Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 4; April-June, 2015 pp. 321-325

http://www.krishisanskriti.org/jmsme.html

Combustion Chamber Liner Wall Design Using High Temperature Composite Materials

A. Aravind Raja[1], N. Ashok Pandiyan[2], S. Karuna Moorthi[3] and M. Syed Abudthahir[4]

[1,2,3,4]*Park College of Technology*
E-mail: [1]rvnd93@gmail.com, [2]nashokaero@gmail.com, [3]karnamani912@gmail.com, [4]syedflyingwarrior@gmail.com

Abstract—*Usually many materials in the aircraft gets damaged due to the overheating and these materials can affect the aerodynamic forces. One of the most heat produced area in the aircraft is the engine section. This paper describes the design and analysis of combustion chamber liner walls (CCL) through ANSYS. Now a days titanium alloys are widely used for combustion chamber liner. This material has poor corrosion resistance and oxidation resistance (removal of oxygen). In order to overcome this drawback we are suggesting SiC (Silicon Carbide) ceramic matrix composites to get good corrosion resistance and oxidation resistance to improve life of the material. We made an analysis among these ceramic coating materials by using ANSYS to determine the thermal performance of the material. On comparison SiC has good thermal performance than other materials.*

Keywords*: Combustion chamber liner, Lifecycle, Ceramic coating, Thermal conductivity, SiC*

1. INTRODUCTION

The liner is the interior covering of the combustion chamber. It is used to prevent the higher temperature in the combustion chamber. The fuel is injected by the sprayers in center of recirculation zone and enters in the combustor along an hollow cone surface. The temperature of gas produced by combustion is approximately 1800-2000°C, that is by far too much high to enter in turbine. Systems of advanced cooling (Effusion cooling) are constituted by a series of small diameter holes that cross the combustor wall. The combustion must finish before zone of dilution holes, otherwise the flame is cooled with result of an incomplete combustion. The fuel is fed in the combustor in two different ways. The way more usual and more traditional is to directly inject it in the primary zone by sprayers or vaporizers.

2. COMBUSTION CHAMBER

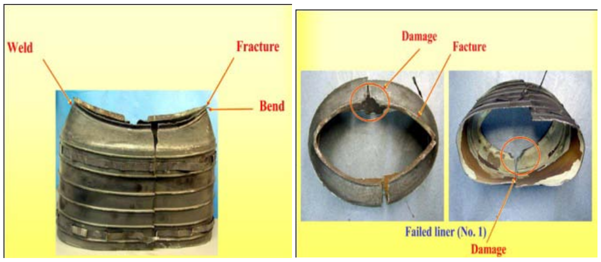
The combustion chamber is that turbo-engine component which fuel, supplied by feeding nozzles, is mixed with air flow coming from the compressor and burns releasing heat to obtain a gas stream to a temperature as much as possible uniform in condition requested form turbine. This task must be carried out with the possible minimum of pressure leaks and with the maximum possible release of heat respect the limited space available.

The air coming from the compressor enters in the combustion chamber with speed that can reach 150 m/s. This speed is too much high for combustion, so first the must happen in a combustor is a spread, that is a deceleration of air with a consequent increase of the static pressure. The amount of fuel supplied to the air depends by requested temperature raising. However the maximum temperature is limited in 850 - 1700 C interval, depending by characteristics of materials of which turbine vanes and blades are constituted and by cooling system of same blades and vanes.

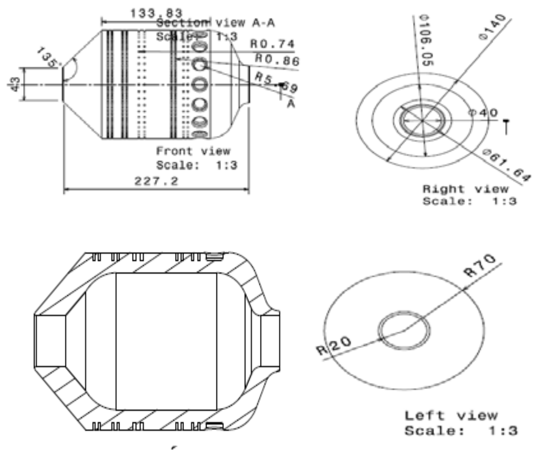
Titanium, due to its high strength to weight ratio, has been a dominant material in compressor stages in aero engines. Titanium content has increased from 3 % in 1950s to about 33% today of the aero engine weight. Unlike predictions made for requirements of ceramic and metal matrix composites for aero engines, predictions made for titanium alloys have come true or even surpassed. High temperature titanium alloys have found extensive application in aero engines. Ti-6Al-4V is used for static and rotating components in gas turbine engines. Castings are used to manufacture the more complex static components. Forgings are typically used for the rotating components.

