

Modelling and Static & Thermal Analysis of I.C Engine Exhaust Valve

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Abstract. In engines valves are essential components for better working of engine. The Intake and exhaust valves are used to control the flow and exchange of gases. These valves seal the working space inside the cylinder against the manifolds and are opened and closed with the valve train mechanism. Smooth-running of internal combustion engine is possible because of exhaust valve. Role of the exhaust valve is to pass on the exhaust gases to the exhaust manifold from the combustion chamber. During the operation of internal combustion engine, exhaust valves are subjected to the axial stresses due to exhaust gas pressure, cyclic stresses due to return spring load, thermal stresses due to very high temperature inside the combustion chamber and inertia force arising on the account of valve assembly. This project aims to Design and static -thermal analysis on poppet valve applications of CI engine. Modeling of the valve was done in the Catia and static-thermal analysis was carried out in the ANSYS. In thermal analysis determined, total heat flux and temperature. Here used five materials are Stainless steel, Nimonic 80A, Nimonic 105, Aluminum nitride, Silicon Nitride finally suggested best material for poppet valve on these materials.

1. Introduction

A valve system is the main component of diesel engine. A valve system controls the quantity of air to be drawn into the cylinder and exhaust gas to be liberated from the exhaust manifold. The function of the valve in the cylinder of the engine is to confess the air in C.I. engine and to compel out the exhaust gases. The exhaust valve is subjected to the complex thermo-mechanical loading. The mechanical load is acted by the spring force during the closing of valve and the valve had contact with hot exhaust gases which are at High temperature due to which the non-uniform temperature causes the thermal loading on the valve. This reduces the fatigue and static Properties of valve material. In diesel engine the intake valve is less failed than the exhaust valve as exhaust valves are subjected to high temperature burnt gases. In order to proper working of diesel engine the valve must work properly. There are different types of valve are used likely poppet valve is used as exhaust valve. Failure of any valve causes the performance of engine due to which it is necessary to make the failure analysis of the valve of internal combustion engines.



The possible failure of valve are fatigue failure, thermal failure, wear, corrosion, overheating of valves or the carbon deposit on the valve. Exhaust valve is termed as essential component of an IC engine as it provides path to expel out the exhaust gases generated after combustion of the fuel in the combustion chamber. If there is inappropriate design of exhaust valve then it ultimately influence its dependability i.e. exhaust valve fails before performing its intended function and thus the following stroke will begin to mix with exhaust fumes rather than clean air. This may be insufficient for good combustion and it guides to reduced running conditions. Exhaust valve fail at higher rate than intake valve. Because intake valves are virtually cooled by fresh air, however exhaust valves are subjected to a very high temperature burnt gases. Because of that it can be exposed to very high thermal stresses more than intake valves and hence there are more chances of failure of exhaust valves rather than intake valves. The detailed literature is available relevant to the proposed study.

1.1. Poppet Valve

A poppet valve is a type of check valve often linked with kill and chokes lines. 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.

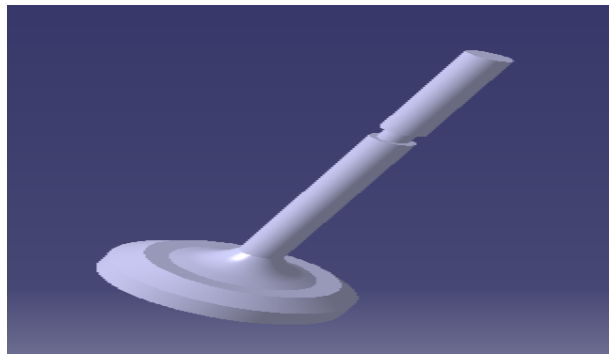


Figure 1. Exhaust valve

2. Literature Review

Sanoj. T et al. [1] proposed the Thermo Mechanical Analysis of Engine Valve. In this thermal and structural analysis of valve with different materials (Nimonic 80A and Nimonic 105A) were used for valve analysis.

The different works are performed on the exhaust valve for different parameters in recent years. Lucjan Witek [2] work on "Failure and thermo-mechanical stress analysis of the exhaust valve of diesel engine" In this work the failure analysis of the exhaust valve of diesel engine was performed. In order to explain the reason of premature valve damage, the non-linear finite element analysis was utilized. The results of stress analysis performed for the valve with the carbon deposit showed, that in the valve stem a high bending stresses were occurred.

