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Steady State Thermal Analysis of I.C. Engine Poppet Valve Using ANSYS

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Abstract: Design of the poppet valve based on variousfactors like performance of material at peak temperature, vibrations, fluid dynamics of burnt gases, oxidization features of valve metal and burnt gas, fatigue behavior of valve material, structure of the cylinder head, coolant movement and the form of the port. This project deals with the analysis of thermal stress developed in a valve due to high pressure within the combustion chamber at high temperature situations. For modelling Solidwork is to be utilized and to optimized the Poppet valve ANSYS will be utilized as the tool. Steady State thermal analyses are to be performed on the valve based on fillet radius at 3 mm, 6 mm and 10 mm and Chamfer at 2 mm, 4 mm and 6 mm at 45 ^{0} angle. Maximum thermal stresses found 24.783 MPa at 6 mm chamfer at 45 ^{0} angle.Hence it is clear that 6 mm fillet radius of poppet valve is best and safe for designing of I.C. Engine inlet and outlet valve.

Keywords: Poppet valve, FEM, ANSYS, Valve mechanism.

I. Introduction

Two and four-stroke engines have different capabilities that may be desirable to combine. For a same engine volume, four-stroke generate a better part load consumption while two-stroke engines give higher specific power and torque output. For this to happen in four-stroke operation, the engine volume needs to be at least double of that of the two-stroke mode. This requires more fuel consumption, greater and heavier parts that may not be economically produced. For a similar engine displacement although two-stroke operation consumes more fuel than the four-stroke option, this is effectively lower than increasing the engine displacement. On the negative side, two-stroke Poppet valve ported engines produce higher levels of pollutants than the four-stroke ones, which is obtained at the expense of having more engine components. A possibility of overcoming their problems is to run a poppet valve spark ignition internal combustion engine configuration. In this case the main problem is the camshaft timing operation and configuration to allow for the increase/decrease of the camshaft speed when varying between the firing operations. Intake and outlet valves are very essential engine elements that are utilized to regulate the flow and interchange of gases in internal combustion engines. They are utilized to close the functioningareawithin the cylinder as per the manifolds and are opened and closed through what is identified as the valve train apparatus. valves of Internal combustion engine are the accuracy engine elements. They open and close as and when required. The newfuel mixture is enters through inlet valves and the parts of burning fuel get discharged to atmosphere during exhaust valves. There are variouskind of engine valves utilized by the manufactures; some common kinds of valves being poppet valves, slide valves, rotary valves and sleeve valve.

II. Poppet valve

A poppet valve is a directional controller valve and is usuallyconsidered as presence a high stream, fast performingdesign because of the large stream paths through the main form of the valve. Usually, the poppet valve can be opened relatively rapidly. The inlet valves are designed from plain nickel, nickel chrome. Whileoutlet valves are crafted from nickel chrome, silicon chrome steel, excessive velocity metal, stainless steel, high nickel chrome, tungsten metallic and cobalt stainless-steel. With the assist of these elements, valve performs its function precise as it should be in internal combustion engine. The valve spring, keeps the valve pressed towards its seat and make sure a leakage proof operation and additionally convey again the valve right away throughout its ultimate. When the engine is started out, it receives heated up step by step thereby inflicting the valve stem to expands. The clearance placed in outlet valve is barely extra than that of inlet valve. This is because of barely greater growth in exhaust valve due to higher temperature of hot exhaust gases produced at some stage in combustion.