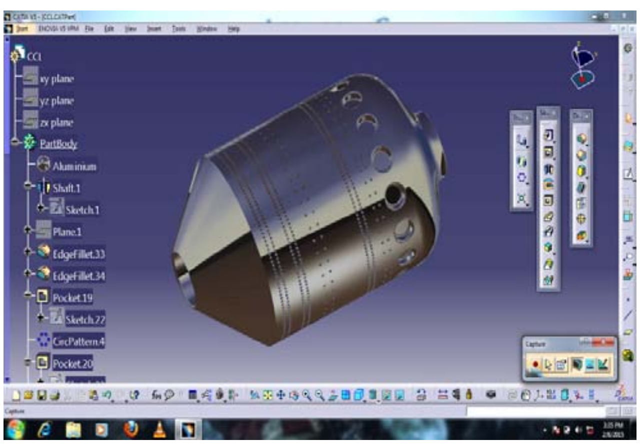
2.1 Effect of using Titanium Alloy

- Liners failed due to Stress Rupture.
- Due to overheating in the combustor, the above mentioned material starts corroding.
- The material fails due to the low thermal conductivity.
- The welded surface in the liner causes the stagnation pressure in that area due to this stagnation the material will get corrode.
- A void is formed in the corroded area and these voids gets nucleated then the fracture will be appear.



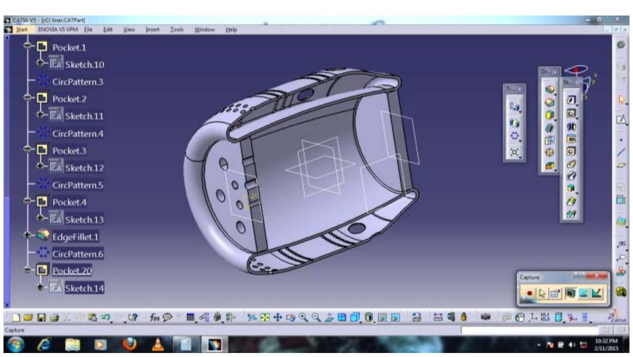
3. COMBUSTOR DESIGN





The combustor is designed in CATIA software.

3.1 Cross section of combustor liner



4. CERAMIC MATRIX COMPOSITES (CMCS)

The manufacturers of gas turbines are continually striving to increase the operating temperatures of their engines, leading to greater thermal efficiency, and reduced emission of harmful exhaust gases. These two drivers place an ever increasing burden on the materials used in, and the design of, hot gas path components. The introduction of CMCs into hot gas path components such as combustion chamber liners has long since been identified as a possible route to the achievement of increasing operating temperatures without incurring the penalties associated with increased cooling air use.

4.1 SiC

SiC matrix composites appear to be highly tailorable materials suitable to gas turbine application at high temperatures. Melt infiltrated (MI) SiC/SiC composites are particularly attractive for gas turbine applications because of their high thermal conductivity, excellent thermal shock resistance, creep resistance, and oxidation resistance compared to other CMCs. They are tough, although their constituents are intrinsically brittle, when the fibermatrix bonding is properly optimized through the use of a thin interphase deposited on the fibers prior to the infiltration of the matrix. They display good mechanical properties at high temperatures when prepared from stable fibers, as well as a high thermal conductivity if their residual porosity is low enough. The matrix composition can also be tailored to improve the oxidation resistance of the composites. Replacing the super alloys by light, tough, refractory and creep resistant SiC-matrix composites will permit a significant increase of service temperature and hence an increase of the engine efficiency, a reduction of the NOx/CO emission (through an optimization of the fuel/air ratio), a simplification of the part design and a weight saving (typically, 30–50%). However, their use still raises a number of questions dealing with their durability, reliability, manufacture, design and cost. Presently, the development of SiC-matrix composites is limited mostly to non-rotating parts including combustor liners, after-burner components (exhaust cone and flame holder) and exhaust nozzles (outer and inner flaps) in military aero jet engines, as well as combustor liners of large size in stationary gas turbine for electrical power/steam cogeneration. The GE Rolls-Royce Fighter Engine Team's F136 development engine for the Joint Strike Fighter (JSF) contains third-stage, low-pressure turbine vanes made by GE from CMCs. In summary, although substantial progress has been made, significant risks and challenges still remain before these composites can be commercialized for gas turbine components. The reader is referred to an overview on design, preparation and properties of non-oxide CMCs for application in gas turbine engines (Naslain, 2004). The SiC have thermal conductivity is 26.3 W/(m-K). The SiC interior coated on combustion chamber liner.