Kum-Chul, et al. [3] presented "A Study of Durability Analysis Methodology for Engine Valve Considering Head Thermal Deformation and Dynamic Behavior" the authors describe the problem of exhaust valve fracture of gasoline engines. From the results, it was found that the maximum stress occurred at the stem region and that stem region is the same region at which higher temperature occurred. The stress at the valve head is similar to the stress under the combustion pressure condition, but the stress on the valve neck goes up to high level where the failure occurred.

Yuvraj K Lavhale et al. [4] had studied the overview of failure trends of inlet and exhaust valve. There are different causes for the failure of the exhaust valve such as fatigue failure, wear, thermal

loading, failure due to corrosion-erosion which leads to degradation of mechanical properties of valve material and its performance.

B.E. Gajbhiye et al. [5] "Vibration Testing and Performance Analysis of IC Engine Exhaust Valve Using Finite Element Technique" Author had performed the Modal analysis of valve using FEA software. It was found that Stem of valve is most affected zone. The deformation is observed at the bottom side of the valve. The reason for exhaust valve damage may be high vibrations at resonance frequency value which are slightly greater than natural frequency of exhaust valve.

3. Structural Static Analysis

A static analysis calculates the effects of study loading circumstances on a configuration, while ignores inertia and damping results, such as those caused by time varying loads. A static analysis be able to though comprise steady inertia loads and time varying loads that can be approximated as static equivalent loads. The kinds of loading that can be applied in static analysis include:

- Externally applied forces and pressures.
- Steady state inertial forces
- Imposed displacement
- Temperatures Fluences (for nuclear swelling)
- Imposed displacement

3.1. Procedure of Static Analysis

Create the geometry in catia workbench and save the file in igs format and open Ansys workbench apply engineering data(material properties), create or import the geometry, apply model(meshing), apply boundary conditions(setup) shown the results(stress, deformation, heat flux).

3.2. Structural Analysis of exhaust valve

Combustion of gases in the combustion chamber exerts pressure on the head of the exhaust valve during power stroke. The pressure force will be taken as boundary condition in structural analysis. Fixed support (displacement) has given at top of exhaust valve. Due to the exhaust valve move up and down .

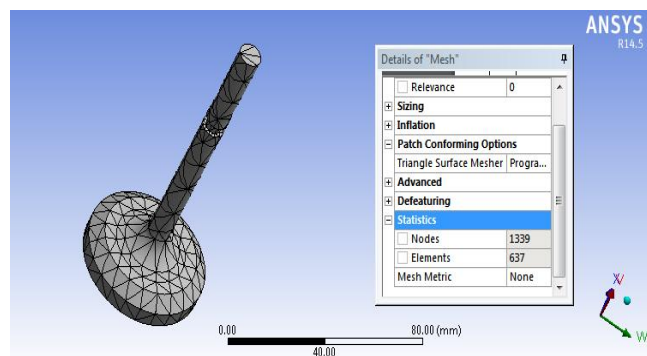


Figure 2 .Mesh body

3.3. Boundary conditions and in static analysis

1. Maximum load at the exhaust valve head crown 1034.8 N
2. Temperature at the surface of the Exhaust valve head 750, 650, 500⁰c
3. Exhaust valve top part are fixed $DX = DY = DZ = 0$