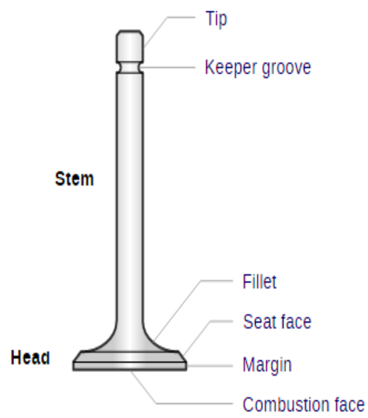


Figure 1: Nomenclature of Poppet valve

III. Valve Mechanism in internal combustion Engine

In this category of valve appliance, the cam actuates the rotation of the valve via the tappet. Hence the replaceable valve burnt gases movements up and down in the valve stem manual. This program is developed by means of revolution of camshaft and cam, that generally works on the partial engine speed. The valve spring, keeps the valve pressed towards its seat and make sure a leakage-evidence operation and additionally carry returned the valve very quickly at some point of its last. Once the engine is began, it becomes heated up gradually subsequently affecting the valve stem to expand. A valve tappet clearance is continually supplied to allow the expansion of valve stem and also different components. This clearance value relies upon the length of the valve, its cloth and the operating temperature of the engine. The poppet valve allowance may be setup by rotating the adjusting screw. Where adjusting screw is not supplied to differ the clearance, it can be multiplied through grinding the lowest of the valve stem and face or additionally by way of the use of the longer valve. Due care must be taken due to the fact even a slightly inadequate clearance may additionally result in the valve now not nicely resting towards its seat because the engine receives heated inflicting expanded noise stage and lack of strength. The clearance furnished in exhaust valve is barely more than that of the inlet valve. This is because of slightly more growth in exhaust valve due to better temperature of hot exhaust gases produced in the course of combustion.

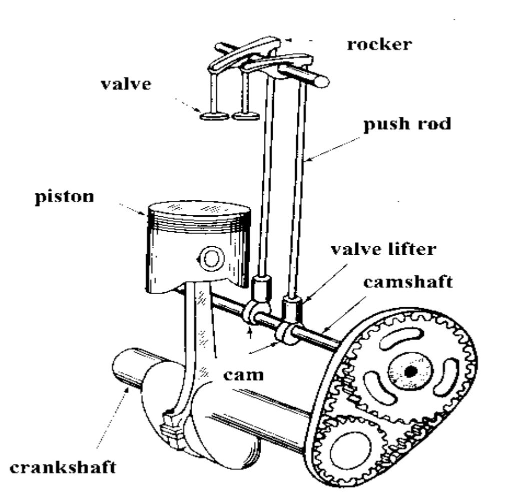


Figure 2: Valve Mechanism

IV. Modelling of Poppet valve

Modeling of the Poppet valve of I.C. Engine done using Solidwork has been explained in detail. The intention of finite element investigation is to reconstruct the mathematical behavior of an actual engineering structure. Here two type of poppet valve designed for study i.e. poppet valve with chamfer and poppet valve with fillet. the dimension of fillet or chamfer varies. The model includes all the nodes, elements, material functions, real constants, boundary circumstances and extra features that are used to characterize the physical system. First model be generated then specific boundary conditions will be applied on the specific nodes then final analysis will be conducted.

V. Analyzing the model in ANSYS

After designing the model in Solidwork, the. IGS FILE has been converted to IGES format. This configuration allows the design to be compatible in the ANSYS software. After importing the design in ANSYS, the process of analysis begins.The Poppet valve is designedallowing to the process and requirement which are specified in machine design and data reference books.

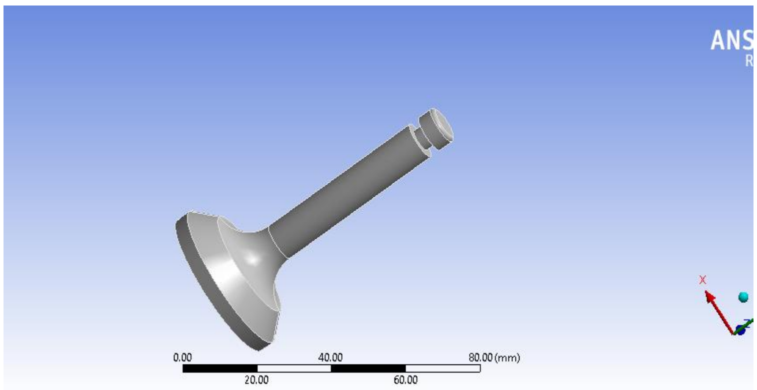


Figure 3: Model of Poppet Valve

VI. Meshing the model

Mathematically, the Poppet Valve model to be investigates is subdivided into a mesh of finite sized elements of simple form. Within each component, the difference of displacement is assumed to be calculated by simple polynomial profile functions and nodal movements. Equations for the strains and stresses are generated in terms of the unidentified nodal deflections. From this, the equations of equilibrium are assembled in a matrix form which can be easily programmed.

