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Structural Design and Functional Assembly of a Ceramic Poppet Valve

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ABSTRACT
Poppet valve is used to removal of smoke and products of combustion after working of engine and is accounted for as mobile elements of cylinder head. Poppet valve is of elements that must be designed so accurately to be able to work correctly since it is subjected to high thermal and mechanical stresses. Another part of cylinder head which is in relation with poppet valve is the support which cooling the poppet valve by transferring the contact heat between them in addition to supporting the poppet valve. The support of poppet valve should be has an enough resistance against high temperature and corrosiveness of passed gases through it. The support is a ring with rectangular cross section which one of its internal corners is conical so that the poppet valve can sit on it. The poppet valves should be resistance against mechanical loads, combustion pressure and temperature and it should be dyke between combustion chamber and exit pipe when it is closed. In addition, it should be stable in millions of cycles and these issues should be considered in design of poppet valve.

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 collected from the literature available and 3D model is done in CATIA and Analysis is done in ANSYS.

Thermal and structural and modal 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 models without changing the dimensions.

INTRODUCTION
Cylinder Pressure is the pressure in the engine cylinder during the 4 strokes of engine operation (intake, Poppet valves are used in most piston engines to open and close the intake and exhaust ports in the cylinder head. The valve is usually a flat disk of metal with a long rod known as the valve stem attached to one side.

The engine normally operates the valves by pushing on the stems with cams and cam followers. The shape and position of the cam determines the valve lift and when and how quickly (or slowly) the valve is opened. The cams are normally placed on a fixed camshaft which is then geared to the crankshaft, running at half crankshaft speed in a four-stroke engine.

On high-performance engines, the camshaft is movable and the cams have a varying height, so by axially moving the camshaft in relation with the engine RPM, also the valve lift varies. See variable valve timing.

For certain applications the valve stem and disk are made of different steel alloys, or the valve stems may be hollow and filled with sodium to improve heat transport

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and transfer. Although better heat conductors, aluminium cylinder heads require steel valve seat inserts, while cast-iron cylinder heads often used integral valve seats in the past. Because the valve stem extends into lubrication in the cam chamber, it must be sealed against blow-by to prevent cylinder gases from escaping into the crankcase, even though the stem to valve clearance is very small, typically 0.04-0.06 mm. A rubber lip-type seal ensures that excessive amounts of oil are not drawn in from the crankcase on the induction stroke and that exhaust gas does not enter the crankcase on the exhaust stroke. Worn valve guides or defective oil seals are characterized by a puff of blue smoke from the exhaust when pressing back down on the accelerator pedal after allowing the engine to overrun, such as when changing gears.

In multi-valve engines more than one intake valve and one exhaust valve per cylinder is used to improve engine performance. Compression, combustion and expansion, and exhaust). You could argue that pressure during expansion is the most important, because that is the cylinder pressure pushing on the piston to produce power. But the cylinder pressure during all 4 strokes is necessary for accurate engine performance prediction.

The poppet valve is fundamentally different from slide and oscillating valves; instead of sliding or rocking over a seat to uncover a port, the poppet valve lifts from the seat with a movement perpendicular to the port. The main advantage of the poppet valve is that it has no movement on the seat, thus requiring no lubrication. The operating principle of poppet valves is described in the online article "How Poppet Valves Work". In most cases it is beneficial to have a "balanced poppet" in a direct-acting valve. Less force is needed to move the poppet because all forces on the poppet are nullified by equal and opposite forces. The solenoid coil has to counteract only the spring force.