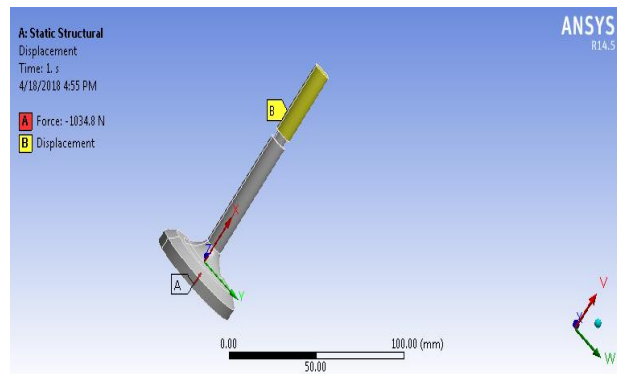


Figure 3. Boundary condition of static analysis

3.4. Static Analysis Process

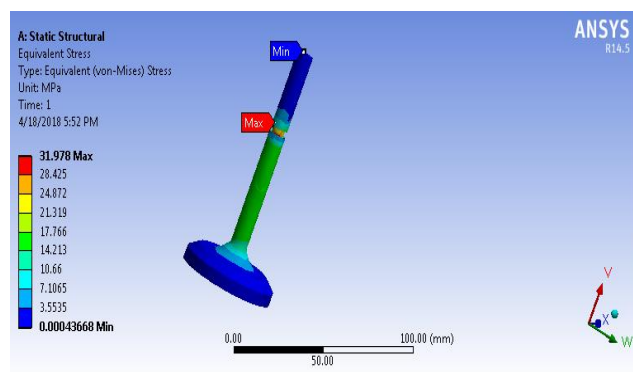


Figure 4. Stress for Stainless steel

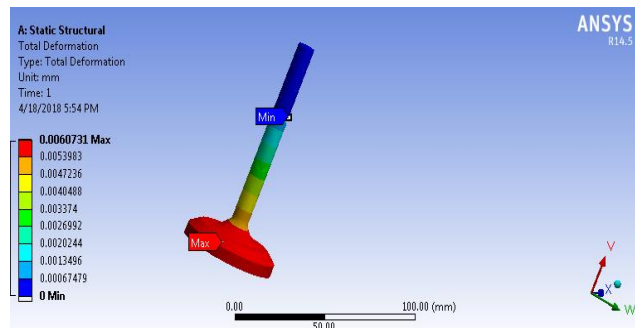


Figure 5. Total deformation for Nimonic 80a

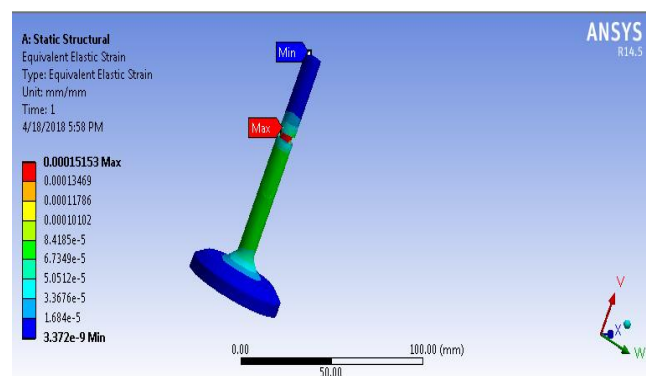


Figure 6. Strain for Nimonic 105

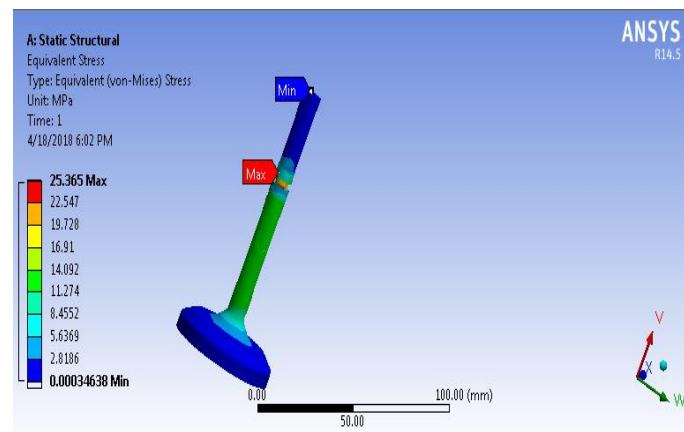


Figure 7. Stress for Aluminium nitride

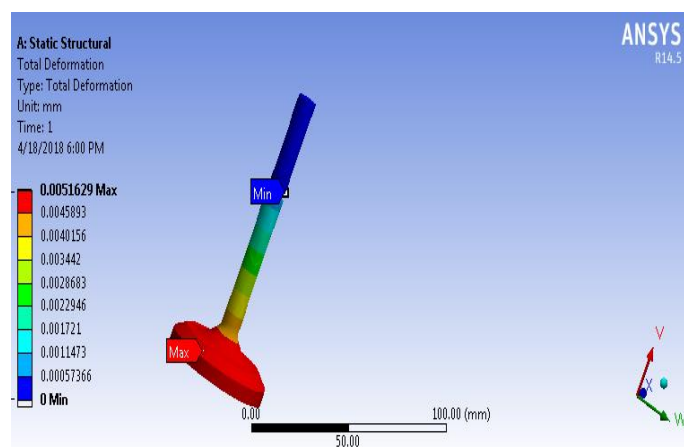


Figure 8. Total deformation for silicon nitride

4. Thermal Analysis

Thermal analysis is a branch of materials science where the properties of materials are studied as they change with temperature. Several methods are commonly used

- Dielectric thermal analysis (DEA): dielectric permittivity and loss factor.
- Differential thermal analysis (DTA): temperature difference versus temperature or time.
- Differential scanning calorimetry (DSC): heat flow changes versus temperature or time
- Laser flash analysis (LFA): thermal diffusivity and thermal conductivity
- Thermogravimetric analysis (TGA): mass change versus temperature or time.