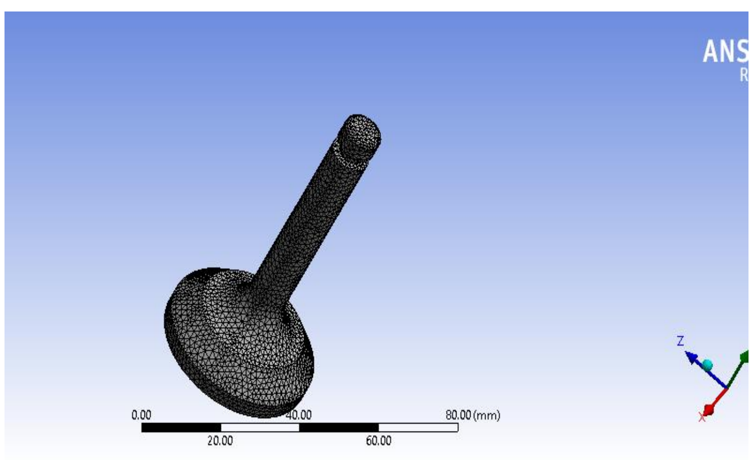


Figure 4: Meshing the Poppet valve using ANSYS

VII. Boundary conditions for analysis of Poppet valve using ANSYS

After the Poppet valve is meshed, we need to apply the suitable boundary condition under which the thermal Analysis will be completed.

Figure 5 represents the applied boundary conditions on Poppet valve has been kept fixed while convection on the outer surface of the Poppet valve has been applied, to optimize failure of Poppet valve. Figure 5 shows the applied boundary conditions of Poppet valve.

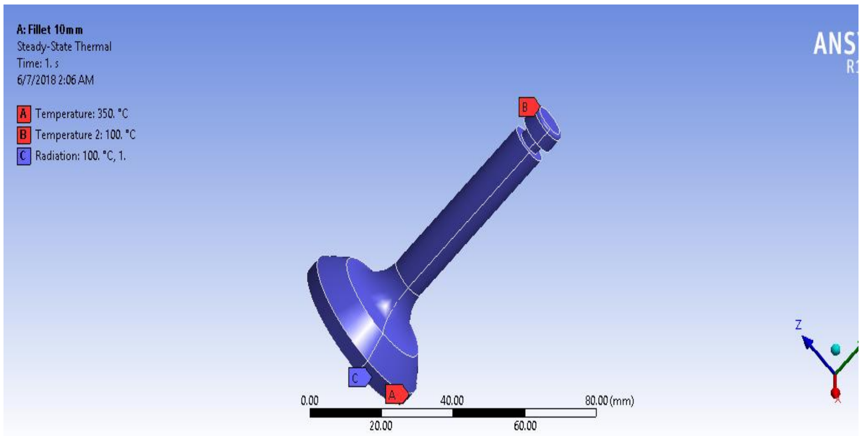


Figure 5: Static thermal boundary conditions of Poppet valve

The maximum applied temperature is 350 ^{0}C, and it acts uniformly on the base of the valve surface. The three freedom degrees of poppet valve are restrained to let the valve in a static thermal condition. The above two boundary conditions are referred as temperature restraints and convection temperature applied 100 ^{0}C. The boundary conditions are as shown in figure 5.Boundary conditions applied on both geometry poppet valve with chamfer and fillet.

VIII. Results and Discussion

1. Material Properties

Structural steel considered as material in present study. Properties of material are described below. The various boundary conditions and load is imposed on the FEA model and three different kinds of the stress field, named as thermal stress field, mechanical stress field can be obtained. Here two type of poppet valve designed for study i.e poppet valve with chamfer and poppet valve with fillet. the dimension of fillet or chamfer varies.

