STRUCTURAL AND THERMAL ANALYSIS OF POPPET VALVE MADE OF DIFFERENT COMPOSITE MATERIALS

Yalla M Surya Chandra Rao , V.V. Ramakrishna , S. Mohan Krishna

[1] student MTech Thermal Engineering, Kakinada Institute of Technology And Science, Andhra Pradesh, India.
[2] Asso. professor, Department of Mechanical, Kakinada Institute of Technology And Science, Andhra Pradesh, India.
[3] Asst .Professor, Department of Mechanical, Kakinada Institute of Technology And Science, Andhra Pradesh, India.

***

Abstract - ***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 an exhaust valve with a suitable material for a four wheeler diesel engine using Finite element analysis. 2D drawings are drafted from the calculations and 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. Analysis will be conducted when the study state condition is attained at 5000 cycles using different ceramic composite materials.

Key Words: *CATIA, ANSYS, Ceramic Composites, etc…*

1. INTRODUCTION

Safety valves, which are usually of the poppet type, open at a predetermined pressure. The movable element may be kept on its seat by a weighted lever or a spring strong enough to hold the valve closed until the pressure is reached at which safe operation requires opening.On gasoline engines[1], poppet valves are used to control the admission and rejection of the intake and exhaust gases to the cylinders. The valve, which consists of a disk with a tapered edge attached to a shank, is held against the tapered seat by a compressed spring. The valve is raised from its seat by the action of a rotating cam that pushes on the bottom of the shank, permitting gas flow between a region, which leads to the intake or exhaust pipes, and to region, which leads to the cylinder.

The word poppet shares etymology with "puppet": it is from the Middle English popet ("youth" or "doll"), from Middle French poupette, which is a diminutive of poupe. The use of the word poppet to describe a valve comes from the same word applied to marionettes, which – like the poppet valve – move bodily in response to remote motion transmitted linearly. In the past, "puppet valve" was a synonym for poppet valve; however, this usage of "puppet" is now obsolete.

1.1 Poppet Valve wear

In the early days of engine building, the poppet valve was a major problem. Metallurgy[2] was not what it is today, and the rapid opening and closing of the valves against the cylinder heads led to rapid wear. They would need to be re-ground every two years or so by a process known as a valve job. Adding tetraethyllead to the petrol reduced this problem to some degree, as the lead would coat the valve seats, in effect lubricating the metal. In more modern vehicles and properly machined older engines, valve seats may be made of improved alloys such as stellite and the valves themselves may be made of stainless steel. These improvements have generally made this problem disappear completely and made leaded fuel unnecessary.

Valve burn (overheating)[3] is another major problem. It causes excessive valve wear and defective sealing, as well as engine knocking. It can be solved by valve cooling systems that use water or oil as a coolant. In high performance engines[4] sometimes sodium-cooled valve stems are used. These hollow valve stems are partially filled with sodium and act as a heat pipe. A major cause of burnt valves is a lack of valve clearance at the tappet, meaning the valve cannot completely close. This removes its ability to conduct heat to the cylinder head via the seat, and also forces extremely hot Combustion gases between the valve and the seat.

2. MATERIAL PROPERTIES

Table -2.1: Material properties of SUH 1 STEEL

Material : SUH 1 STEEL		
Density	7.7	g/cc
Young's modulus	200	Gpa
Poisson's ratio	0.265	
Specific heat	502.416	J/kg-k
Thermal conductivity	23	W/m-k
Coefficient of thermal expansion	1.20e-09	m/m-k

Table-2.2: Material properties of Al2O3/ Al2O3 Composite

Material : ALUMINA/ ALUMINA COMPOSITE		
Density	3.69	g/cc
Young's modulus	215	Gpa
Poisson's ratio	0.21	
Specific heat	880	J/kg-k
Thermal conductivity	18	W/m-k
Coefficient of thermal expansion	8.10e-10	m/m-k