4.1.1 Production of SiC

The most common forms of SiC include powders, fibers, whiskers, coatings and single crystals. There are several methods to produce SiC depending on the product form desired and its application. Purity of the product imposes certain restrictions on the selection of the method of production. The following methods are used to produce the SiC.

4.1.1.1 POCO Process

The most common forms of SiC include powders, fibers, whiskers, coatings and single crystals. There are several methods to produce SiC depending on the product form desired and its application. Purity of the product imposes certain restrictions on the selection of the method of production. The following is a typical reaction for the generation of SiO gas:

$$SiO2 + C \Leftrightarrow SiO + CO$$

POCO has engineered the process so that SiO gas is transported efficiently from the generation zone to the conversion zone and distributed evenly to ensure uniform conversion. In the conversion zone, the reaction between the SiO and graphite takes place according to the following reaction:

$$SiO + 2\,C \Leftrightarrow SiC + CO$$

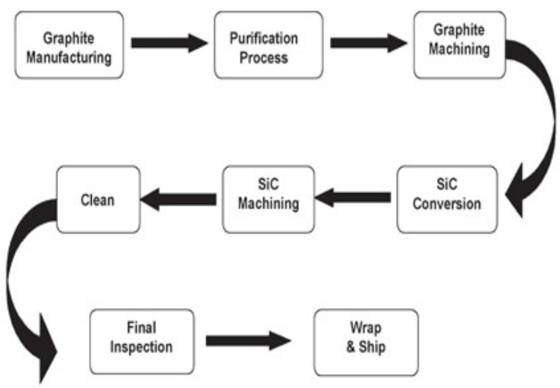


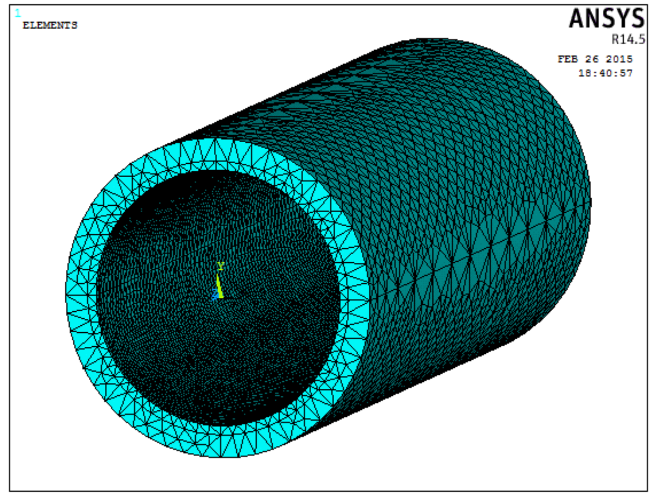
Fig. 2: Flowchart of POCO's SiC Manufacturing process

4.1.2 Properties

- Low density
- High strength
- Low thermal expansion
- High thermal conductivity
- High hardness
- High elastic modulus
- Excellent thermal shock resistance
- Superior chemical inertness