DESIGN

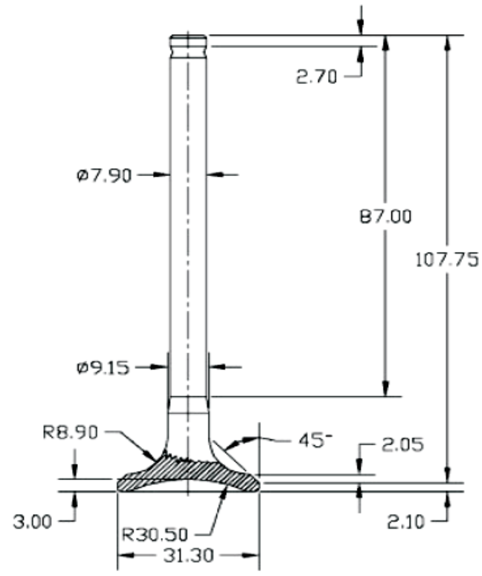

Fig 1 Drafting of Basic model of poppet valve

ANALYSIS

Thermal and thermal static analysis has been performed on basic model and some other different models of poppet valve for Steel 214N, carbon ceramic composite, Aluminum oxide-silicon carbide

Geometry

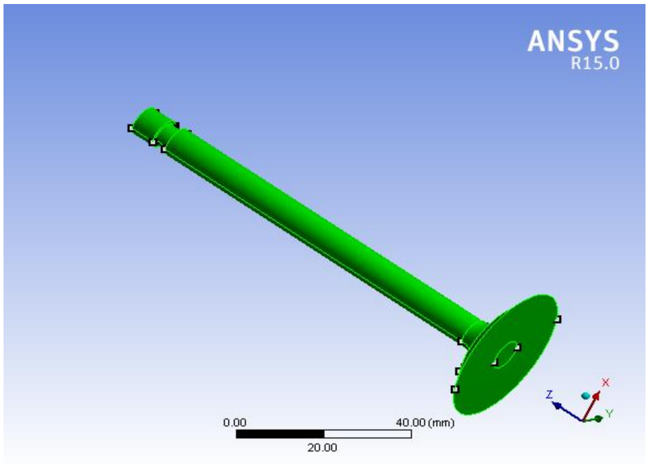

Fig 2 Geometric modelling of Basic model

Mesh

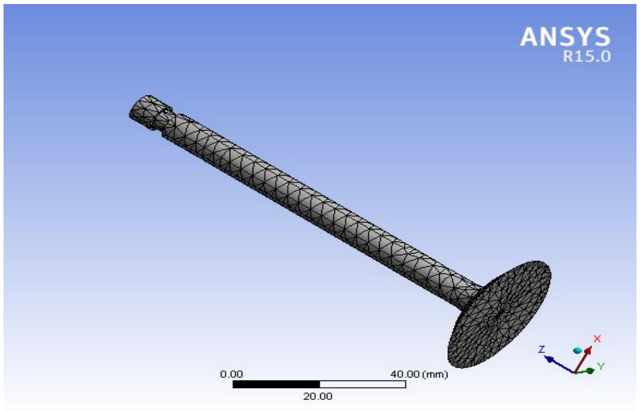

Fig 3 Modelling meshing of Basic model

Boundary conditions

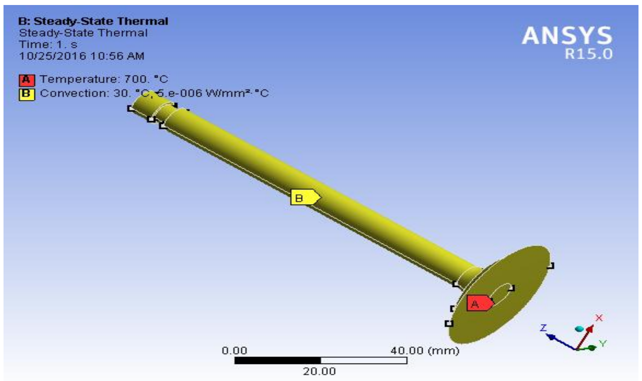

Fig 4 Applying boundary conditions to Basic model

Temperature distribution

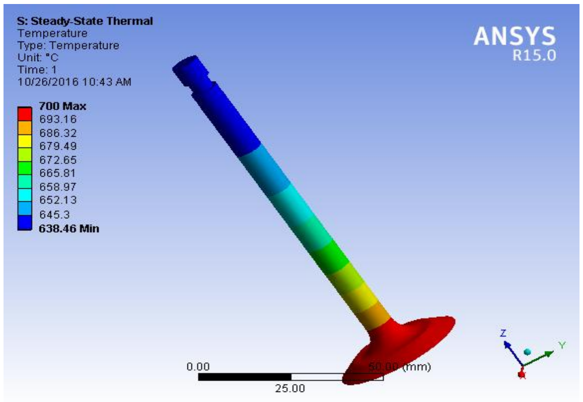

Fig 5 Temperature of Basic model

Thermal fluxes

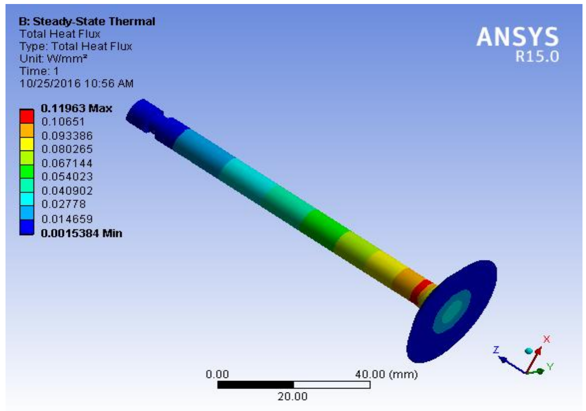

Fig 6 Total heat flux of Basic model

Directional thermal fluxes

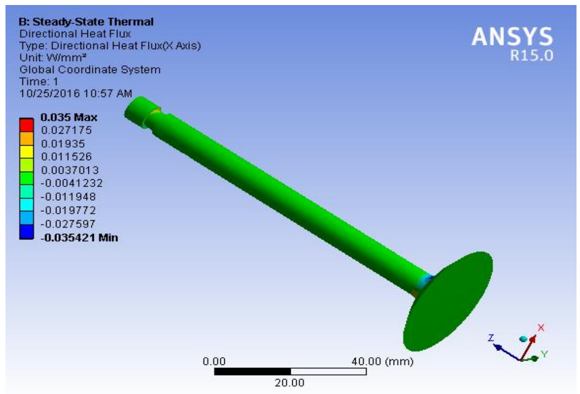

Fig 7 Directional heat flux of Basic model

Deformations

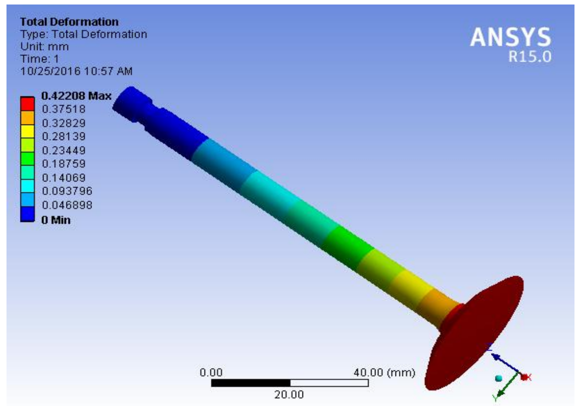

Fig 8 Deformation of Basic model

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Thermal stress

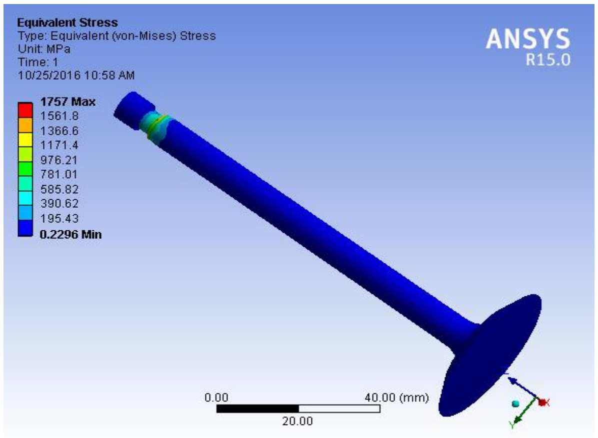

Fig 9 Stress of Basic model

Thermal strains

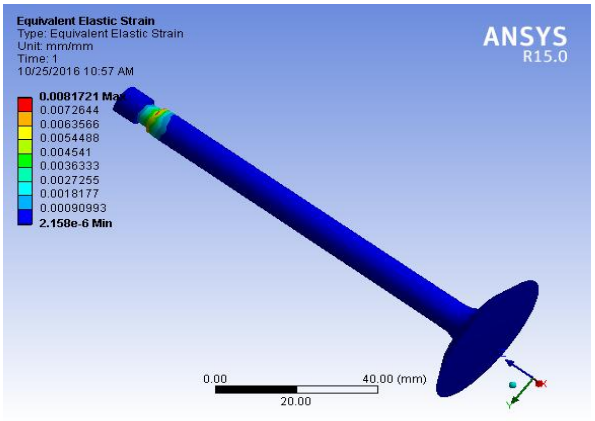

Fig 10 Strain of Basic model

Material	Temperature(°C)		Total Heat Flux(W/mm²)		Directional Heat Flux(W/mm²)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Steel 214N	331.64	700	1.54E-03	0.11963	-3.54E-02	3.50E-02
