TRANSIENT THERMAL ANALYSIS OF A DIESEL ENGINE EXHAUST VALVE

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Abstract— **The valves used in the IC engines are of three types, Poppet or mushroom valve, Sleeve valve and Rotary valve. Of these three types, Poppet valve is most commonly used. Since both the inlet and exhaust valves are subjected to high temperatures of 1930°C to 2200°C during the power stroke, it is necessary that the materials of the valves should withstand these temperatures. The temperature at the inlet valve is less compared to exhaust valve. Thus the inlet valve is generally made of nickel chromium alloy steel and exhaust valve is made of silchrome steel. The aim of the project is to design an exhaust valve for a four wheeler diesel engine using theoretical calculations and 3D modelling is done in PRO-ENGINEER. Thermal analysis is to be done on the exhaust valve and analysis is done in ANSYS. Analysis will be conducted when the steady state condition is attained. Steady state condition is attained at 5000 cycles at the time of when valve is closed is 127.651 sec and valve is opened 127.659 sec. The material used for exhaust valve is EN52 steel. We are doing material optimization by doing analysis on material EN52. Static Modal analysis is also done on the exhaust valve to determine mode shapes of the valve for number of modes.**

Keywords— **Valve, 3D modelling, Static Modal analysis, Exhaust valve**

I. INTRODUCTION

1.1 Valves Train Components of Internal Combustion Engine

1. Inlet and Exhaust Valves.
2. Valve Guides.
3. Tappets.
4. Camshafts.

1.2 Purpose of Engine

a) It generates the power required for moving the vehicle or any other specific purpose.

b) It converts the energy contained in fuel to useful mechanical energy, by burning the fuel inside a combustion chamber.

c) An engine contains number of parts like Valves and other Valve train components, Piston, camshaft, Connecting rod, Cylinder block, Cylinder head etc., from which REVL supplying some of the valve train components to engine manufacturers.

1.3 Valve description

a)It is the set of components in a 4-stroke engine, responsible for smooth functioning of the inlet and exhaust valve.

b)It makes the valve to open and close as per the timing required for the correct functioning of the engine.

c)The performance of the engine is severely depends proper functioning of valve train. Any malfunctioning in the valve train system could even lead to severe damage to the engine.

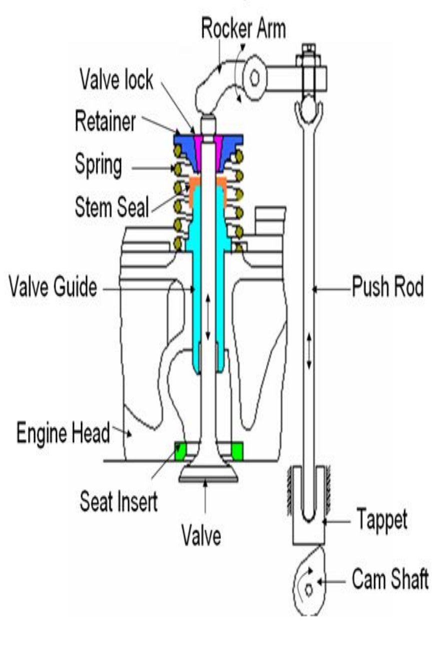

Figure 1.1 Typical Valve Train Assembly

1.4 About Valves

Engine Valve is one of the main parts which are used in all IC Engines. Each cylinder in the engine has one inlet and one exhaust valve. Now a day’s engine are designed with multi valves viz., two inlet and one exhaust or Two inlet and Two exhaust valves which prevents air pollution and improves engine efficiency.

1.4.1 Valve Efficiency

As compared to inlet, exhaust valve operates at high temperature as exhaust gases (around 800°C) escape through it. As it resulting in early ways and gets corrosion, austenitic steel is used for manufacture of exhaust valve and martens tic steel is used for manufacture of inlet valve.

The manufacturing process involves upset and forging, heat treatment machining and special processes like TIG welding, Projection Welding, PTA Welding, Friction Welding, Induction Hardening and Nitriding.