4.1. Procedure of Thermal Analysis

Create the geometry in catia workbench and save the file in igs format and open Ansys workbench apply engineering data(material properties), create or import the geometry, apply model(meshing), apply boundary conditions(setup) shown the results(stress, deformation, heat flux).

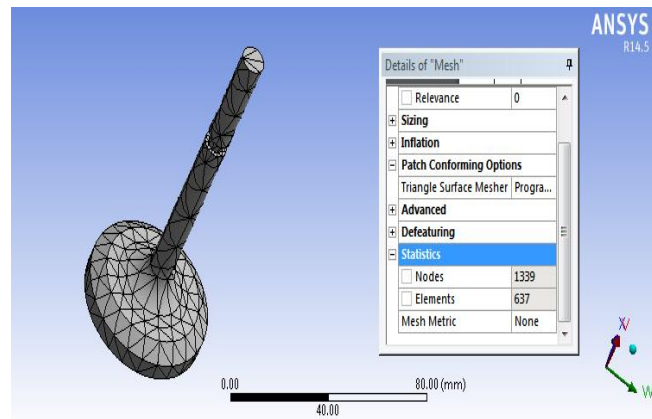


Figure 9. Mesh Body

4.2. Boundary conditions and in thermal analysis

1. Maximum load at the exhaust valve head crown 1034.8 N
2. Temperature at the surface of the Exhaust valve head 750, 650, 500 °C
3. Exhaust valve top part are fixed $DX = DY = DZ = 0$

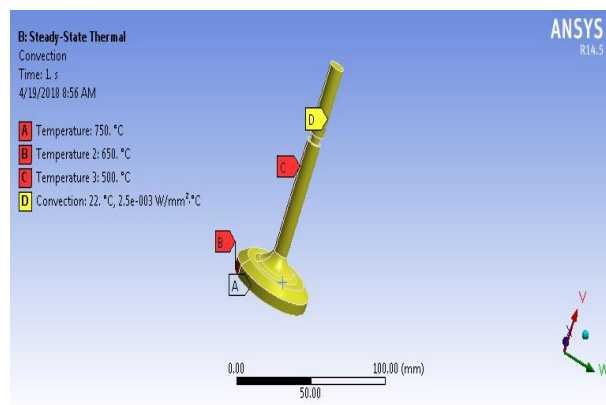


Figure 10. Boundary conditions and loads at thermal analysis

The constructed exhaust valve in catia is analyzed using ANSYS V14.5 and the results are depicted below. Combustion of gases in the combustion chamber exerts pressure on the head of the exhaust valve. Fixed support has given at surface of exhaust valve top part. Because the exhaust valve will move from up and down.

