Liner Material Thermal Analysis for Diesel Engines

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ABSTRACT- It is observed that approximately 50% of the heat input is converted into work in an IC engine particularly in diesel engine . About an equal amount of heat is carried away by cooling system and the remaining heat is lost in exhaust and friction. The main objective of this project is to study the performance of the diesel engine by changing the cylinder wall i.e sleeve material. About 2500°F temperature is produced while combustion process in internal combustion engine with diesel as fuel. In this combustion process approximately 35% of heat is lost through the cylinder walls; heat transfer in excess to the coolant will also reduce the engine performance. The scope of this project is to select proper material for the cylinder liners, so that the heat loss through liner wall in IC engine can be reduced. To achieve this low thermal conductivity materials with required mechanical properties is considered and compared.

Keywords: Wet liners, liner material, Inconel 713 C, grey cast iron, combustion, mechanical properties,CFD

INTRODUCTION

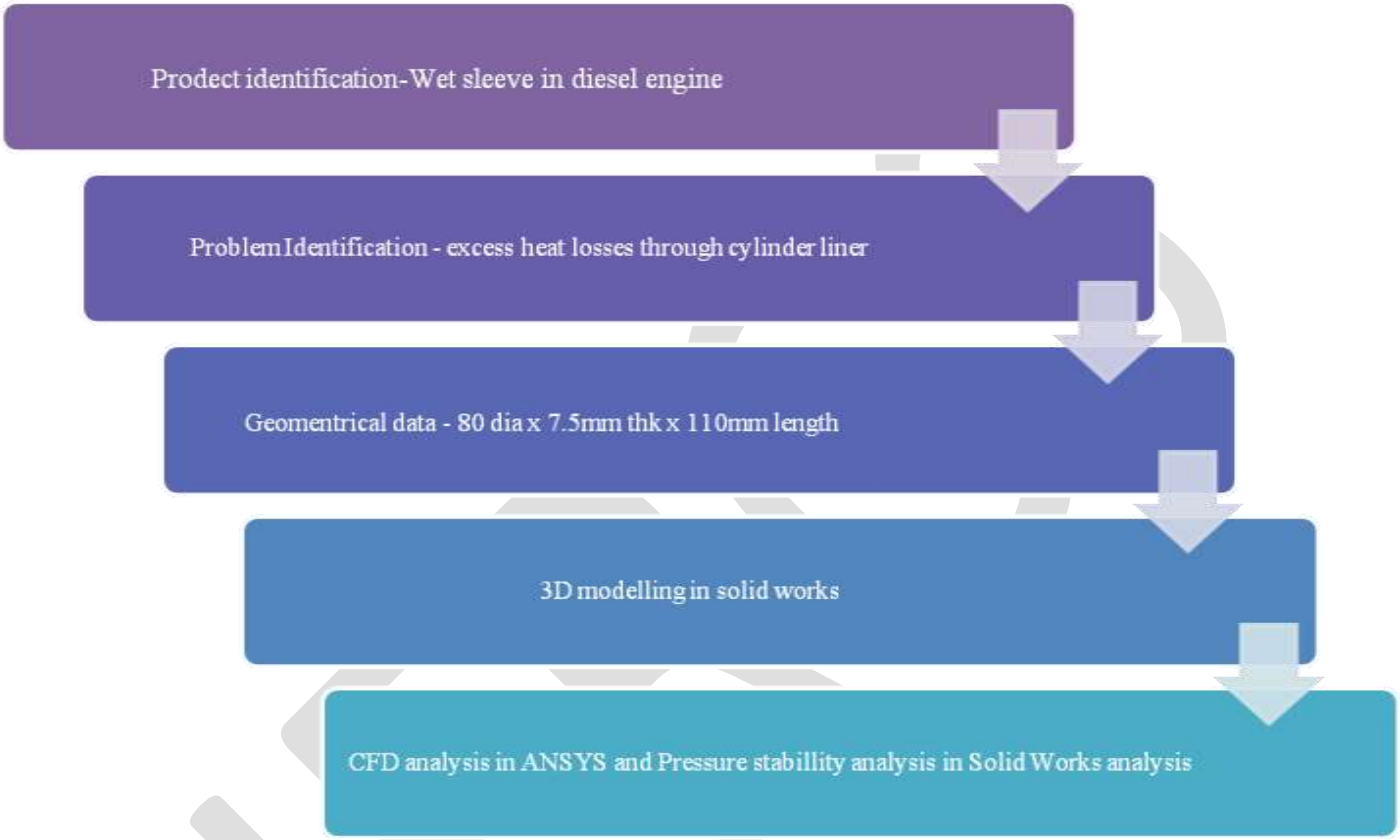
Nowadays the main scope of the automotive industry is to optimize, the engine design, in order to meet the reduction in heat loss and at the same time to maintain the engine performance at high levels. To this scope, computer simulation engine models are extensively used to investigate how each engine parameter affects engine performance and efficiency. As computer power increases, the role of Computational Fluid Dynamic (CFD) models is becoming more and more significant, using detailed sub-models for the various processes and finer grids together with high quality dynamic mesh techniques.

