ISSN (ONLINE): 2321-3051
INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING

Thermal Analysis of Engine Chamber using FEM

CH. Sreenivasa Rao[1], Dr.M.M.Nayak[2], Dr.E.S.Prakash[3]

[1]Research Scholar, UBDTCE, Davanagere, India, chsrao70@gmail.com
[2] Visiting Professor, Centre for nanoscience and engg, IISc.,Banalore, India
[3] Professor, Dept. Of Mech. Engg., UBDTCE, Davanagere, India

Abstract

An engine is a propulsive device used by missiles, rockets and satellites in the reaction control system. These engines are used in reaction control system for station keeping and attitude control. High temperature gases are produced on combustion or decomposition of the propellant. The products produced are discharged through nozzle to achieve high gas velocity and thereby desired thrust. Suitable design of chamber, nozzle plays vital role for effective utilisation of propellant energy. Chamber with one side convergent divergent nozzle and the other side flange model was considered as model. Control valve to be mounted to flange to provide propellant as and when required. Being control valve mating, the flange to be kept at minimal temperature. On combustion, thermal flux produced for the given propellant is assumed as $1W/mm^2$. Two cases have been considered with different engine chamber lengths. Assuming SS304L is the material and Thermal Analysis has been carried out for two cases. Analysis test results indicated the flange, nozzle throat and exit temperatures are in safe limit after cut off to combustion or decomposition for both the cases.

***Keywords**:* Thermal analysis, Chamber, Finite Element Method.

1. Introduction

Small engines are used for station keeping, attitude control in reaction control system. Reaction control systems are required for any of the propulsive systems like missiles, launch vehicles, satellites. On combustion or decomposition of the propellant in chamber gives rise to high temperature gases. These high temperature gases consist of good amount of thermal energy. The temperature in turn thermal energy is in proportion to the propellant capability. The phenomenon of decomposition or combustion takes place in chamber. High temperature gases produced upon combustion or decomposition pass through convergent divergent nozzle. Thermal energy of exhaust gases will be converted to kinetic energy, by which exhaust gases moves in nozzle with high velocity. Literature in the same field has been referred for formulation of problem and analysis by using FEM [1-3].

2. Geometric Model

Chamber casing is selected with simple cylinder configuration. Cylinder diameter is assumed as 6mm with uniform wall thickness of 0.75mm and nozzle area ratio as 75. One end of the chamber cylinder is connected to CD nozzle and the other end of the chamber cylinder is having a circular flange to facilitate the connection with control valve. Control valve is required to provide propellant to chamber as and when required. Chamber martial is selected as SS304 with thermal conductivity of 18W/m-K and maximum thermal flux produced on combustion for the given propellant is assumed as 1W/mm^2.

2.1 Problem Description

On command to control valve, propellant flow takes place to engine chamber and temperature increases in the defined portion of the engine chamber where combustion or decomposition takes place. During the combustion, hot gases will be moving out through CD nozzle, where in which thermal energy is converted to kinetic energy. During this process convection takes place and flange temperatures will be benign. Once the control valve is commanded to close, there is no flow in forward direction and further no convection phenomenon. With an assumption of no radiation, only conduction phenomenon happens because of flange and nozzle exit are at lower temperatures compared to chamber and nozzle throat.

It is important to maintain minimal rise in circular flange temperatures, so that the control valve will be at safe temperatures. Two different cases have been considered with chamber lengths of 30mm and 40 mm. Temperature profiles estimation for the model for different engine chamber lengths are analysed.

2.2 Loads Applied

An axi-symmetric model of engine chamber is created for the chamber with nozzle and flange as single unit. The model is meshed using Quadrilateral 8-noded 2D solid elements. It is a eight noded element with two degree of freedom at each node. Thermal flux of 1W/mm^2 is assumed for both models. Model of 40mm chamber length with thermal flux and corresponding temperature distribution are shown in Fig.1 & Fig.2.