Table -2.3: Material properties of C/C composite

Material : CARBON/CARBON COMPOSITE		
Density	2.9	g/cc
Young's modulus	64.5	Gpa
Poisson's ratio	0.22	
Specific heat	800	J/kg-k
Thermal conductivity	20	W/m-k
Coefficient of thermal expansion	6.00e-10	m/m-k

Table -2.4: Material propertis of C/SiC composite

Material : CARBON/SILICON CARBIDE COMPOSITE		
Density	2.4	g/cc
Young's modulus	150	Gpa
Poisson's ratio	0.4	
Specific heat	750	J/kg-k
Thermal conductivity	120	W/m-k
Coefficient of thermal expansion	2.50e-10	m/m-k

3. ANALYSIS

3.1 SUH1 STEEL

Total deformation

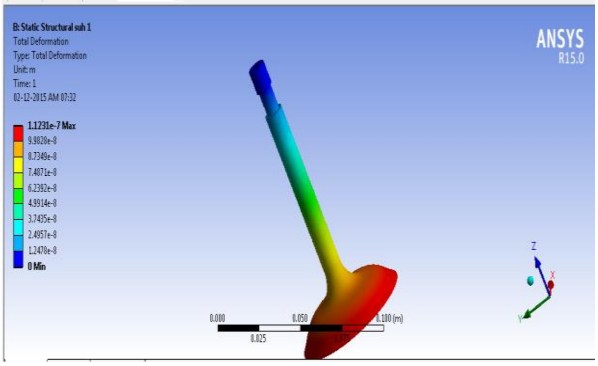

Fig 3.1.1 Total deformation of poppet valve of SUH1 steel

Von-Misses stress

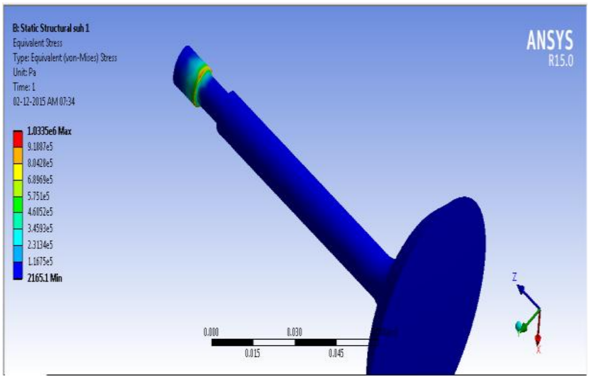

Fig 3.1.2 Von-Misses stresses of poppet valve of SUH1 steel

Strain

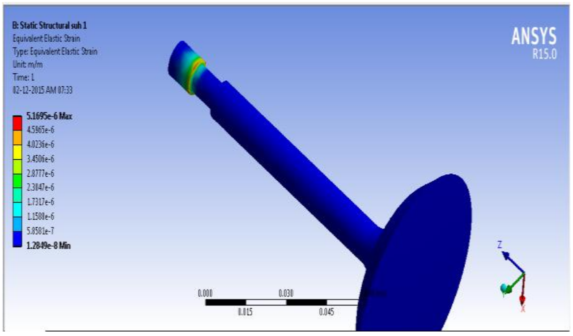

Fig3.1.3 Strains of poppet valve of SUH1 steel

Temperature Variations

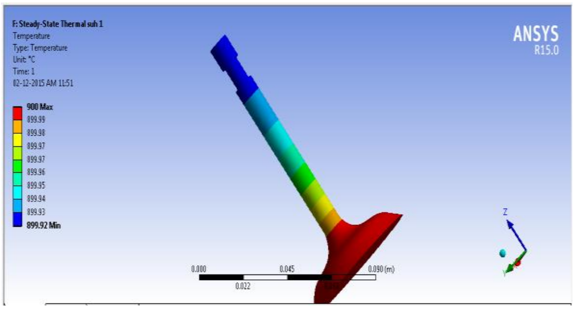

Fig3.1.4 Temperature of poppet valve of SUH1 steel

Total Thermal flux

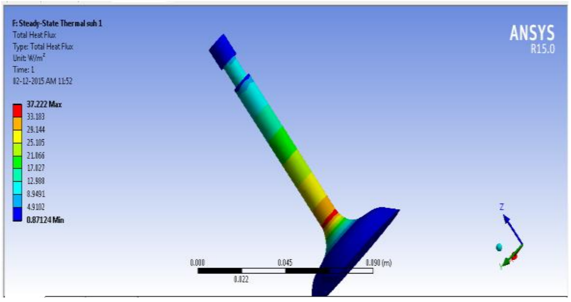

Fig3.1.5 Total heat flux of poppet valve of SUH1 steel

Directional Heat flux (X-direction)