1.5 Valve Dimensions

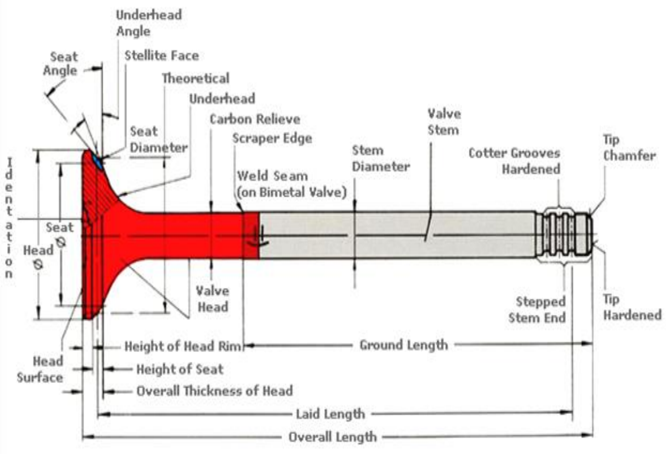

Figure.1.2 Valve Dimensions

1.6 Working Requirements for Valves

1.6.1 Inlet Valve

a) Allow incoming charge into the engine.
b) Seal the port without leak for remaining period.
c) Resistance to wear at the mating surfaces.
d) Good sliding surface for seizure resistance.

1.6.2. Exhaust Valve

a) Allow gases go out of the engine.
b) Seal the port without leak for remaining period.
c) Strength to with stand high temperatures.
d) Resistance to wear at the mating surfaces.
e) Good sliding surface for seizure resistance.

II. Literature Review

2.1 Computer Based Selection and Performance Analysis of Marine Diesel Engine - M. Morsy el gohary, Khaled M.Abdou

The major steps in two-stroke diesel technology have been surprisingly few over the pastcentury, now we have another major step – electronically controlled marine diesel engines. Thispaper will discuss how the use of computer helps to select diesel engines, compare between differenttypes, increase the performance of the conventional diesel engines and generate the different performance curves for such engines.

2.2 Using Engine Exhaust Gas as Energy Source for an Absorption Refrigeration System - Andre Aleixo Manzela, Sergio Morais Hanriot, Luben Cabezas-Gomez, Jose Ricardo Sodre

This work presents an experimental study of an ammonia–water absorption refrigeration system using the exhaust of an internal combustion engine as energy source. The exhaust gas energy availability and the impact of the absorption refrigeration system on engine performance, exhaust emissions, and power economy are evaluated.

2.3 Second-law analyses applied to internal combustion engines operation - c.d. Rakopoulos, E.G. Giakoumis

This paper surveys the publications available in the literature concerning the application of the second-law of thermodynamics to internal combustion engines.The latter being particularly important since they are not identified in traditional first-law analysis. In identifying these processes and subsystems, the main differences between second- and first-law analyses are also highlighted. The survey extends to the various parametric studies conducted, including among other aspects thievery interesting cases of low heat rejection engines, the use of alternative fuels and transient operation. Thus, the main differences between the results of second- and first-law analyses are highlighted and discussed.

2.4 Thermodynamic characteristic study of a high-temperature flow-rate control valve for fuel supply of scramjet engines - Zeng Wen, Tong Zhizhong, Li Songjing, Li Hongzhou, Zhang Liang

Thermodynamic characteristics are of great importance for the performance of a high-temperature flow-rate control valve, as high-temperature environment may bring problems, such as blocking of spool and increasing of leakage, to the valve. In this paper, a high-temperature flow-rate control valve, pilot-controlled by a pneumatic servo system is developed to control the fuel supply for scramjet engines. After introducing the construction and working principle, the thermodynamic mathematical models of the valve are built based on the heat transfer methods inside the valve. By using different boundary conditions, different methods of simulations are carried out and compared. The steady-state and transient temperature field distribution inside the valve body are predicted and temperatures at five interested points are measured. By comparing the simulation and experimental results, a reasonable 3D finite element analysis method is suggested to predict the thermodynamic characteristics of the high-temperature flow-rate control valve.

