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DESIGN & ANALYSIS OF A MODEL COMBUSTION CHAMBER OF GAS TURBINE

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ABSTRACT
Development of a country is assessed by it's power consumed per capital. Gas turbine is highly dependable power generating source in every country. As a developing country Bangladesh needs a huge amount of power. To keep pace with the other developed countries and their technologies, it is customary to have a great amount of power generating sources. Gas turbine can easily serve this purpose. For fulfilling this purpose our present effort is to design & analysis of a combustion chamber which is a vital part of gas turbine. This paper summarizes the design and analysis of gas turbine combustion chamber.3D model of the combustion chamber is generated & finite element method is used for meshing and applying boundary conditions for static and thermal analysis. Here we have done the study on different materials which are suitable for improvement of combustion chamber. This paper also validates the design using available alloys. Any development regarding this project will be accepted based on it's validity.

Keywords: Design ; Combustion chamber ; Analysis ; F.E method.

1.0 Introduction

A combustion chamber is an enclosure in which combustion takes place just like burning of fuel & oxidant. It is the 2nd subsequent part of a gas turbine. It is also known as burner, flame holder or combustor. High pressure air or gas comes from compression system and enter into the combustion chamber. The combustion chamber then heats this air at constant pressure. After heating, air passes from the combustion chamber through the nozzle guide vanes to the turbine. At constant pressure, a high temperature is produce which is sustained by combustor wall. So it is necessary to design a combustion chamber with appropriate temperature sustainable metal.

In spite of having different available metal, it is difficult to find out proper one. The ability to heat consume depends on the yield strength of metal. This property changes metal to metal according to their molecular arrangement, impurities or other containing ingredient. But it is not possible to find out these properties one by one in real life. For this reason there arise the topics of simulation for different metal which will be used to construct a combustor.

There are different methods of analysis of metal properties. From all of those finite element method is considered as perfect and less time consuming method. It is a numerical method for finding approximate solution of boundary value problems. For a combustion chamber, inlet pressure, temperature are known value just like initial condition and there also exist a boundary condition. So applying this conditions and other affecting parameter, the internal heat generating environment and condition of combustor wall are easily determined by the iteration of F.E.M.

According to design criteria and simulation result, some metals are selected. Among them, most reliable and financially less consuming metal is find out to use as a combustor outer wall & components.

All recent research allow the procedure of construct a combustion chamber in this systematic way. But metal by metal analysis is uniqueness of this procedure which application can be more popular than before.

2.0 Finite Element Method

The finite element method (FEM) rapidly grew as the most useful numerical analysis tool for engineers and applied mathematicians because of it natural benefits over prior approaches. The main advantages are that it can be applied to arbitrary shapes in any no of dimensions. The shape can be made of any number of materials. The material properties can be non-homogeneous. (depends on location) and/or anisotropic (depend on direction). The way that the shape is supported (also called fixtures or restraints) can be quite general, as can the applied sources (forces, pressures, heat flux, etc.). The FEM provides a standard process for converting governing energy principles or governing differential equations in to a system of matrix equations to be solved for an approximate solution. For linear problems such solutions can be very accurate and quickly obtained. Having obtained an approximate solution, the FEM provides additional standard procedures for fol -low up calculations (post-processing), such as determining the integral of the solution or its derivatives at various points in the shape .The post-processing also yields impressive color displays, or graphs, of the solution and it's related information. Today, a second post-processing of the recovered derivatives can yield error estimates that show where the study needs improvement. Indeed, adaptive procedure allowed

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automatic corrections & resolutions to reach a user specified level of accuracy. However, very accurate & pretty solutions of models that are based on errors or incorrect assumptions are still wrong. When the FEM is applied to a specified field of analysis (like stress analysis, thermal analysis, or vibration analysis) it is often referred to as finite element analysis(FEA) . FEA is the most common tool for stress and structural analysis . Various field of study are often related. For example, distributions of non-uniform temperatures induce non obvious loading conditions on solid structural members .Thus it is common to conduct a thermal FEA to obtain temperature results that in turn become input data for a stress FEA.