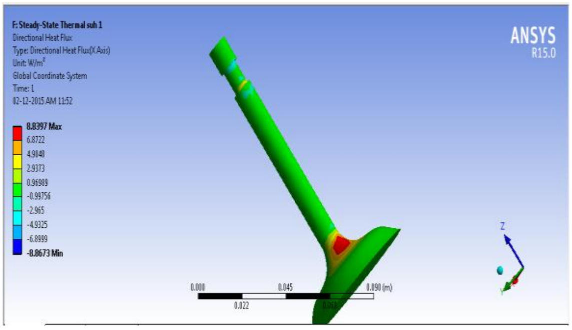

Fig3.1.6 Directional heat flux of poppet valve of SUH1 steel

3.2 AL2O3 / AL2O3 COMPOSITE

Total Deformation

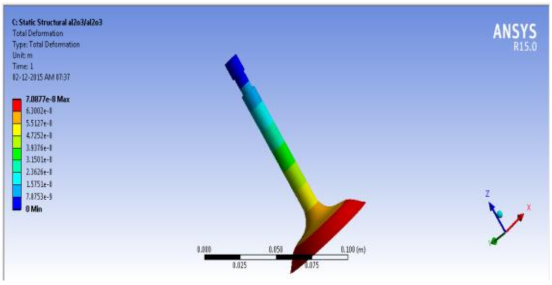

Fig3.2.1 Total deformation of Al2O3/Al2O3 composite

Vonmisses stress

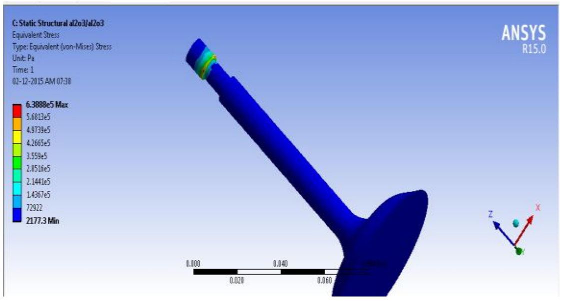

Fig3.2.2 Von-Misses stresses of Al2O3/Al2O3 composite

Strain

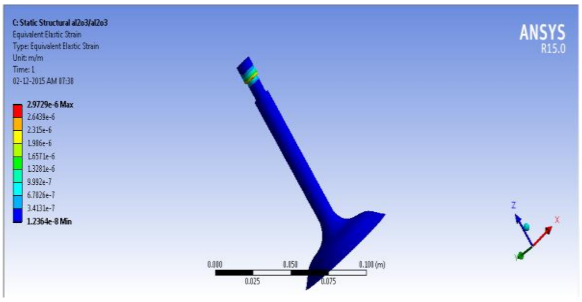

Fig3.2.3 Strains of Al2O3/Al2O3 composite

Temperature variations

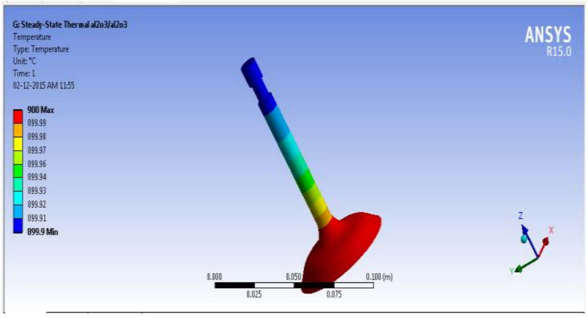

Fig 3.2.4 Temperature of Al2O3/Al2O3 composite

Total Thermal flux

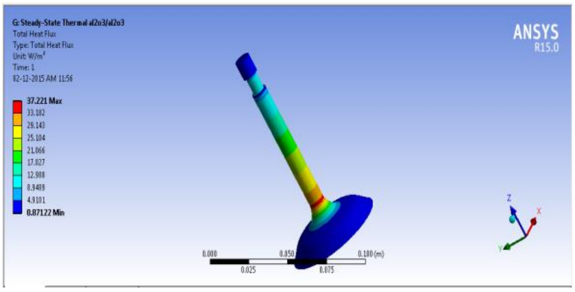

Fig3.2.5 Total Thermal Flux of Al2O3/Al2O3 composite

Directional Heat flux(X-direction)