III. Modeling

3.1 Introduction to PRO/E

As the world's one of the supplier of software, specifically intended to support a total link integrated product development process, parametric technology corporation (PTC) is recognized as a strategic partner which can help to manufacturer to turn a process into competitive advance, greater market share and higher profit and industrial and mechanical design to functional stimulation manufacturing and information management. Fully associated Pro/E solutions encompass all aspects of the development cycle and cut design time by half, improve product quality and ensure a terms success. Pro/E mechanical design solution will improve our design productivity allowing us to finish more complex and challenging project in less time.

"Feature-based" means that we create parts and assemblies by defining features like extrusion, sweep, cuts, holes, slots, rounds, and so on, instead of specifying low-level geometry like lines, circles and arcs. This means that the designer can think of the computer model at a very high level and leave all the low-level geometric detail forPro/E to figure out. Setting values and attributes of elements such as reference planes or surfaces, direction of creation, pattern parameters, shapes, dimensions, and specific features.

3.2 Modules in pro/e

There are many different modules in Pro/E using which we can perform different tasks. Following are the important modules of Pro/E.

1)Sketch module.
2)Part module.
3) Assembly module.
4) Drawing module.

3.2.1 Sketch Module

Sketch module enables us to create sections. Sketcher techniques are used in many areas ofPro/E. Using sketch mode we create geometric without regard to the exact relationship between part of the sketch or the exact dimensions. When we generate the section, Pro/E makes explicit assumptions. For example if we draw nearly horizontal line it becomes exactly horizontal and these assumptions are displayed graphically.

3.2.2 Part Module

Part module enables us to create components. In Part Mode, we create part files (.prt), the separate components that are joined together in an assembly file (.asm). Part mode we can create and edit the features–the extrusions, cuts, blends, and rounds–that comprise each part being modelled. Most features start with a two dimensional outline, or section.

3.2.3 Assembly Module

After we have created the parts, we create an empty assembly file for the model, then assemble the individual parts within it, assigning the positions the parts will occupy in the final product. We can also define exploded views to better examine or display part relationships.

3.2.4 Drawing Module

Drawing mode lets you create finished, precise mechanical drawings of the design, based directly on the dimensions recorded in the 3D part and assembly files. In fact, it is not necessary to add dimensions to objects as you may have done in other programs. Instead, in Pro/ENGINEER you selectively show and hide dimensions that have been passed from the 3D models. Any information objects—dimensions, notes, surface notes, geometric tolerances, cross sections, and so on—that have been created for the 3D model can be passed to the drawing mode. When these objects are passed from the 3D model, they remain associated, and may be edited to affect the 3D model from within the drawing.

3.3 Benefits of pro/e

Pro/E has many benefits over CAD packages.

It is much faster and more accurate than any other CAD systems.Once a design is complete, 2-D and 3-D views are readily obtainable.The ability change in late design processes is possible. It provides a very accurate representation of our model specifying all other dimensions etc. It provides a greater flexibility for change. For example, if we like to change the dimensions of our model, all the related dimensions in design assembly, manufacturing etc will automatically change.It provides clear 3-D models, which are easy to visualize or models created and it also decreases, the time required for assembly to a great extent.

3.3.4 Design calculations of exhaust valve

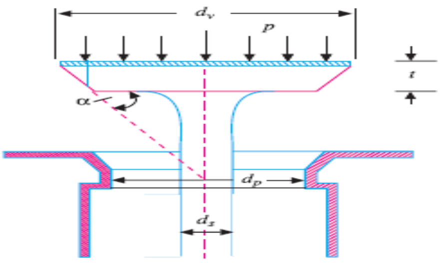

Figure 3.4 Design Valve

3.4.1 Design of Outlet Valve

a. Size of Valve Port

$$a_p v_p = aV$$

V = 90m/s = 90000mm

$$a_p = \frac{3802.66 \times 10933.33}{90000} = 462mm$$

$$a_p = \frac{\pi}{4}(d_p)^2$$

$$(d_p)^2 = \frac{462 \times 4}{\pi} = 588.53 \quad = \quad d_p = 24.25mm$$

b.Thickness of Valve Disc

$$t = Kd_p\sqrt{\frac{p}{\sigma_b}}$$

$$t = 0.42 \times 24.25\sqrt{\frac{10.936}{100}} = 3.36mm$$

c. Maximum Lift of the Valve

h = lift of the valve

$$h = \frac{d_p}{4\cos\alpha} = \frac{24.25}{4\cos 30^0} = \frac{24.25}{3.46} = 7mm$$