carbon ceramic composite	637.72	700	3.14E-03	0.1873	-5.61E-02	5.53E-02
Aluminum oxide-silicon carbide	373.25	700	1.75E-03	0.12886	-3.82E-02	3.78E-02

Table 1 Thermal analysis results for basic model

Material	Total Deformation(mm)		Equivalent Elastic Strain(mm/mm)		Equivalent (von-Mises) Stress(Mpa)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Steel 214N	0	0.42208	2.16E-06	8.17E-03	0.2296	1757
carbon ceramic composite	0	0.19767	1.02E-06	5.51E-03	0.1461	1322.1
Aluminum oxide-silicon carbide	0	0.39023	1.52E-06	7.71E-03	0.24413	2312

Table 2 Thermal stress analysis results for basic model

	Temperature(°C)		Total Heat Flux(W/mm²)		Directional Heat Flux(W/mm²)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Model 1	332.56	700	1.57E-03	0.1198	-3.82E-02	3.91E-02
Model 2	328.59	700	1.60E-03	0.11938	-3.48E-02	3.56E-02
Model 3	344.23	700	1.67E-03	0.24713	-9.02E-	9.14E-02

Table 3 Thermal analysis results for Models Made with Carbon Ceramic Composite

	Total Deformation(mm)		Equivalent Elastic Strain(mm/mm)		Equivalent (von-Mises) Stress(Mpa)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Model 1	0	0.43724	1.01E-06	8.04E-03	0.16833	1728.3
Model 2	0	0.48471	1.03E-06	7.91E-03	0.21241	1701.2
Model 3	0	0.40872	1.05E-06	8.40E-03	0.16381	1806.1

Table 4 Thermal stress analysis results for Models Made with Carbon Ceramic Composite

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	Temperature(°C)		Total Heat Flux(W/mm²)		Directional Heat Flux(W/mm²)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Model 1	327.21	700	1.58E-03	0.12077	-3.69E-02	3.60E-02