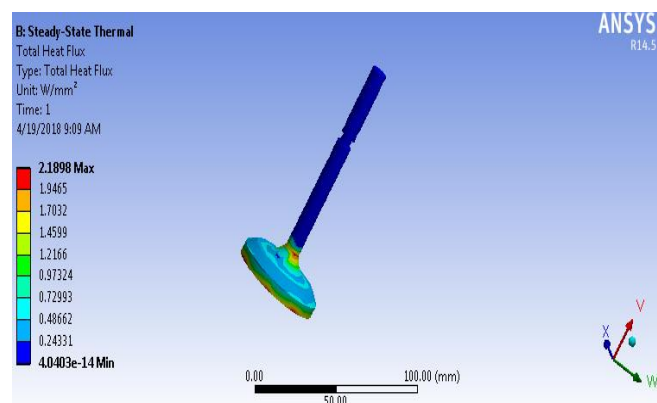


Figure 11. Total Heat flux For Stainless Steel

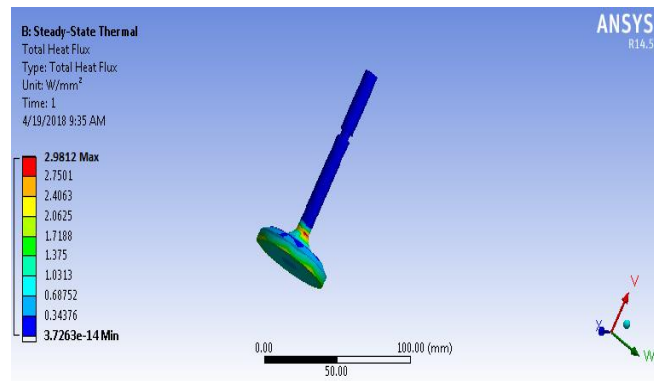


Figure 12. Total Heat flux For Nimonic 80a

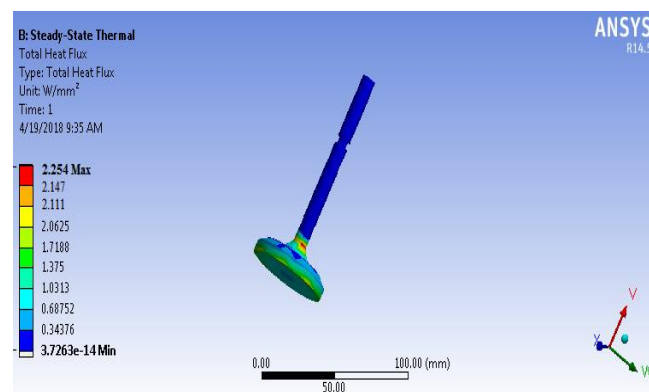


Figure 13. Total Heat flux For Nimonic 105

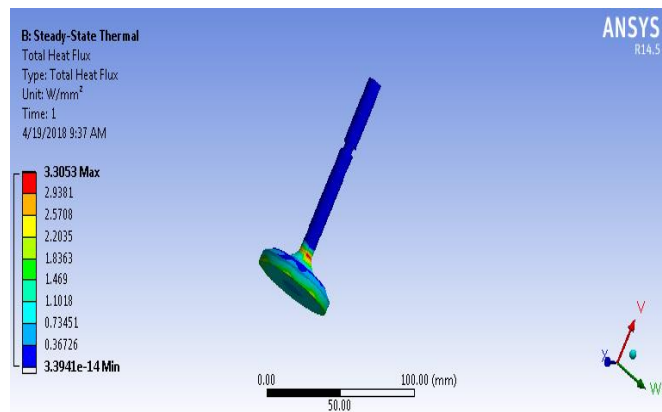


Figure 14. Total Heatflux For Aluminium Nitride

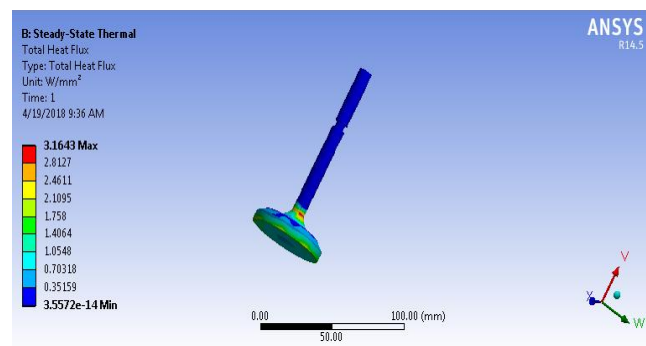


Figure 15. Total Heatflux For Silicon Nitride

5. Results and Discussion

5.1 Static Structural Analysis

The static structural analysis of Stainless steel, Nimonic 80A, Nimonic 105, Aluminium Nitride, Silicon Nitride are done and results are obtained for Equivalent (Von-Mises) stress, equivalent elastic strain, total deformation and heat flux. These results are plotted graphically and a comparison is made between these results.

5.1.1. Von-mises stress (Mpa)

we can observe that in case of equivalent (von-mises) stress, exhaust valve made of Stainless steel, Nimonic 80A, Nimonic 105, Aluminium Nitride, Silicon Nitride aluminum nitride is found to have least stress of 25.365MPa in comparison with remaining materials including the present material. Highest stress of 31.978MPa is observed as shown below figure

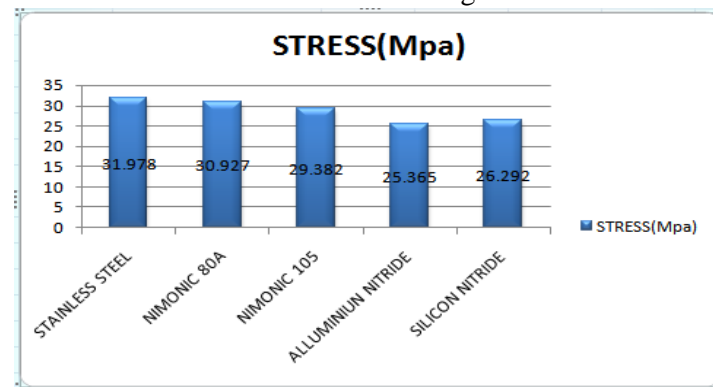


Figure 16. Stress Graph

5.1.2. Equivalent strain

we can observe that in case of equivalent strain, exhaust valve made of Stainless steel, Nimonic 80A, Nimonic 105, Aluminium Nitride, Silicon Nitride, but aluminum nitride is found to have least strain of 0.00013 in comparison with remaining materials including the present material. Highest strain of 0.00016 is observed exhaust valve.