Table.5.1: Material Properties for Structural steel

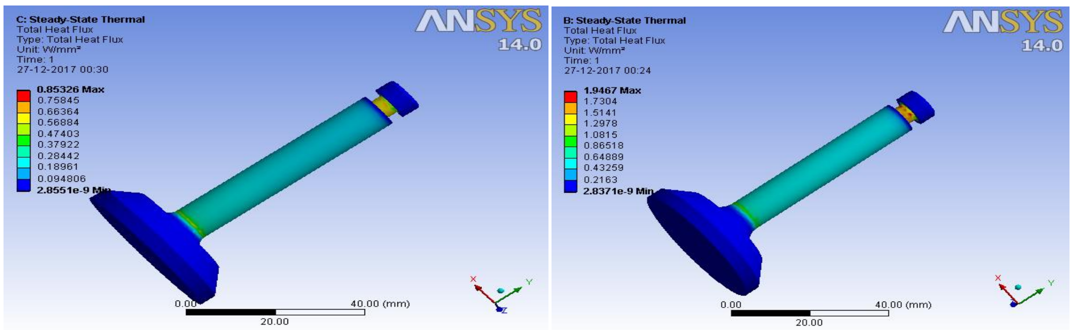
Structural Steel	
Density	7850kg/m^3
Poisson ratio	0.3
young's modulus	200000 MPa
tensile ultimate strength	460mpa
tensile yield strength	250mpa
thermal conductivity	60.5w/m/c
coefficient of thermal expansion	1.20e-05

2. Analysis of Poppet valve with variations of fillet radius

The purpose of this fillet is to streamline the gases so they will pass freely out of the exhaust manifold. Most poppet valves are made at an angle of forty-five degrees, and being round they permit, the exhaust gases to rush towards each other in a circle and under terrific pressure at an enormous velocity. This actually creates a vacuum that completely scavenges the cylinder. Poppet valve analyzed in ANSYS with fillet radius of 3 mm, 6 mm and 10 mm.

3. Heat Flux analysis in ANSYS of Poppet valve with fillet radius

Heat flux analysis on ANSYS shows for poppet valve with 3 mm, 6 mm and 10 mm radius and in figure 6 and 7 with fillet radius shows maximum heat flux found 0.85326 W/mm^2. Minimum heat flux found 2.8551e-9 W/mm^2.



(a) valve with 3 mm fillet radius (b) valve with 6 mm fillet radius

Figure 6: Heat flux of valve with 3 mm and 6 mm Fillet Radius

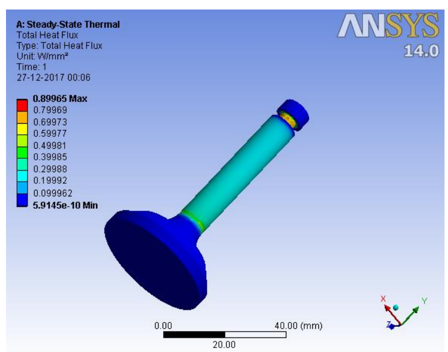
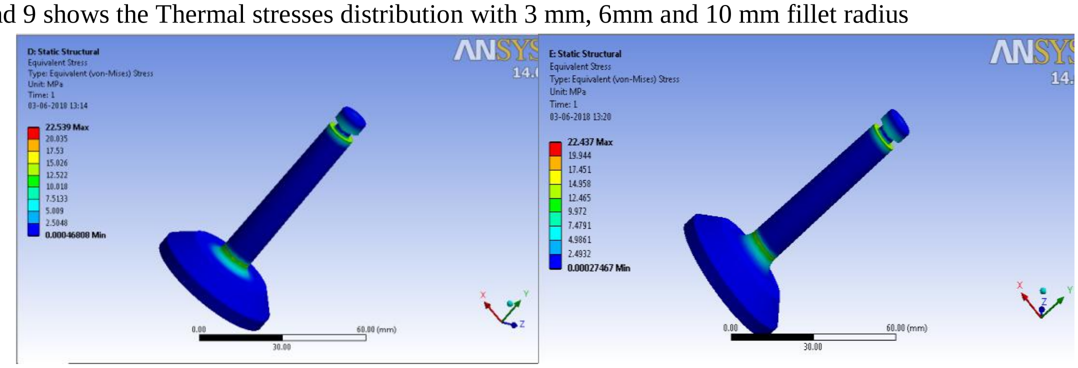