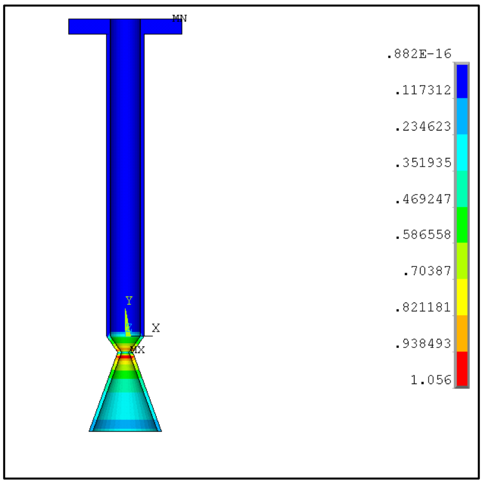

Fig.1 Model of chamber (40mm length) with nozzle and circular flange

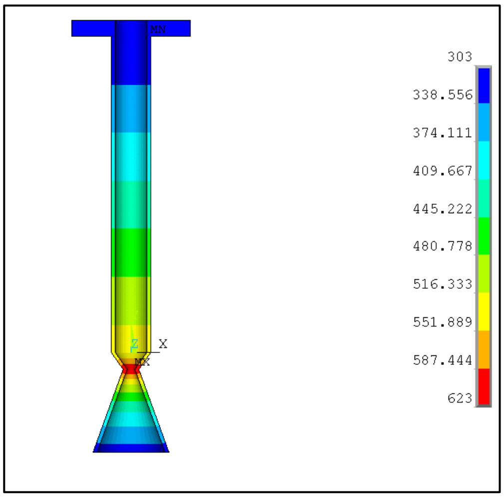

Fig.2. Chamber (40mm length) initial temperature distribution due to thermal flux

Vol.2 Issue.2,
February 2014.
Pgs: 125-130

3. Analysis

Analysis has been carried out for engine chamber for two different lengths with thermal flux as input. Thermal analysis has been carried out for 300sec after combustion or decomposition cut-off, to identify the temperature phenomenon both in nozzle as well as in circular flange. Thermal analysis test results for both 30mm, 40mm length chambers are shown in Fir.3 and Fig.4 respectively.