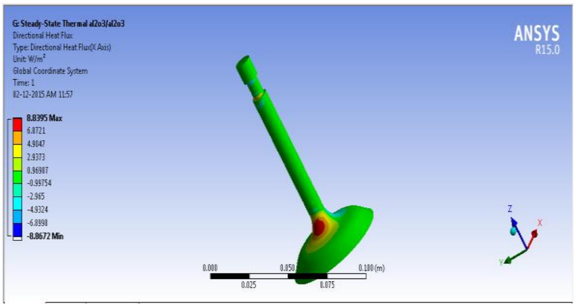

Fig 3.2.6 Directional Heat flux of Al2O3/Al2O3 composite

3.3 CARBON / CARBON COMPOSITE

Total Deformation

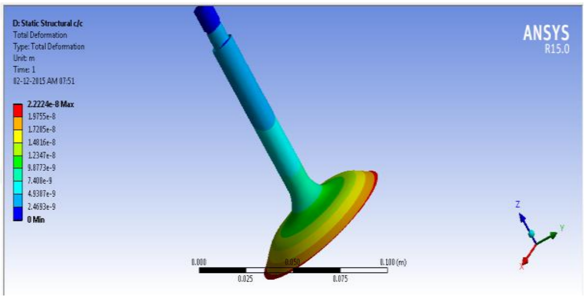

Fig3.3.1 Total Deformation of C/C composite

Von-Misses Stress

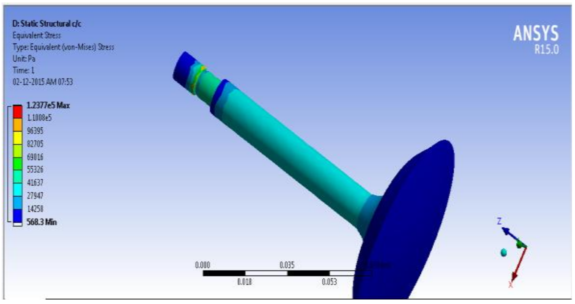

Fig3.3.2 Von misses Stress of C/C composite

Strain

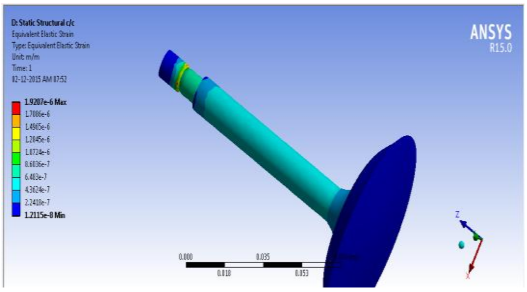

Fig 3.3.3 Strains of C/C composite

Temperature Variations

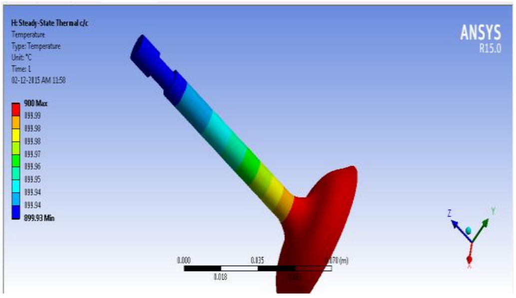

Fig 3.3.4 Temperatur of C/C Composite

Total Heat flux

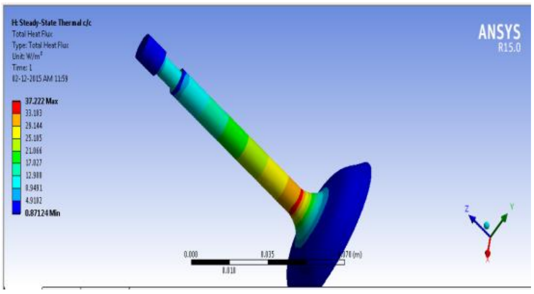

Fig 3.3.5 Total Heat flux of C/C composite

Directional Heat flux (X-direction)