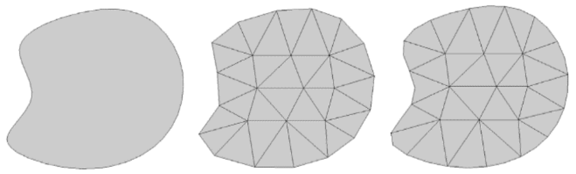


Fig.1 An area meshed with linear and quadratic triangles.

The sum the areas of the individual triangles:

$$A = \sum_{k=1}^{n} A^k.$$

About assigning a linear material to each part, modern FEA systems have a material library containing the "linear" mechanical, thermal, and/or fluid properties of most standardized materials. They also allow the user to define custom properties.

3.0 Types of Combustion Chamber

There are usually 4 types of combustion chamber .These are:

- can type
- can-annular type
- annular type
- reverse flow type

3.1 Can type

Can combustors are self contained cylindrical combustion chambers. Each can get an air source from individual opening .For the same air flow, it is longer , since the individual can diameter must be held to a minimum. The individual can are wasteful of the available space, since they use the individual cross-sectional area inefficiently.

3.2 Can-annular type

Like the can type combustor, can annular combustors have discrete combustion zones contained in separate lines with their own fuel injectors. Unlike the can combustor, all the combustion zones share a common air casing. Each can has primary air admitted near the fuel nozzle & is perforated so that secondary cooling air may be admitted downstream of the primary zones. There usually is a flame tube that joints the cans enabling the flame to pass from can to can during starting.

3.3 Annular type

Annular combustors do away with the separate combustion zones and simply have a continuous liner and casing in a ring (the annulus). It consists of one or two continuous shrouds. The fuel is introduced through nozzles at the inlet to the shroud, with secondary air entering though holes. This secondary air keeps the flame away from the shroud & the dilutes the combustion chamber gases to the desired turbine inlet temperature.

3.4 Reverse flow type

Reverse flow combustion chamber, especially known as reverse flow ring combustion chamber, for gas turbine propulsion units. Which have at least one flame tube wall with film-cooling arrangement. It includes an annular chamber enclosed between flame tube wall sections to which cooling air is so supplied from an outer annular channel acted upon with secondary air opposite the main flow direction in the flame tube in such a manner that the cooling air that it is blown out in the opposite flow direction film-like against an adjoining flame tube wall.

4.0 Simulation setup & grid generation:

For the simulation at first what is need, is a CAD model. So a cad model of is used in the analysis. The CAD model was of arbitrary dimensions & was modeled in SolidWorks. Though it has an arbitrary dimensions, the shape has quite similarities with the actual combustion chamber that is used now–a-days.

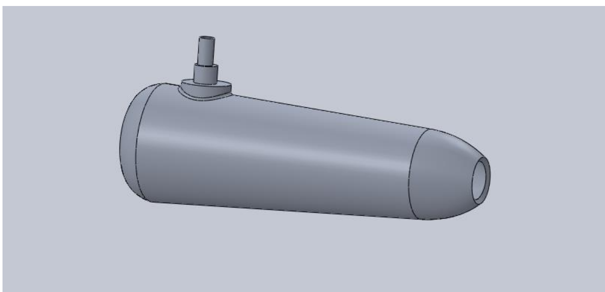


Fig.2 Integrated CAD part of a Combustion Chamber.

The sction view of the combustion chamber is also attached here for better understanding of the internal views.

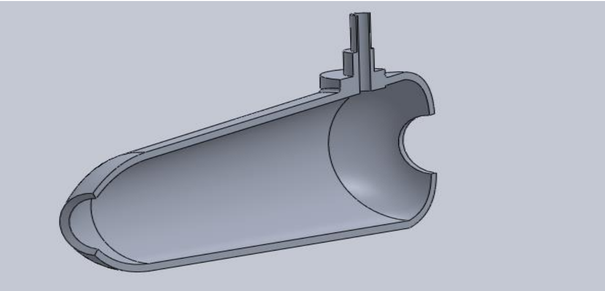


Fig.3 Section view of the generated CAD model.