d. Valve Stem Diameter

$$d_s = \frac{24.25}{8} + 6.35 \text{ or}$$

ds = 3.03 + 6.35 ;

$$d_s = 9.38 \text{ (or) } 1403mm$$

$$\tan\alpha = \frac{2(h+t)}{(\frac{d_v}{2})} = \frac{2(h+t)}{d_v}$$

$$\tan 30 = \frac{2(3.36 + 7)}{d_v}$$

$$d_v = \frac{20.72}{0.577} = 35.9\text{mm} = 36\text{mm}$$

IV. Finite Element Analysis

4.1 Introduction to FEA

Finite element analysis (FEA) is a fairly recent discipline crossing the boundaries of mathematics, physics and engineering and computer science. The method has wide application and enjoys extensive utilization in the structural, thermal and fluid analysis areas. The finite element method is comprised of three major phases:

(1) Pre-processing, in which the analyst develops a finite element mesh to divide the subject geometry into sub domains for mathematical analysis, and applies material properties and boundary conditions,

(2) Solution, during which the program derives the governing matrix equations from the model and solves for the primary quantities, and

(3) Post-processing, in which the analyst checks the validity of the solution, examines the values of primary quantities (such as displacements and stresses), and derives and examines additional quantities (such as specialized stresses and error indicators).

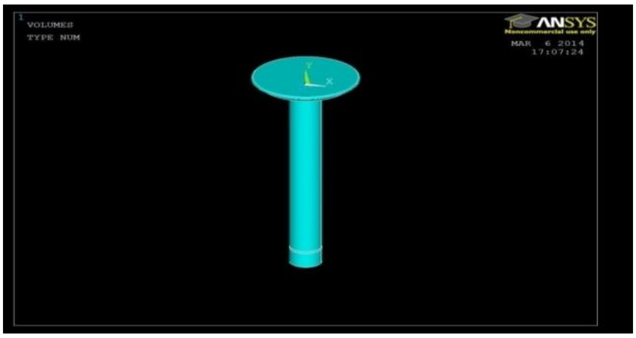

Fig 4.1 Importing Diagram from pro-e

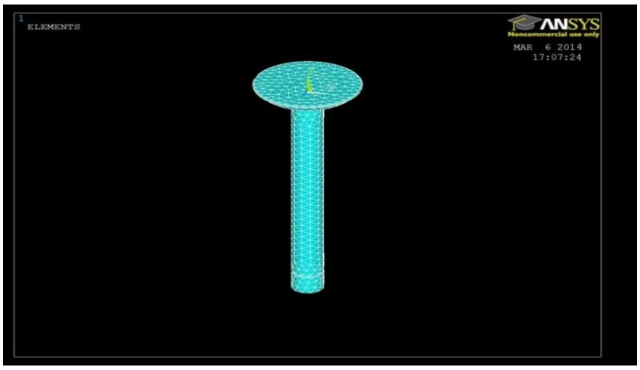

Fig 4.2 Meshing object

4.2 Model Generation

Two different methods are used to generate a model. They are: Solid modelling and Direct generation.

With solid modelling, we can describe the geometric boundaries of a model, establish controls over the size and describe the shape of the element and then instruct the ANSYS program to generate all the nodes and elements automatically. By contrast with the direst generation method we determine the location of every node and size, shape and connectivity of every element prior to defining these entities in our ANSYS model. Solid modelling is usually more powerful and versatile than direct generation and is commonly the preferred method for generating the model.

To judge which method is more suitable for a given situation, the relative advantages and disadvantages of two approaches are summarized as follows.