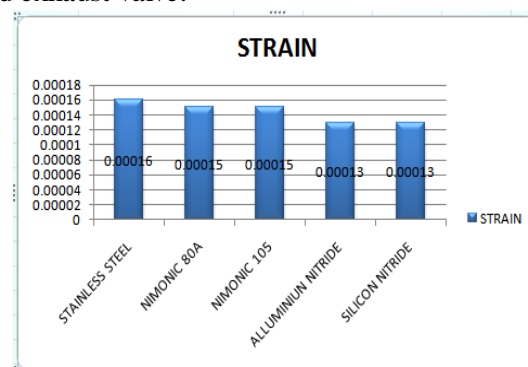


Figure 17. Equivalent strain graph

5.1.3. Total deformation

we can observe that in case of total deformation, exhaust valve made of Stainless steel, Nimonic 80A, Nimonic 105, Aluminium Nitride, Silicon Nitride, but aluminum nitride is found to have least total deformation of 0.0049MPa in comparison with remaining materials including the present material. Highest total deformation of 0.0062mm is observed.

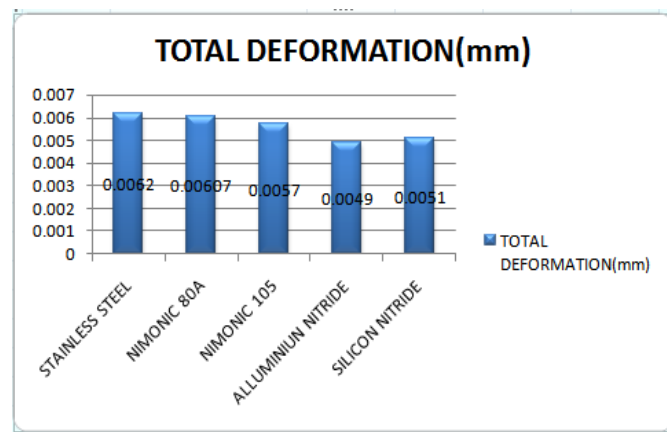


Figure 18. Total deformation graph

5.1.4. Heat flux

we can observe that in case of heat flux, exhaust valve made of Stainless steel, Nimonic 80A, Nimonic 105, Aluminium Nitride, Silicon Nitride, but aluminium nitride is found to have highest heat flux of 3.305 W/mm^2 in comparison with remaining materials including the present material.

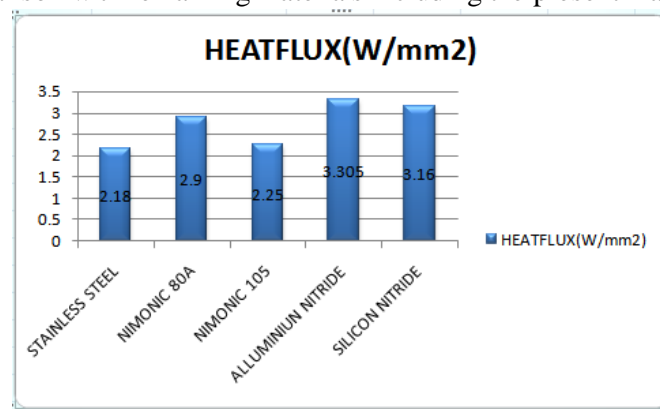


Figure 19. Heat flux graph

6. Conclusion

In this paper the 3D model of poppet valve were designed by using catia software. The model is meshed by using ANSYS. The FEA was done by ANSYS. The static and thermal analysis was successfully carried out to determine the stress, strains, deformation and total heat flux, on the valves. exhaust valve were analyzed with different materials. Compared and suggested best material for exhaust valve. In this study found out in thermal analysis • maximum heat flux was observed in Aluminum nitride (3.305 W/mm^2) for exhaust valve finally aluminum nitride material is suitable material for exhaust valve because of less stress (25.3 mpa), strain (0.00013), deformation (0.0049) etc.,

7. References

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