Figure 7: Heat flux of Poppet valve with 10 mm fillet radius

4. Thermal stresses analysis in ANSYS of Poppet valve with fillet radius

Figure 8 and 9 shows the Thermal stresses distribution with 3 mm, 6mm and 10 mm fillet radius



(a) Poppet valve with 3mm fillet radius(b) Poppet valve with 6 mm fillet radius

Figure 8: Thermal stresses of Poppet valve with 3mm and 6 mm Fillet Radius

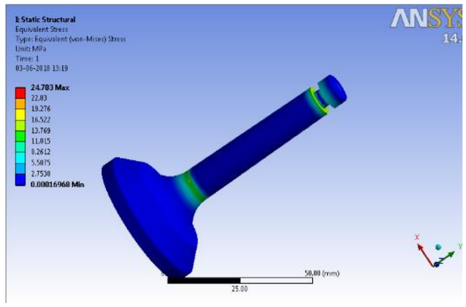


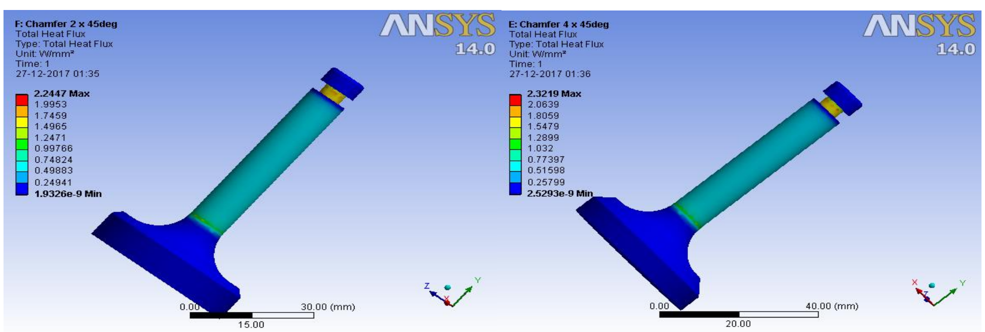
Figure 9: Thermal stresses of Poppet valve with 10 mm fillet radius

5. Analysis of Poppet valve with variations of chamfer

Poppet valve analyzed in ANSYS with chamfer of 2 mm, 4 mm and 6 mm at 45 degrees of each.

A. Heat Flux analysis in ANSYS of Poppet valve with various chamfers

Heat flux analysis on ANSYS shows for poppet valve with chamfer of 2 mm, 4 mm and 6 mm at 45 degrees of each and in figure 10 and 11 with 2 mm chamfer shows maximum heat flux found 2.2447 W/mm^2. Minimum heat flux found 1.9326e-9 W/mm^2.