4.3 Types of Meshing

4.3.1 Manual Meshing

In manual meshing the elements are smaller at joint. This is known as mesh refinement, and it enables the stresses to be captured at the geometric discontinuity. Manual meshing is long and tedious process for models with any degree of geometric complication, but useful tool emerging in pre-processors, the task is becoming easier.

4.3.2 Meshing Controls

The default meshing controls that the program uses may produce a mesh that is adequate for the model we are analysing. In this case, we need not specify any meshing controls. However, if we do not use meshing controls, we must set them before meshing the solid model.

V. Results and Conclusions

5.1 Thermal Analysis

To import a model from any designing software to ANSYS its format should be portable for ANSYS. That format depends on the designing software for the model made PRO/E the portable format for ANSYS is ".iges". So before importing the model into ANSYS the model should be saved in the ".iges".

Open ANSYS and go to file menu -> import -> IGES -> select IGES file which we saved -> ok.

Then our model directly imports into ANSYS now it looks like this.

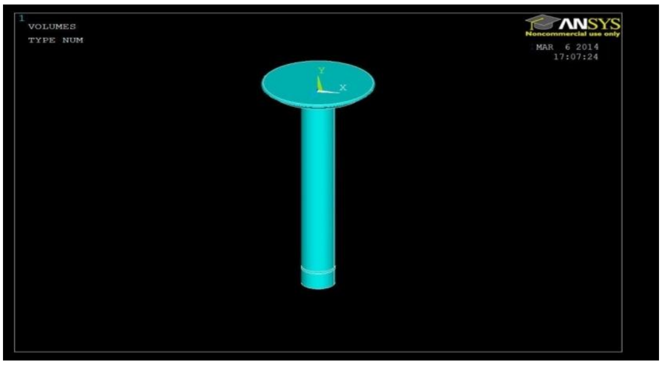

Fig5.1 ValveafterImport

Material properties:

Austenitic Stain less Steel

Element type : solid 20 node 90
Thermal conductivity: .03 w/mm°C.
Specific heat : 620 j/kg°C.
Density : .00000901kg/mm3

For an EN52 steel
Thermal conductivity : 03 w/mm°C.
Specific heat : 06 j/kg°C.
Density : 0.0000789 kg/mm3.

Element Properties: Select the preference ->thermal -> p-method ->ok. Go to pre-processor -> element type -> solid 20 node 90 -> ok.

Material Properties: Material models -> thermal -> conductivity -> isotropic ->Thermal conductivity-> define specific heat -> define density.

Mesh: Pre-processor -> Mesh tool -> global set -> give the node size -> pick all -> ok.

After meshing the model is looks like this.

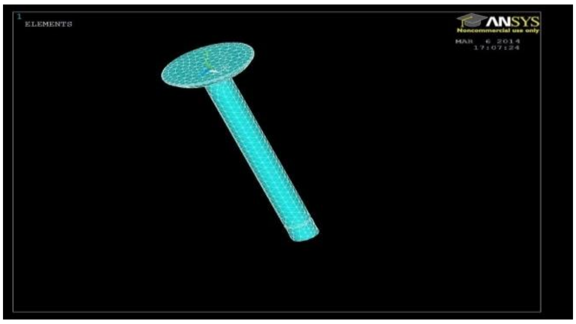

Fig 5.2 Valve after Meshing

Apply Temperature: Select solution -> Analysis type -> new analysis -> Model -> ok.Select temperatures -> click on areas -> apply temperature -> ok.Select Convection -> click on areas -> apply film coefficient & bulk temperature ->ok.

Solution: Solve -> current LS ->ok.