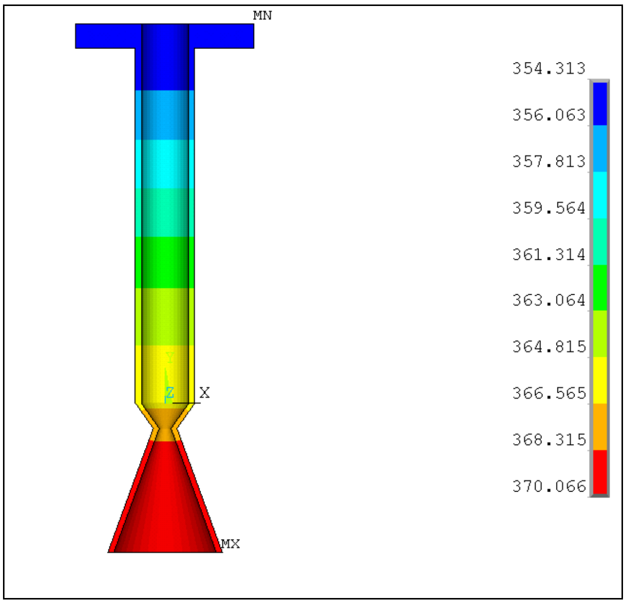

Fig.3 Thermal Analysis of chamber (30mm length) at 300sec

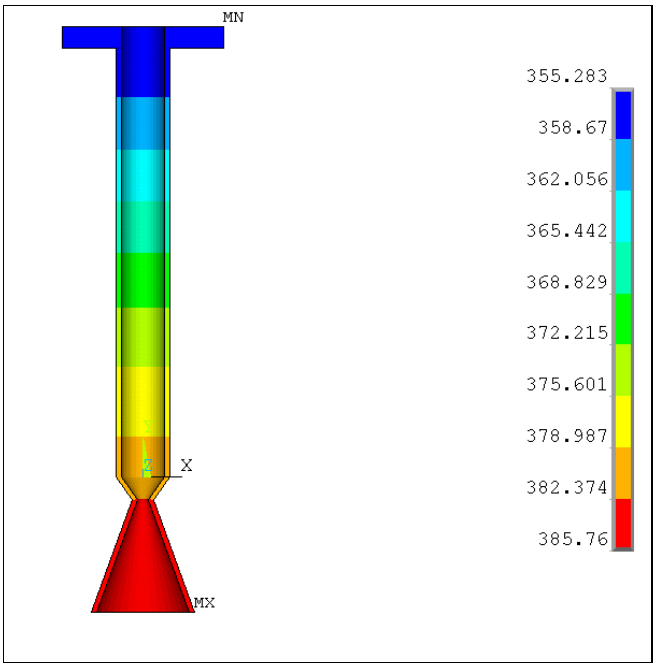

Fig.4 Thermal Analysis of chamber (40mm length) at 300sec

3.1 Results

Based on analysis results, Variation of nozzle throat and exit temperatures for 300sec after combustion or decomposition cut off for two different chamber lengths are shown in Fig.5 and Fig.6.

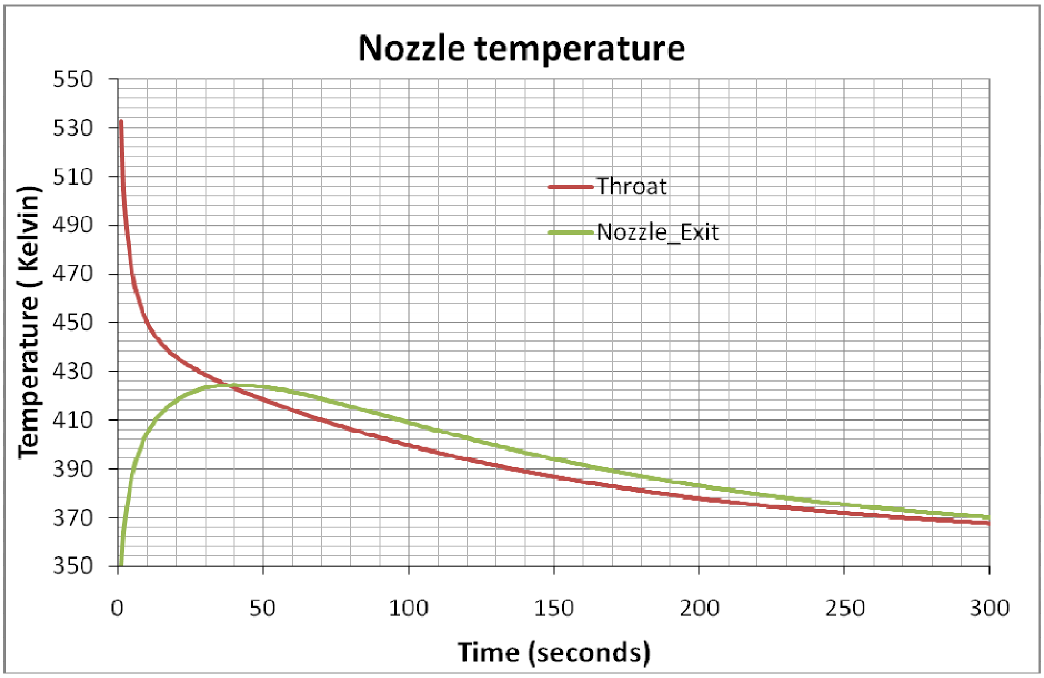

Fig.5 Temperature variation of nozzle throat and exit for chamber (30mm length)