(a) valve with 2x 45^0 mm chamfer (b) Valve with 4 x 45^0 mm chamfer

Figure10: Heat flux of Poppet valve with 4x 45^0 mm chamfer

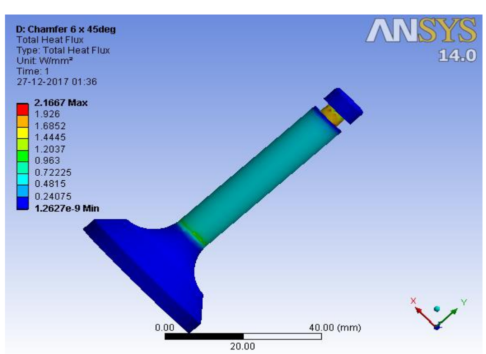
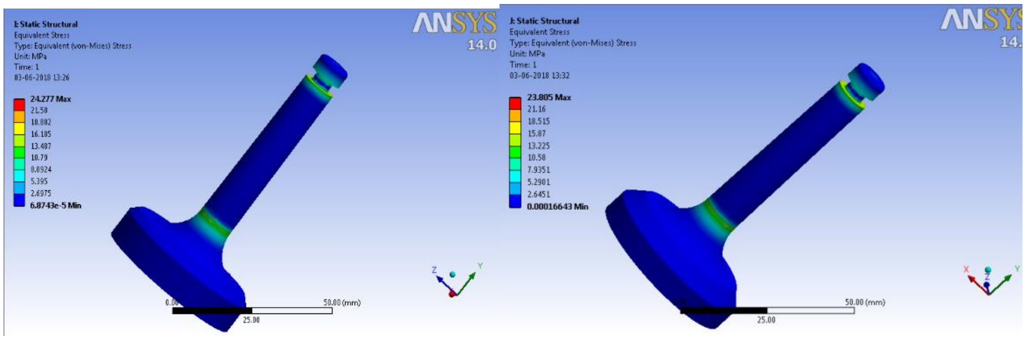


Figure 11: Heat flux of Poppet valve with 6x 45^0 mm chamfer

B. Thermal stresses analysis in ANSYS of Poppet valve with chamfer

Figure 12 and 13 shows the Thermal stresses distribution with 2 mm, 4 mm and 6 mm at 45 degrees of each.



(a) Valve with 2x 45^0 mm chamfer **(b) Valve with 4x 45^0 mm chamfer**

Figure 12: Thermal stresses of Poppet valve with 2 x 45^{0}and4x 45^0 mm chamfer

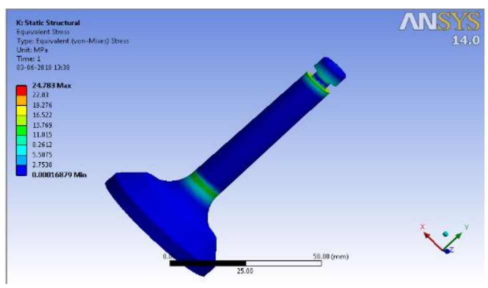


Figure 13: Thermal stresses of Poppet valve with 6x 45^0 mm chamfer

The Inlet outlet valve plays a major role in the engine performance; The maximum stress intensity is on the bottom surface of the valve surface in both fillet and chamfer are studied in this analysis. Highest value of maximum temperature found in Poppet valve is due to thermal conductivity of the materials and the total maximum heat flux is absorbed in both the Poppet valve materials. Thus, further research can be carried with the advance materials and different designing, analysis tools.

C. Results due to fillet radius on Poppet valve

Table 5.2: Thermal stresses and heat flux variations due to various fillet Radius

Fillet	**Maximum Thermal Stress (Mpa)**	**Maximum Heat Flux (W/mm^2)**
3mm	22.539	0.853
6mm	22.437	1.94
10mm	22.783	0.899

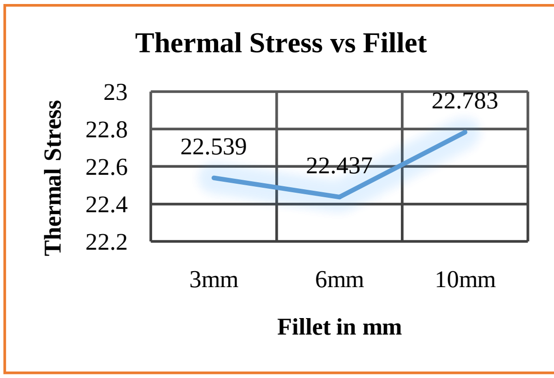
D. Results due to Chamfer on Poppet valve

Table 5.3: Thermal stresses and heat flux variations due to various Chamfers

Chamfer	**Maximum Thermal Stress (Mpa)**	**Maximum Heat Flux (W/mm^2)**
2*45deg	24.277	0.932
4*45deg	23.805	0.964
6*45deg	24.783	0.899

IX. Comparison of Results

Figure 14 and Figure 16 Shows the total Thermal stresses distribution on the whole surface of Valves. Figures 14, 16 show the stresses distribution due to thermal load. From Fig.14, we can see that the maximum thermal stress is 22.783 MPa, from figure 16 we can see maximum thermal stresses 24.783 which does higher than fillet radius applied valve and it occurs at all surface of valve.