5.2 Temperature Distribution for Steel Materials

Stain Less Steel for Valve When it is Open Condition

Time sec	Min temp Due to wf	Max temp Due to wf
0	0	251
200	251	457

Table5.1 Temperature Distribution Due While Functioning(wf)

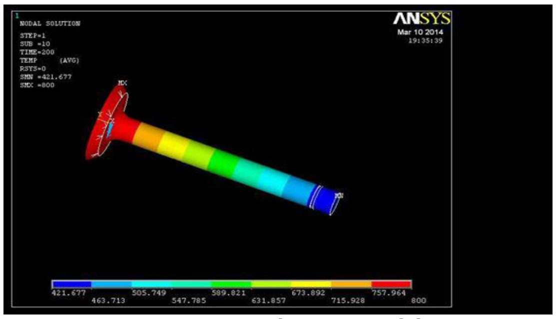

Fig 5.3 Temperature Distribution Due While Functioning

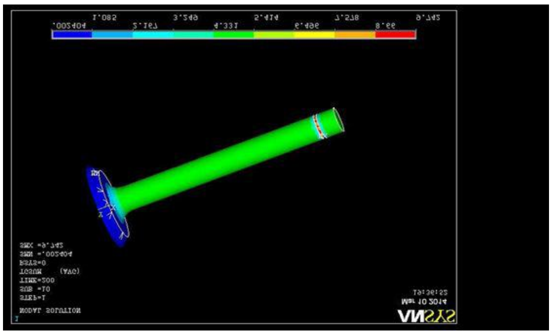

Fig 5.4 Thermal Gradient Distribution

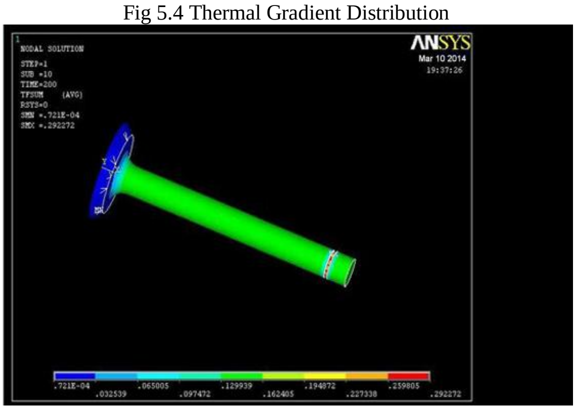

Fig 5.5 Thermal Flux Distribution

5.2.2 Stain less Steel for Valve When it is Closed Condition

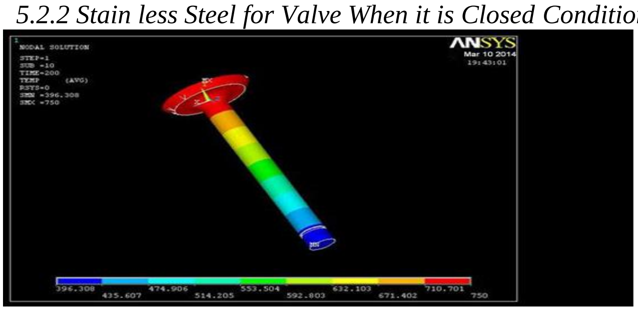

Fig 5.6 Temperature Distribution Due While Functioning

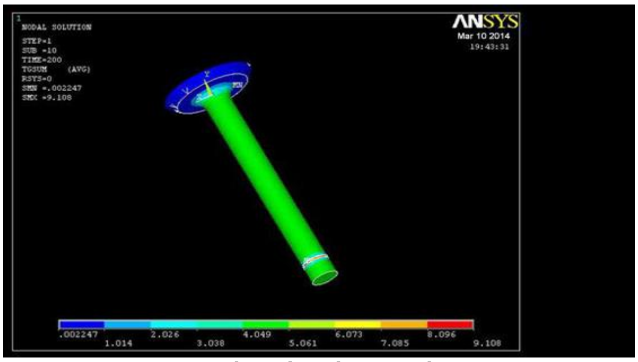

Fig 5.7 Thermal Gradient Distribution

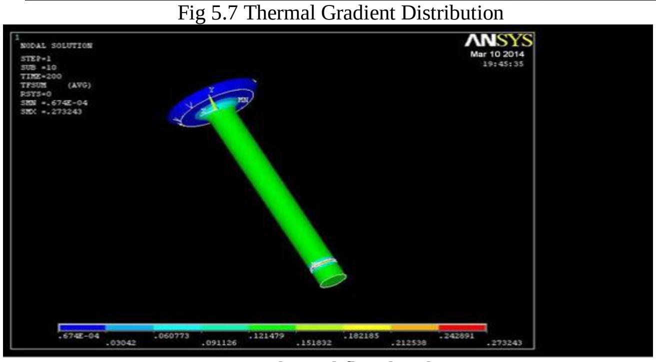

Fig 5.8 Thermal flux distribution

5.3 Temperature Distribution for en52 Steel Material

Apply Temperature: Select solution -> Analysis type -> new analysis -> Model -> ok. Select temperatures -> click on areas -> apply temperature -> ok.Select Convection -> click on areas -> apply film coefficient & bulk temperature ->ok.

Solution: Solve -> current LS -> ok.