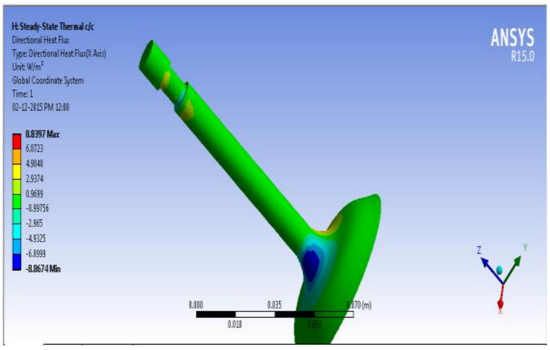

Fig 3.3.6 directional Heat flux of C/C composite

3.4 CARBON/SILICON CARBIDE COMPOSITE

Tatal deformation

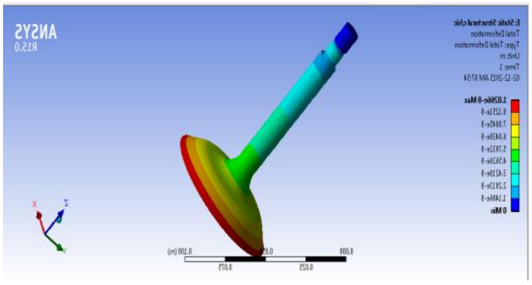

Fig3.4.1 Total deformation of of C/SiC Composite

Von-misses stress

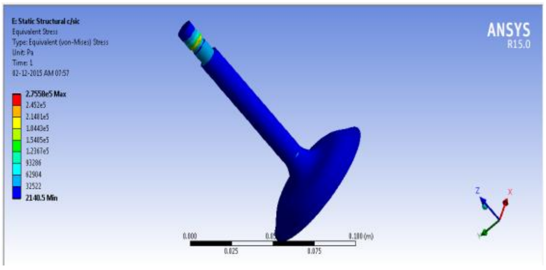

Fig3.4.2 Von-Misses stresses of C/SiC composite

Strain

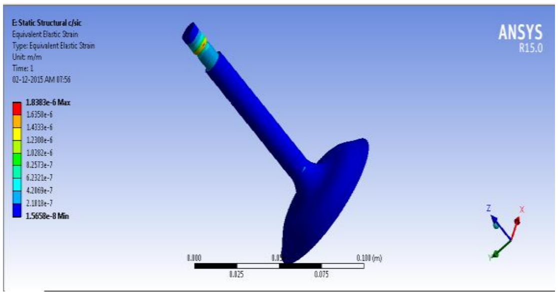

Fig 3.4.3 Strains of C/SiC Composite

Temperature Variation

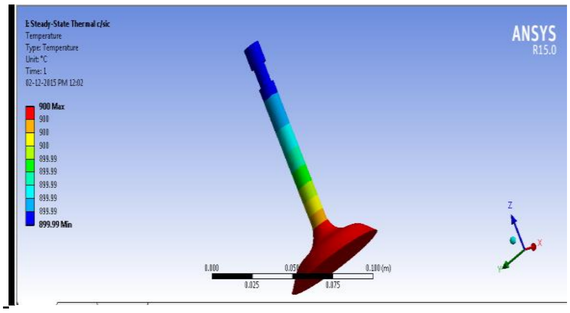

Fig 3.4.4 Temperature of C/SiC Composite

Toatal Heat flux

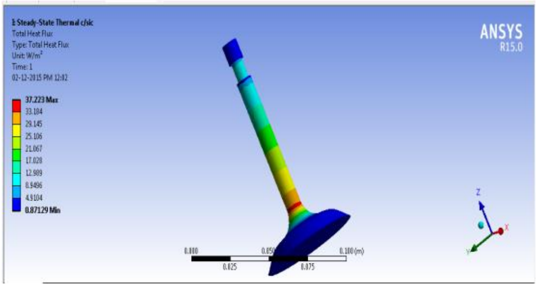

Fig 3.4.5 Total heat flux of C/SiC Composite

Directional heat flux (x-direction)

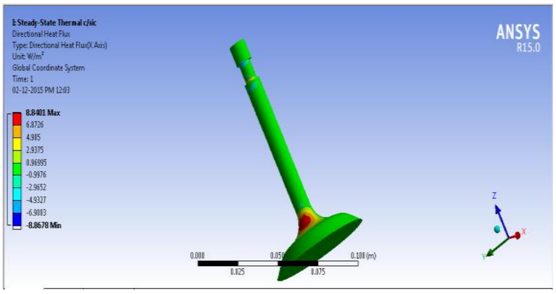

Fig3.4.6 Directional heat flux of C/SiC Composite

4.RESULTS

Table -4.1: Table showing the structural analysis results of a poppet valve

	DEFORMATION (m)		THERMAL STRESS (Pa)		STRAIN	
	MIN	MAX	MIN	MAX	MIN	MAX
SUH 1	0	1.12E-07	2165.1	1.03E+06	1.28 E-08	5.17 E-06
AL2O3/AL2O3	0	7.09E-08	21773	6.39E+05	1.24 E-08	2.97 E-06
C/C	0	2.22E-08	568.3	1.24E+05	1.21 E-08	1.92 E-06
C/SIC	0	1.03E-08	2140.5	2.76E+05	1.57 E-08	1.84 E-06

Table -4.2: Table showing the thermal analysis results of a poppet valve

	TEMPERATURE(^{0}C)		TOTAL HEAT FLUX (W/m2)		DIRECTIONAL HEAT FLUX (W/m2)	
	MIN	MAX	MIN	MAX	MIN	MAX
SUH 1	899.92	9.00E+02	0.87124	3.72E+01	-8.87E+00	8.84E+00
AL2O3/AL2O3	899.9	9.00E+02	0.87122	3.72E+01	-8.87E+00	8.84E+00
C/C	899.93	9.00E+02	0.87124	3.72E+01	-8.87E+00	8.84E+00