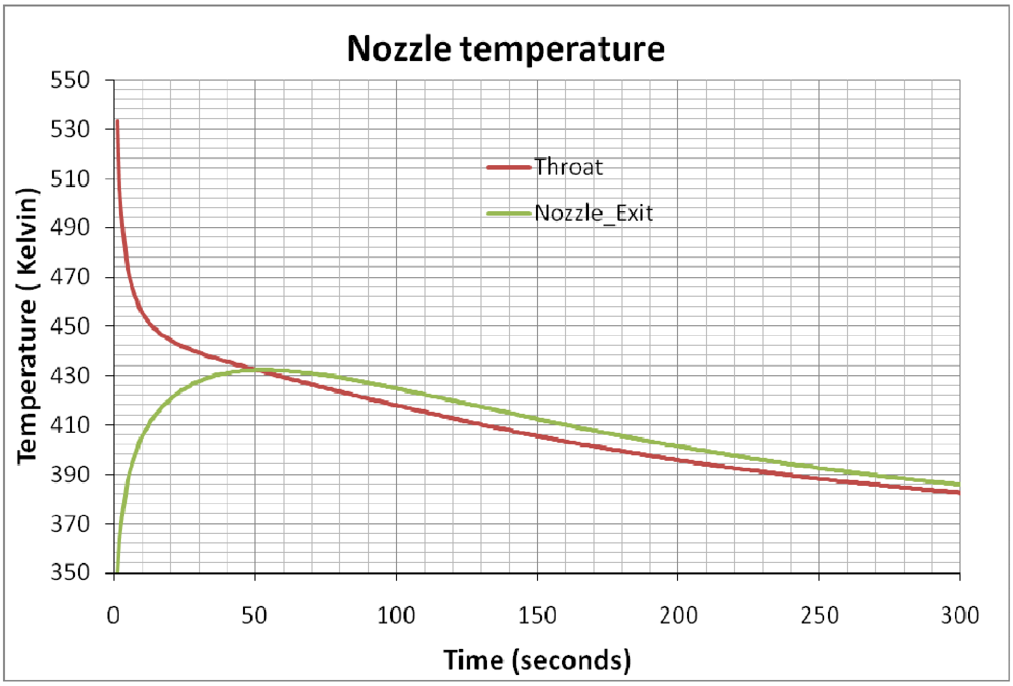

Fig.6 Temperature variation of nozzle throat and exit for chamber (40mm length)

Based on analysis results, Variation of circular flange temperatures for 300sec after combustion or decomposition cut off for two different chamber lengths are shown in Fig.7 and Fig.8.

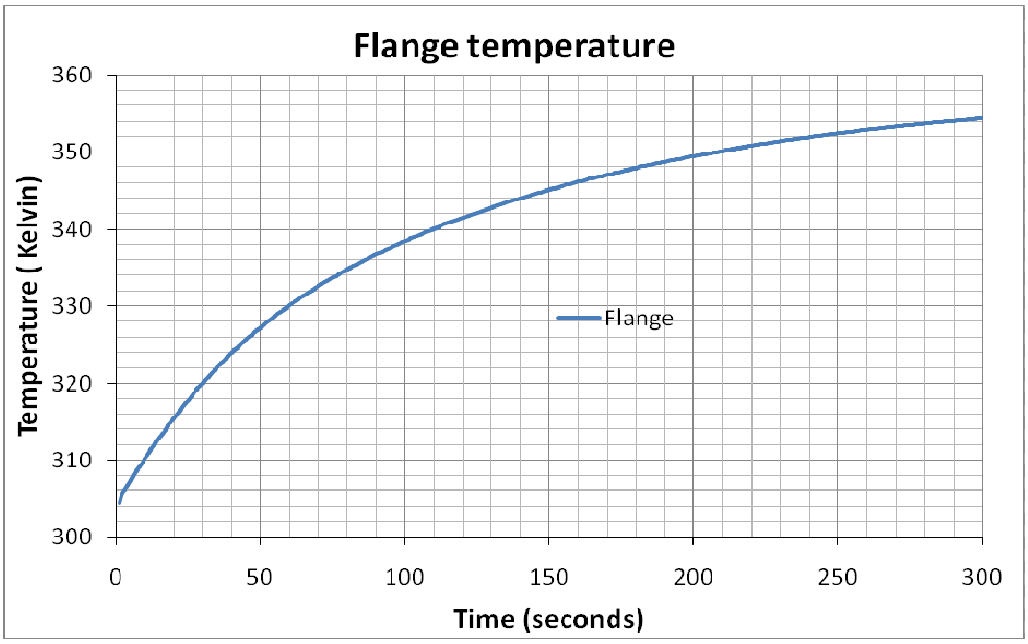

Fig.7 Temperature variation of flange for chamber (30mm length)