5.3.1 *EN52 Steel for Valve When it is Open Condition*

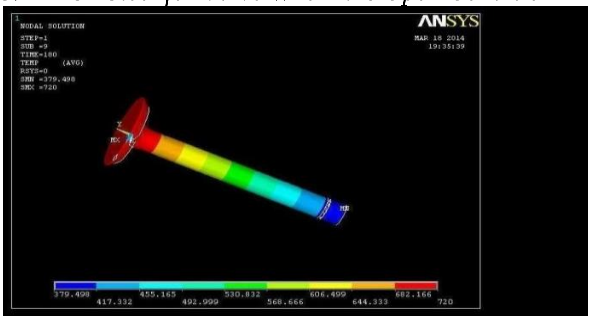

Fig 5.9 Temperature Distribution Due While Functioning

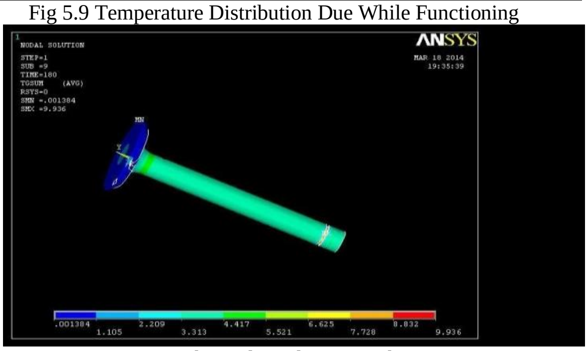

Fig 5.10 Thermal Gradient Distribution

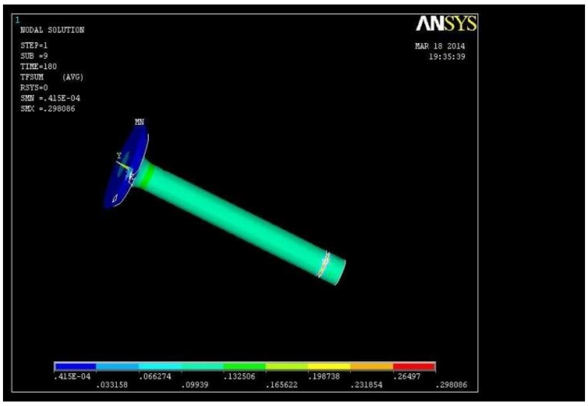

Fig 5.11 Thermal Flux Distribution

5.3.2 EN52 Steel for Valve When it is Closed Condition

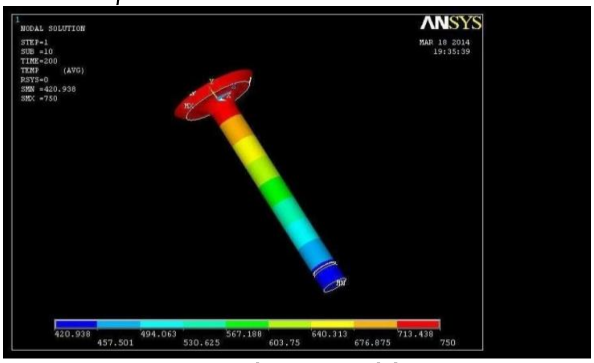

Fig 5.12 Temperature Distribution Due While Functioning

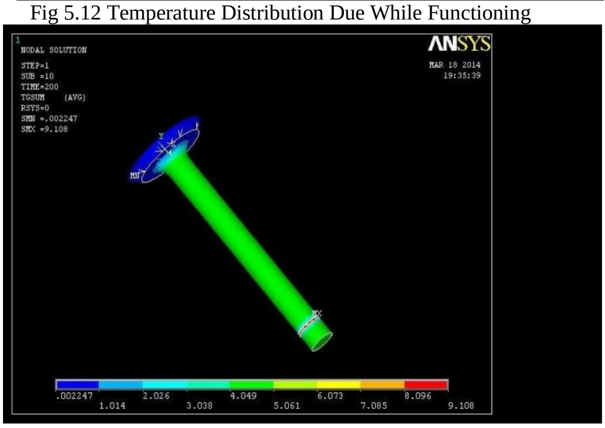

Fig 5.13 Thermal Gradient Distribution

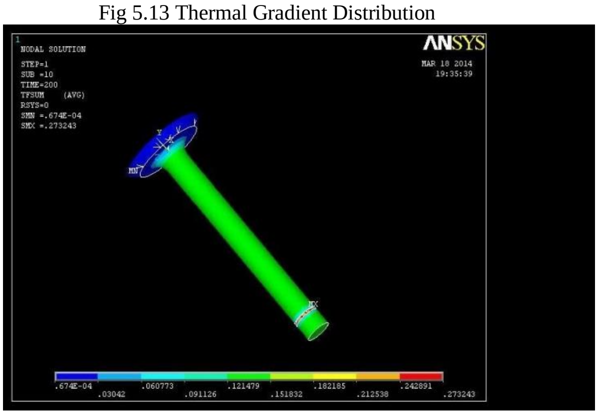

Fig5.14 Thermal Flux Distribution

5.4 Viewing Of Results

General post processor –> read results -> select the set which we want to observe -> plot results -> temperature distribution.

Plot results –> contour plot -> nodal solution -> DOF solution -> displacement vector sum -> ok

5.5 Result and discussion:

Material	Thermal variable &Valve position	Minimum temp	Max temp
Stainless steel	Temp due to while functioning & open	251	457
	Temp gradient distribution & open	0.0024	9.742
	Thermal Flux Distribution & open	721e-4	.292272
stainless steel	Temp due to while functioning & close	396	750
	Temp gradient distribution & close	0.002247	9.18
	Thermal Flux Distribution & close	674e-4	0.273243
EN 52 steel	Temp due to while functioning & open	379	720
	Temp gradient distribution & open	0.001384	9.936
	Thermal Flux Distribution & open	415e-4	0.298086
EN 52 steel	Temp due to while functioning & close	420.938	750
	Temp gradient distribution & close	0.002247	9.108
	Thermal Flux Distribution & close	674e-4	0.273243

