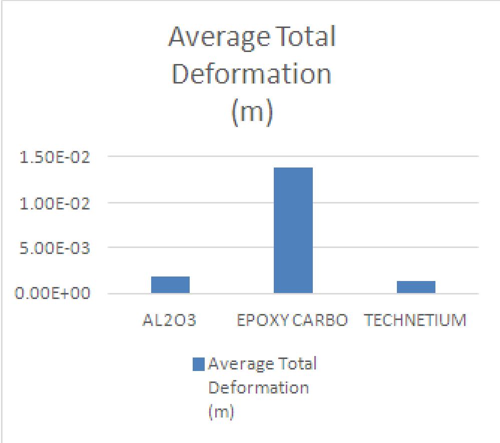


Figure 13: Comparison of Total Equivalent Stress, strain and Avg. Total Deformation for composite mat.

III. CONCLUSION

In this thesis, a poppet valve and even in modified design of the poppet valve considering design (3D modeling) in CATIA V5 software and FEM analysis work is carried out in ANSYS software. Three materials are selected for calculation/observation. They are AL_2O_3 carbon epoxy and technetium. As per observation all the results obtained are plotted into tables and graphs, conclude that stress (1.2865025e7), strain (0.00792685) and total deformation (1.2867e-003) is having the lesser values. These results are obtained for the technetium material. So here is the conclusion that this material is the best material with adequate strength and life of the valve.

REFERENCES

[1]. **Analysis of Valve Mechanism – A Review- A. S. More, S P. Deshmukh.** IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN(e) : 2278-1684, ISSN(p) : 2320–334X, (Sept 2018).

[2]. **Development of Continuously Variable Valve Lift Mechanism for Improved Fuel Economy**-Hermes Fernandez,Youssef Kazour, Michael Knauf, James Sinnamon, Edward Suh and Daniel Glueck. (April 2015).

[3]. **Modeling and Analysis of the Crankshaft Using Ansys Software- K. Thriveni Dr. B. Jaya Chandraiah**. DOI 10.4010/2016.1624 ISSN 2321 3361 © 2016 IJESC (March 2016)

[4]. **Design Analysis and Optimization of Piston using CATIA and ANSYSCh.Venkata Rajam, P.V.K.Murthy**. ISSN 2319-5665 (January 2013, issue 2 volume 1)

[5]. **Comparision Of Materials For Two-Wheeler Connecting Rod Using Ansys** B. Anusha, Dr.C.Vijaya Bhaskar Reddy.(Spet 2013)

[6]. **Effect of temperature on mechanical properties and type of fracture of superalloys Nimonic 80A**-R. Sunulahpa, M. Oruc. ISSN 0543-5846 METABK 50(3) 155-158 (2011)

[7]. **Condition monitoring of valve clearance fault on a small four strokes petrol engine** using vibration signals-Songpon Klinchaeam and Pornchai Nivesrangsan. (July 2018)

[8]. **Performance and Emissions of LPG Fueled Internal Combustion Engine:** A Review Albela H.Pundkar, S.M. Lawankar, Dr. Sameer Deshmukh., International Journal of Scientific & Engineering Research Volume 3, Issue 3, March -2012 1 ISSN 2229-5518

[9]. **Valve timing and valve lift control mechanism for engines**-Kosuke Nagaya Hiroyuki Kobayashi, Kazuya Koike. (oct 2020), **Advanced internal combustion engine Research**-Peter Van Blarigan (May 2013).