Model 2	327.18	700	1.60E-03	0.1188	-3.50E-02	3.58E-02
Model 3	328.61	700	1.59E-03	0.1348	-4.38E-02	4.37E-02

Table 5 Thermal analysis results for Models Made with Aluminium oxide-silicon carbide

	Temperature(°C)		Total Heat Flux(W/mm²)		Directional Heat Flux(W/mm²)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Model 1	327.21	700	1.58E-03	0.12077	-3.69E-02	3.60E-02
Model 2	327.18	700	1.60E-03	0.1188	-3.50E-02	3.58E-02
Model 3	328.61	700	1.59E-03	0.1348	-4.38E-02	4.37E-02

Table 6 Thermal stress analysis results for Models Made with Aluminium oxide-silicon carbide

CONCLUSION

From the study the following observations are made:

1. By introducing a composite insertion in the poppet valve head the heat that is transferred to the stem are optimized hence deformation in stem is reduced
2. Strain and stress levels are almost similar but their location is altered
3. Minimum temperatures in the stem are greatly reduced in first and second model

After considering all the results model 2 made with valve steel 214N with aluminium oxide-silicon carbide insert have better life expectancy and lowest temperature

FUTURE SCOPE

This work is limited to just two materials and four different models, this study can be continued by considering more manufacture models and new materials

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