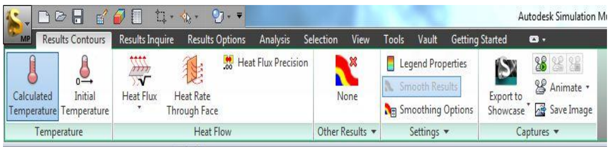
There are three preview window is used of the software during analysis.

FEA editor window: Initial conditions and boundary conditions are given here. Grid generation was also done in this setup.

Results generation window (heat analysis): In this window steady state heat analysis has been done.

Results generation window (linear stress analysis):In this window a linear stress analysis has been done. To deal with the thermal stress analysis of the materials, results from steady state heat transfer analysis has been used in the linear stress analysis.

(a)



(b)

(c)

Fig.4 (a) Grid generation window.
(b) Heat transfer window.
(c) Linear stress analysis window.

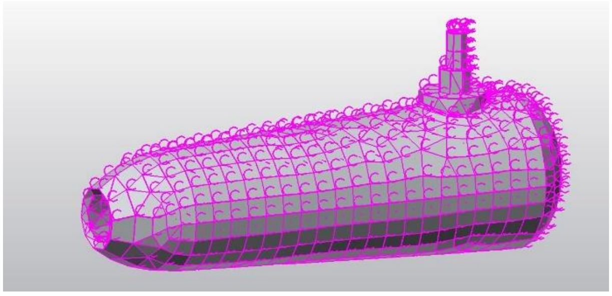


Fig.5 CAD model with grids after meshing.

The primary simulation setup and grid generation is completed. Now the CAD model is ready for simulation and result extraction.

5.0 Model generated in solidworks

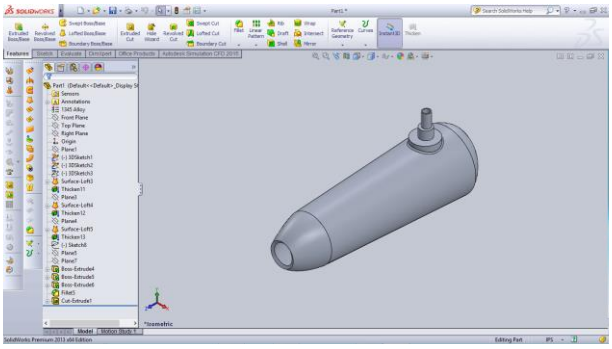


Fig.6 Arbitrary model of combustion chamber.

6.0 Structural analysis

In this analysis calculated maximum temperature, generated heat through faces, heat flux, static stress & static strain are the required criteria.

6.1.0 Thermal analysis for Aluminium alloy 1345

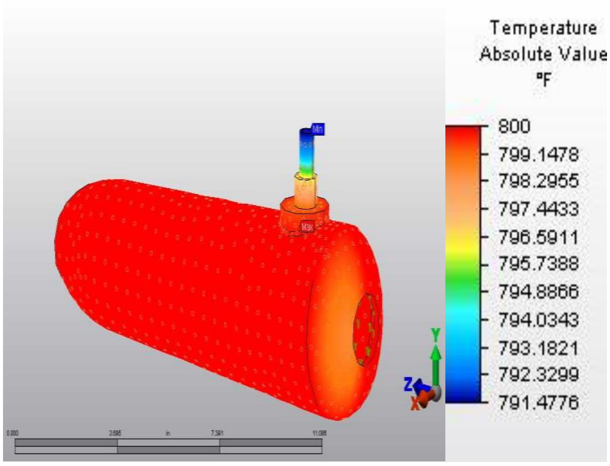


Fig.7 Calculated maximum temperature.