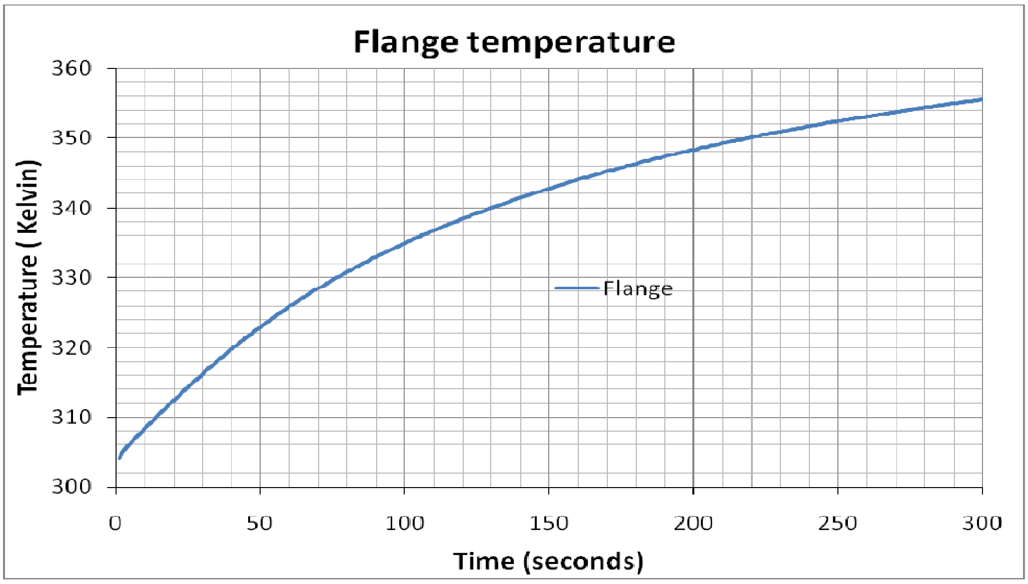

Fig.8 Temperature variation of flange for chamber (40mm length)

3.2 Discussion

Analysis test results for 300sec after cut off to combustion or decomposition are plotted. For both cases of chamber length 30mm and 40mm Nozzle throat, exit temperatures are in the range of 360 to 390K and flange temperatures are in the range of 354-355K.

Vol.2 Issue.2, February 2014. Pgs: 125-130

4. Conclusion

Reaction control systems consists of small engines, which are required for any of the propulsive systems like missiles, launch vehicles, satellites. High temperature gases produced from propellant combustion or decomposition are passes through converging-diverging nozzle to achieve high gas velocity and thrust. The thermal flux is assumed as 1W/mm^2. During engine chamber in active condition, the convective heat transfer is so enormous, which will not allow the flange temperature to increase. Flange temperature increasing phenomenon happens as soon as cut off to combustion or decomposition. Engine chamber with flange and nozzle is modelled as single entity. With the application of thermal flux, FE thermal analysis has been carried out for two chamber lengths of 30mm and 40mm. To have safe temperature zone at control valve, temperature rise on the circular flange should be as minimum as possible. Analysis has been made for 300s after cut off to combustion or decomposition. Based on analysis results it has been observed that the flange temperatures are in the range of 354-355K for both cases. Also the temperatures of nozzle throat and exit are in the range of 360 to 390K. Being flange temperature in both cases are at vey benign values and it is safe for control valve. From the results obtained it is concluded that difference in temperature rise for 30mm and 40mm length of engine chamber is very meagre and the structure is safe under given thermal conditions for both cases.

References

[1] Kardomateas GA. The initial phase of transient thermal stresses due to general boundary thermal loads in orthotropic hollow cylinders, *ASME Journal of Applied Mechanics* 1990;57:719-24

[2] Mukherjee N, Sinha PK,Thermostructal analysis of rotationally symmetric multidirectional fibrous composite structures, Elsevier, *Computers & Structures* Volume 65, Issue 6, 1997, pp 809-817.

[3] Deepthi Ch, Dr.G Vijay kumar, Dr.P Ravindra Reddy, .Thermo-structural response of a rocket thrusters using Fem, *International journal of Engineering and Advanced Technology (IJEAT)*, ISSN:2249-8958, Volume-3, Issue-2, December 2013