5. ANSYS ANALYSIS OF TITANIUM

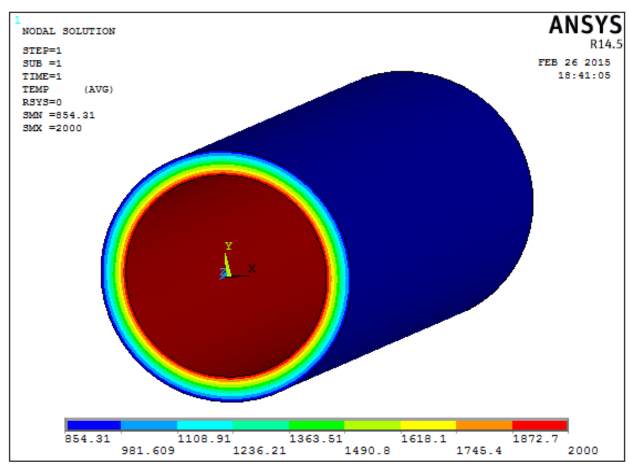
5.1 Mess generation



Triangular node elements have six displacement degrees of freedom, which are placed at the connection nodes. There are two main versions that differ on where the connection nodes are located:

1 The Turner triangle has connection nodes at the corners.
2 The *Veubeke equilibrium triangular* has connection nodes located at the side midpoints.

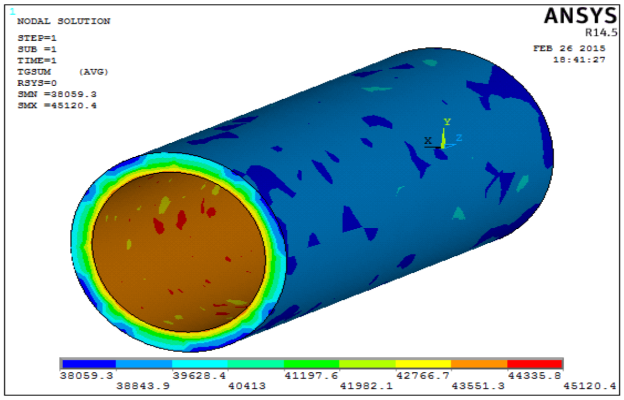
5.2 Nodal temperature



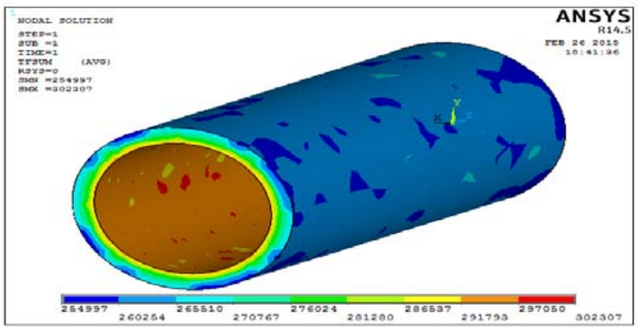
The SiC ceramic coated on combustion chamber liner and it can withstand maximum nodal temperature at 1872.7 degrees.

5.3 Temperature gradient

A temperature gradient is a physical quantity that describes in which direction and at what rate the temperature changes the most rapidly around a particular location. The temperature gradient value is 44335.



5.4 Heat flux



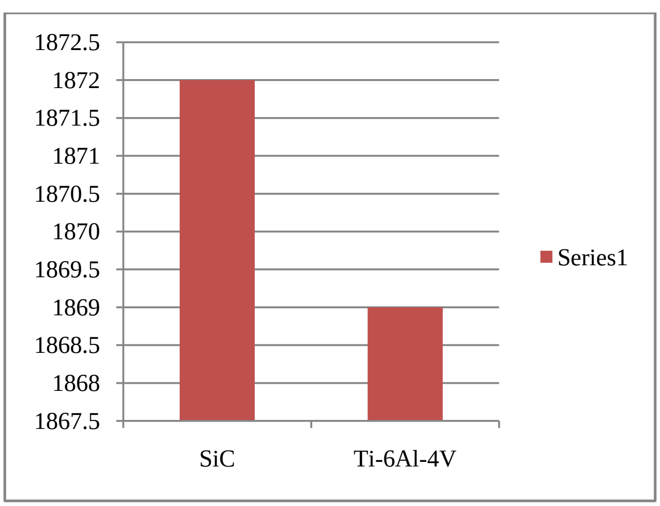
Heat flux or Thermal flux is a rate of heat energy transfer through a given surface, per unit surface. The heat flux value is 30237.