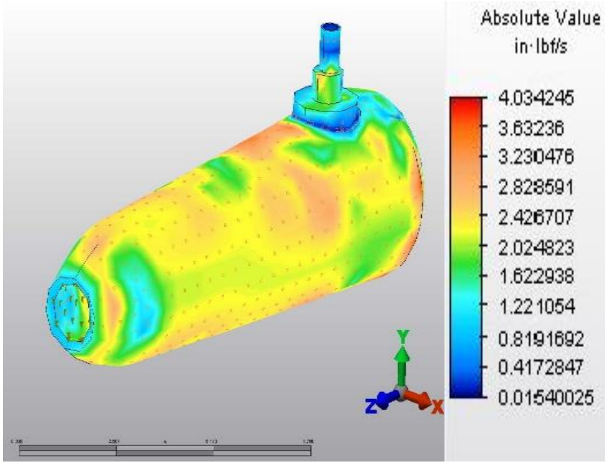


Fig.8 Generated heat.

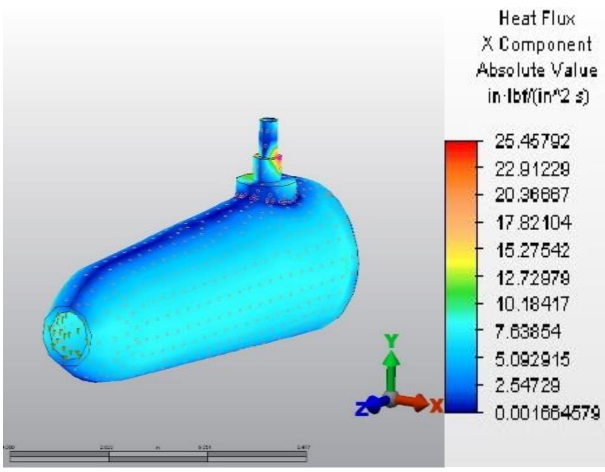


Fig.9 Heat flux along X axis.

6.1.1 Linear static analysis for Aluminium alloy 1345

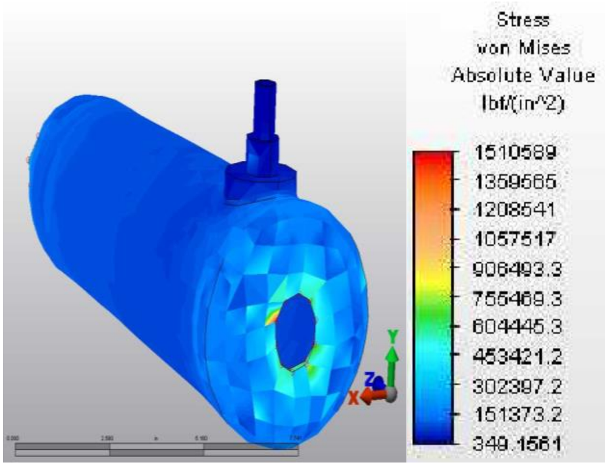


Fig.10 Static stress analysis.

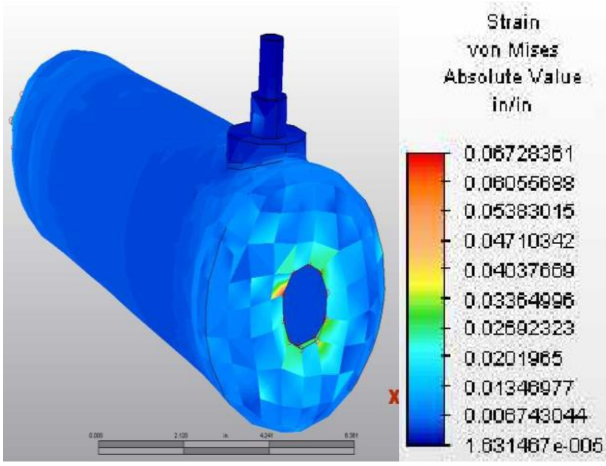


Fig.11 Static strain analysis.