1.Stainless steel material Temp due to while functioning and valve in open positio this material compare to the the EN 52 steel is higher temperature with standing capacity.

2.Temparue gadient distribution in open position comparing to two materials EN52 steel having good temparature controling capacity.

3.EN 52 steel material to produce thermal fluctuation are low compare to the stainless steel.

VI. Conclusion

We designed the diesel engine exhaust valve by using the formulas. We have done the model for the designed model by using Pro/Engineer software. We also conducted Transient thermal analysis at closing and opening condition for validating design.

Thermal analysis of the exhaust valve shows that the maximum temperature of the exhaust valve occurs at the stem of the valve. For these specific thermal boundary conditions, the maximum temperature of the exhaust valve is about 700^{o}C.

At the worst engine operating condition, maximum load and 4,700 rpm, the simulation reaches a steady-state condition after 127.659 s. This time is negligible when compared to the continuous engine running time, which usually lasts for several hours.

The maximum thermal stress is developed at the valve seat contact zone of the valve in the hoop direction, and its value is 208 MPa. According to the yield strength of the material is 210 Mpa; this stress does not cause the valve material to yield.

However, since the mentioned stress is positive, at the worst conditions for the cooling of the valve such as distortion of the seat, this stress causes radial cracks at the edge of the valve. We are going to conclude that our design is safe for the given loads.

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