C/SIC	899.99	9.00E+02	0.87129	3.72E+01	-8.87E+00	8.84E+00

5. CONCLUSIONS

Here, we conducted structural analysis with 900°C temperature and 800 Pa pressure as boundary conditions, and thermal analysis is done at 900°C. Both structural and thermal analysis are conducted with SUH 1 steel, AL2O3/AL2O3 composite, CARBON-CARBON composite and CARBON-SILICON CARBIDE composite and the results are discussed below.

In structure analysis we concentrated on deformations, thermal stress and strains. From the results we observed that least deformation and strains are in C/SiC poppet valve, but least strains are recorded in carbon-carbon composite

Coming to thermal analysis there is no much variations in the temperature, but maximum fluxes are recorded in C/SiC composite followed by carbon-carbon composite

Finally we conclude that carbon-carbon composite is better material for a poppet valve with moderate deformations, and least stress, and moderate thermal fluxes when compared with the remaining three materials.

REFERENCES

[1] Engineering Mechanics of Composite Materials by Isaac and M Daniel, Oxford University Press, 1994.

[2] Analysis and performance of fiber Composites by B. D. Agarwal and L. J. Broutman, Wiley- Interscience, New York, 1980.

[3] Mechanics of Composite Materials, Second Edition (Mechanical Engineering), By Autar K. Kaw, CRC Publishers, 2003

[4] Mechanics of Composite Materials by R. M. Jones, Mc Graw Hill Company, New York, 1975.