In Internal Combustion engine, heat transfer from the working gas to the cooling system of a conventional Diesel engine accounts for up to 30% of the fuel energy. About 50% of this energy is lost through the piston and 30% through the head. In general, the combustion chamber of an internal combustion engine is formed by cylinder wall, head and piston, where the temperature distributions are different for each surface. Typically, the temperature of each surface is assumed to be a constant, where this is not consistent with the actual situation occurring on the surface of the combustion chamber. A cylinder liner or also known as sleeve is a cylindrical component that is placed in an engine block to form a cylinder. It is an important part because it gives a wear protective surface for piston and piston rings. There are two types of liner which are wet liner and dry liner. Wet liner will contact with coolant while dry liner will contact directly with cylinder block. Among important functions of cylinder liners are to form a sliding surface, to transfer heat and to compress a gas.

For the scope, five material are considered such as Grey cast iron ASTM grade 60, Inconel 713C and Cast SS17-PH,H1100, Carbon steel AISI 1095, Nickel aluminium bronze alloy. The liner 3D modeling has been done in Solid Works 2012. The reduction in heat loss and at the same time to maintain the engine performance at high levels. To this scope, computer simulation engine models are extensively used to investigate how each engine parameter affects engine performance and efficiency. As computer power increases, the role of Computational Fluid Dynamic (CFD) models is becoming more and more significant, using detailed sub-models for the various processes and finer grids together with high quality dynamic mesh techniques.

METHODOLOGY

Methodologies of this study starts with the product selection (wet liners) and continue with problem identification it refers to the problem in excess amount of heat loss through liners, collection of geometric data from an already existing diesel engine cylinder wet liners and goes to creation of model using solid works software finally it ends with the CFD analysis to optimize



PROBLEM IDENTIFICATION

Almost about 25 to 35 percentages of chemical energy in internal combustion engines ,at best can transform in the thermal energy into mechanical energy, about 35 percent of the heat generated is lost to the cooling medium, remainder being dissipated through exhaust and lubricating oil.

GEOMENTRICAL DATA & MODELLING

Geometrical Data

For the scope a 5bhp four stroke Diesel engine with direct injection system is selected with the compression ratio of 16.5:1 with 1500rpm. The bore and stroke length is 80mm X 110mm and medium of cooling is water.