6. TABULATION

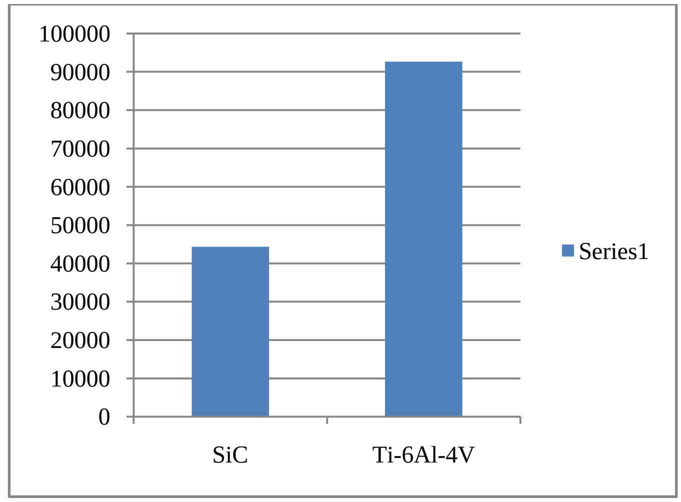
Material	Max. Temp	Temp. Gradient	Heat Flux
SiC	1872OC	44335	302307
Ti-6Al-4V	1869OC	92643	698259

7. GRAPH

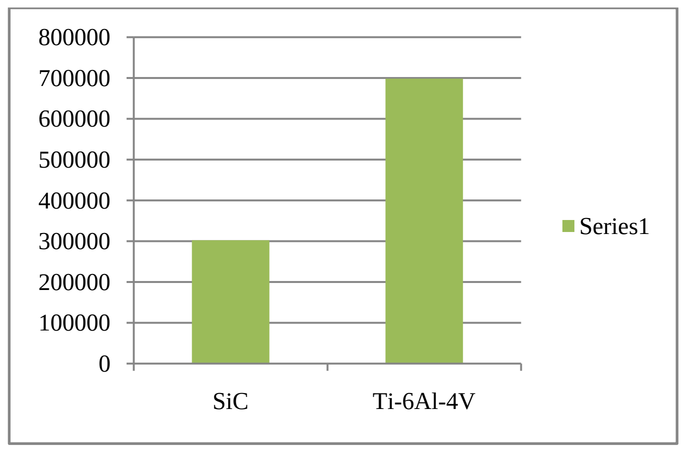
7.1 Nodal temperature



7.2 Temperature gradient



7.3 Heat Flux



8. RESULTS OBTAINED IN ANSYS ANALYSIS

CONTENTS	TITANIUM	SILICON CARBIDE
Thermal conductivity	6.7 W/m-k	26.3 W/m-k
Max. allowable temp	1700^{o}c	1872^{o}c

9. CONCLUSION

From the analysis that is made in the ANSYS. We concluded that, the thermal conductivity of the SiC is more when it is compared to the titanium. We have concluded to say that the thermal properties of the SiC is more than the Titanium.

REFERENCE

[1] J. G. Sun, C. M. Deemer, W. A. Ellingson, and J. Wheeler "NDE Technologies for Ceramic Matrix Composites: Oxide and Non-Oxide". *Energy Technology Division Argonne National Laboratory.*

[2] W. Kowbel*, C. A. Bruce, K.L. Tsou, K. Patel and J.C. Withers "High Thermal Conductivity SiC/SiC Composites for Fusion Applications". *Pacific Northwest National Laboratory, Richland WA 99352.*
[3] Fu Zhenbo, Lin Yuzhen , Li Lin, Zhang Chi "Experimental and numerical studies of a lean-burn internally-staged combustor" *Chinese Society of Aeronautics and Astronautics & Beihang University.*
[4] milan t. jovanović, borislav lukić, zoran mišković, ilija bobić, ivana cvijović, biljana dimčić "processing and some applications of nickel, cobalt and titanium-based alloys". *Institute of Nuclear Sciences "Vinča", 11001 Belgrade, Serbia.*
[5] Kenneth G. Budinski "Tribological properties of titanium alloys" *Eastman Kodak Company, Building 23, 5th Floor, Kodak Park, Rochester, NY I4650 (U.S.A.)*