6.2.0 Thermal analysis for Aluminium Alloy 5005-H18

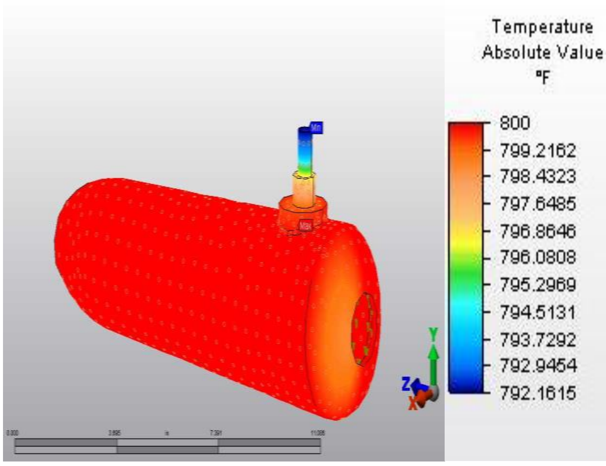


Fig.12 Calculated maximum temperature.

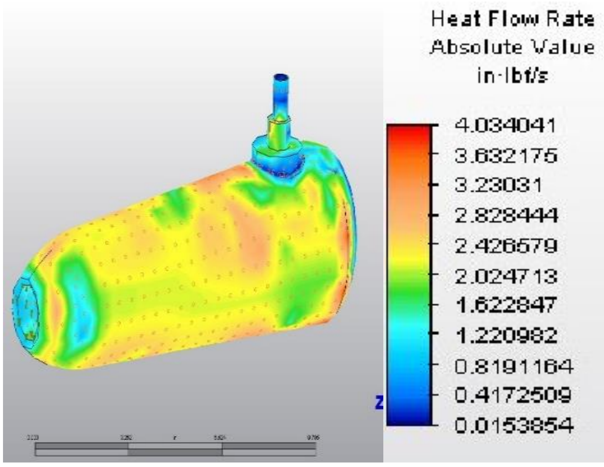


Fig.13 Generated heat.

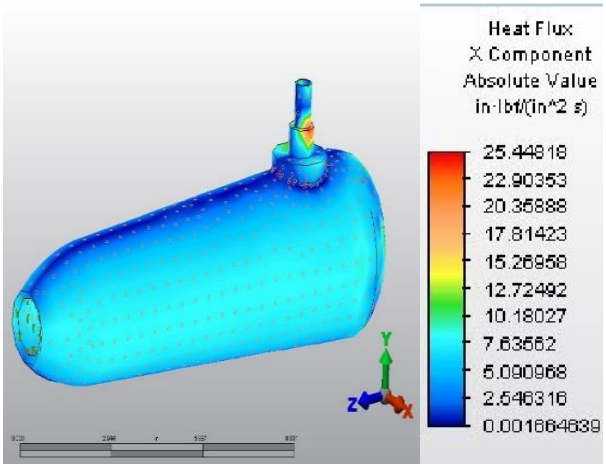


Fig.14 Heat flux along X axis.

6.2.1 Linear static analysis for Aluminium Alloy 5005-H18

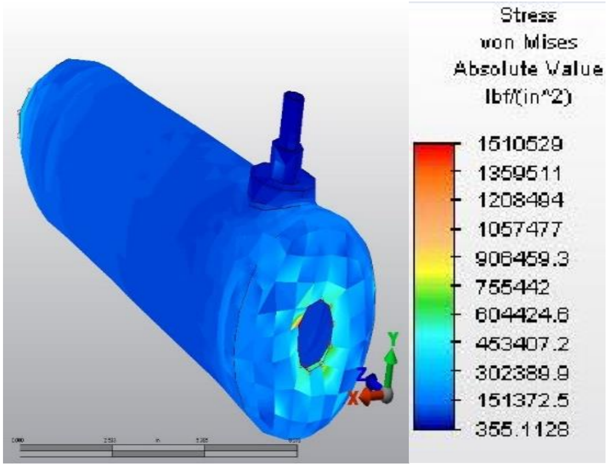


Fig.15 Static stress analysis.