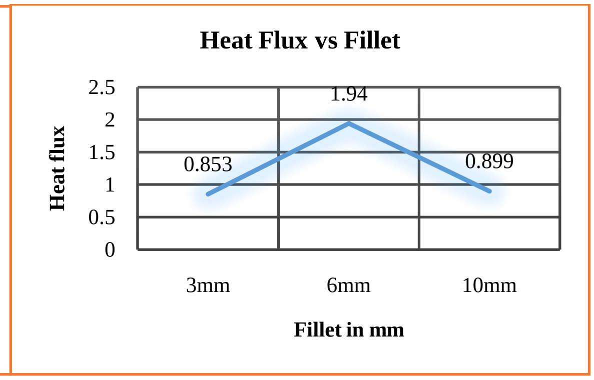
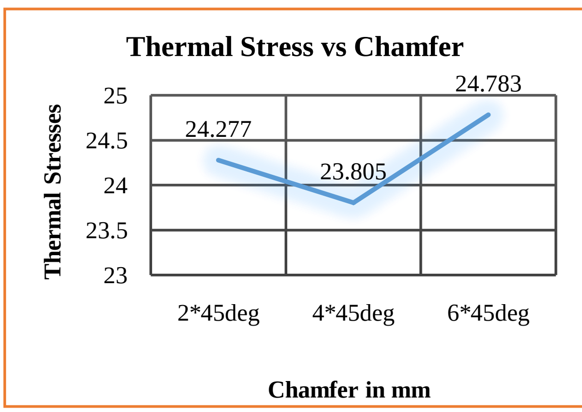


Figure 14: Comparison of Thermal stresses with Fillet radius

Figure 15: Comparison of Heat Flux with respect to Fillet radius



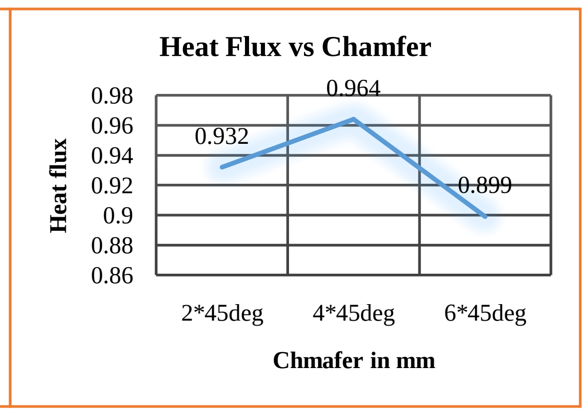


Figure 16: Comparison of Thermal stresses with respect to Chamfers

Figure 17: Comparison of Heat flux with respect to Chamfers

As per above study it is concluded that higher thermal stresses found in chamfer profiled poppet vales and fillet radius valve having low thermal stresses and higher heat transfer so that is it concluded that fillet applied design is best for valve for designing in IC engine.

X. Conclusions

In the thisanalysis, the thermal simulating of poppet valve and its function in thermal conditions of engine and without establishing of combustion in cylinder was considered.

We have done the model for the designed model by using Solidwork software. We conducted Steady State thermal analysis at inlet and outlet condition using Single metal for the Poppet valve with applying fillets and chamfers. We have also conducted thermal analysis.

As per study following conclusions are made.

- Valve basics and materials and its operating are studied in detail which will be useful in further part of work.
- Design of valve is done based on given specifications with study of valves and its failure modes.
- Maximum thermal stress found 24.783 MPa at 6 mm chamfer at 45 ^{0} angle.
- Minimum thermal stresses found 22.437 MPa at 6 mm fillet radius.
- Maximum heat flux found at 6mm fillet radius of poppet valve.
- Hence it is clear that 6 mm fillet radius of poppet valve is best and safe for designing of I.C. Engine inlet and outlet valve.

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