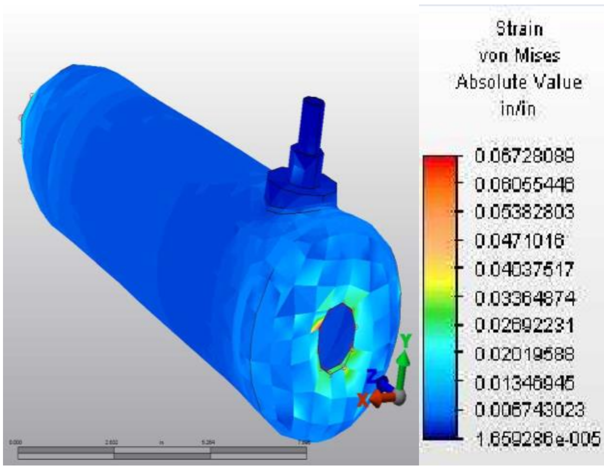


Fig.16 Static strain analysis.

6.3.0 Thermal analysis for Ceram Tec Grade 950Toughned Alumina (Al2o3)

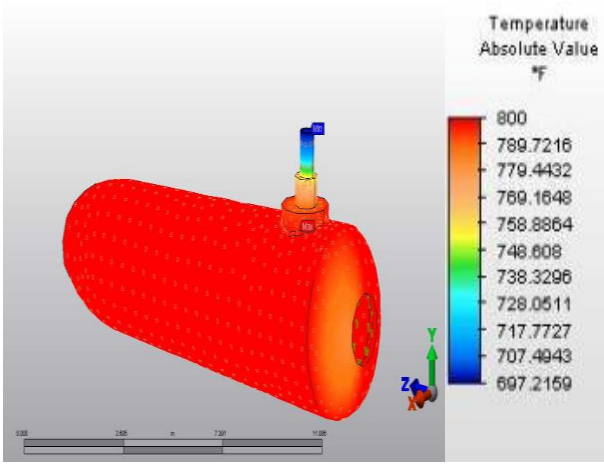


Fig.17 Calculated maximum temperature.

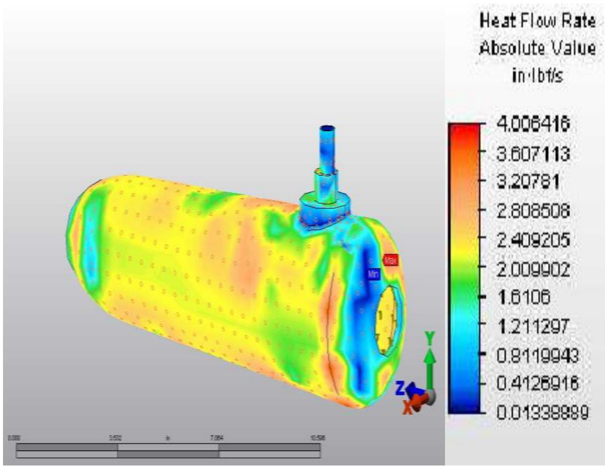


Fig.18 Generated heat.

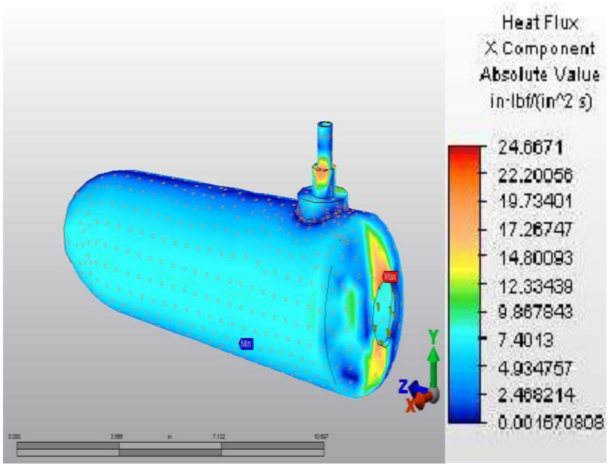


Fig.19 Heat flux along X axis.

6.3.1 Linear static analysis for Ceram Tec Grade 950Toughned Alumina (Al2o3)

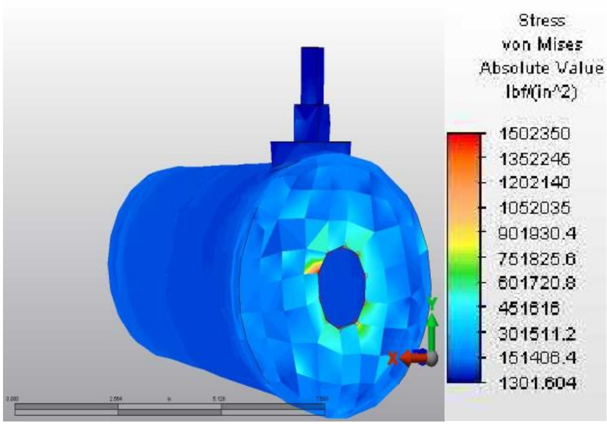


Fig.20 Static stress analysis.

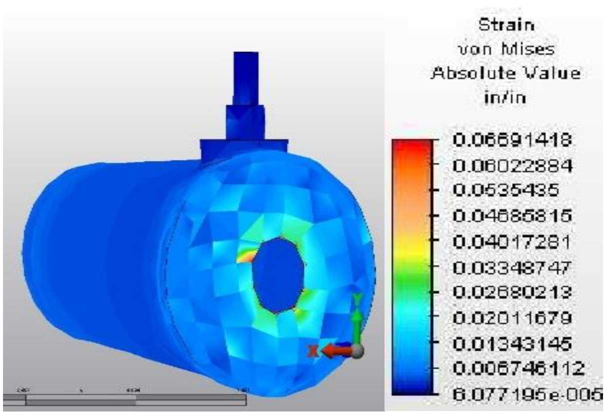


Fig.21 Static strain analysis.

7.0 Results in tabular form

Material	Aluminium alloy 1345	Aluminium Alloy 5005-H18	Ceram Tec Grade 950Toughned Alumina (Al_2O_3)
Material properties			
Mass density	0.00027362	0.00025362	4.1E-04
Thermal conductivity	27.2	25	1.87340785962217
Structural analysis			
Stress (in/in^2)	1510589	1510529	1502350
Strain (in/in)	0.06728361	0.08728089	0.0669142
Displacement (in)	0.03879156	0.03879078	0.0386875
Thermal analysis			
Temperature (°F)	800	800	800
Generated heat (in-lbf/s)	4.034245	4.034041	4.006416
Heat flux (in-lb/in^2 s)	25.75892	25.44818	24.6671

8.0 Conclusion

In this paper we have analyzed previous designs and generals of combustion chamber for gas turbine to do further optimization, Finite element results for free standing combustion chamber give a complete picture of structural characteristics, which can utilized for the improvement in the design and optimization of the operating conditions.

In the first step we have designed a combustion chamber using arbitrary dimensions.

In the second step we have done the study on different materials which are suitable for the improvement of turbine combustor.

In the third step we have validated our design using existing materials.

In the next step we have applied different materials for combustion chamber to suggest best material.

From the above results we can conclude that , using of Ceram Tec Grade 950Toughned Alumina (Al_2O_3) is more efficient and satisfactory among all those materials that has been analyzed , due to low stress displacement, good thermal strength and easy to manufacture.

9.0 REFERENCES

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