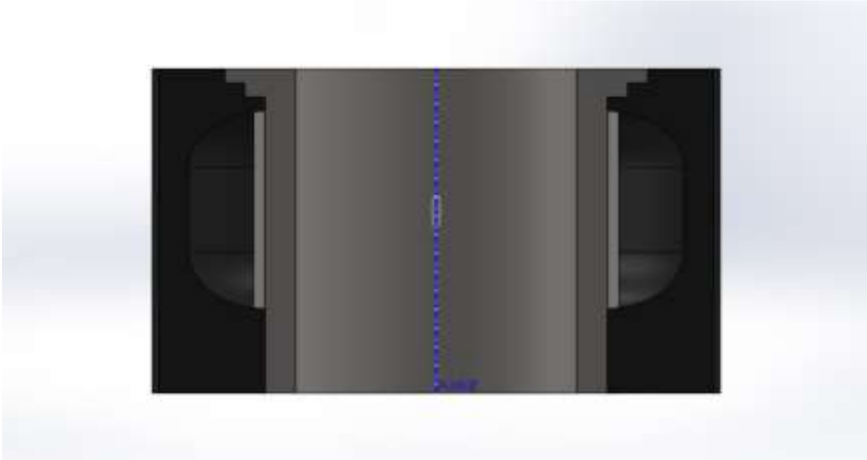


Fig 1 : Section view of Cylinder wet liner with cylinder

3D modeling

Modeling of cylinder wet liner are done in solid works, when compared to other software solid works modeling are more user-friendly The Cylinder liner with 80mm inner dia with 7.5mm thickness are considered. Since it is wet liners the coolant passage width is taken as 19 mm and the length is 75 percentage of stroke length which is 85mm

Fig 2 : 3D view of cylinder liner in solid works

MATERIAL PROPERTIES

The aim of this project is to find the alternate material for the internal combustion engine cylinder liners, so that the engine heat loss in the cylinder liner will reduce considerably and performance of the engine will increase. For these purpose similar materials (Grey cast-iron Grade60, Cast SS17, Inconel 713C,Carbon steel AISI 1095,Nickel Aluminium bronze alloy) with considering the thermal conductivity and working temperature has been.

Grey CI grade 60

- Density - 7100 Kg/m^3
- Hardness - 250 HV
- Tensile Strength - 430 Mpa
- Yield Strength - 276 Mpa
- Youngs Modulus - 206 Gpa
- Max service temperature - 551 °C
- Thermal conductivity - 46 W/mK

Inconel 713C

- Density - 8000 Kg/m^3
- Hardness - 420 HV
- Tensile Strength - 990 Mpa
- Yield Strength - 900 Mpa
- Youngs Modulus - 216 Gpa
- Max service temperature - 980 °C
- Thermal conductivity - 17 W/mK

Cast SS 17 PH,H1100

- Density - 7900 Kg/m^3
- Hardness - 420 HV
- Tensile Strength - 1000 Mpa
- Yield Strength - 914 Mpa
- Youngs Modulus - 207 Gpa
- Max service temperature - 320 °C
- Thermal conductivity - 19 W/mK

Nickel Aluminum Bronze alloy

- Density - 7500 Kg/m^3
- Hardness - 260 HV
- Tensile Strength - 660 Mpa
- Yield Strength - 360 Mpa
- Youngs Modulus - 140 Gpa
- Max service temperature - 650 °C
- Thermal conductivity - 42 W/mK

Carbon Steel AISI 1095

- Density - 7500 Kg/m^3
- Hardness - 260 HV
- Tensile Strength - 660 Mpa
- Yield Strength - 360 Mpa
- Youngs Modulus - 140 Gpa
- Max service temperature - 650 °C
- Thermal conductivity - 50 W/mK

CFD ANALYSIS

CFD analysis is carried out to optimize which material will transfer less heat energy to the to the surrounding by means of the following steps.

1) **Model Creation**
   The Model is created in Solid works for the above discussed dimensions and it is imported in ANSYS.

2) **Mesh Generation**
   After importing the model to the ANSYS, fine meshing is done, the component 2D view and right side of the component is considered for meshing, this is done in order to reduce the processing time and since the liner is a cylinder shaped any one side can be considered for processing.

3) **Applying boundary conditions**
   After fine meshing is done the boundary conditions are applied to this system, as per the working process there are two similar boundary condition i.e. the linear inside and outer side where the heat transfer from working area to the coolant through conduction and convection. The rest of the boundary conditions are taken from the Materials properties as stated above.

4) **Initialization**
   The solver functioning areas its initialization values in constant working temperature at max 1200 °F and with forced convection to the water.

5) **Solution converged plot**
   In solver stage optimum results computed with the solution converged plot. In the below shows fig's, the solution converged plot, which is taken from ANSYS/CFD is shown for three different materials.

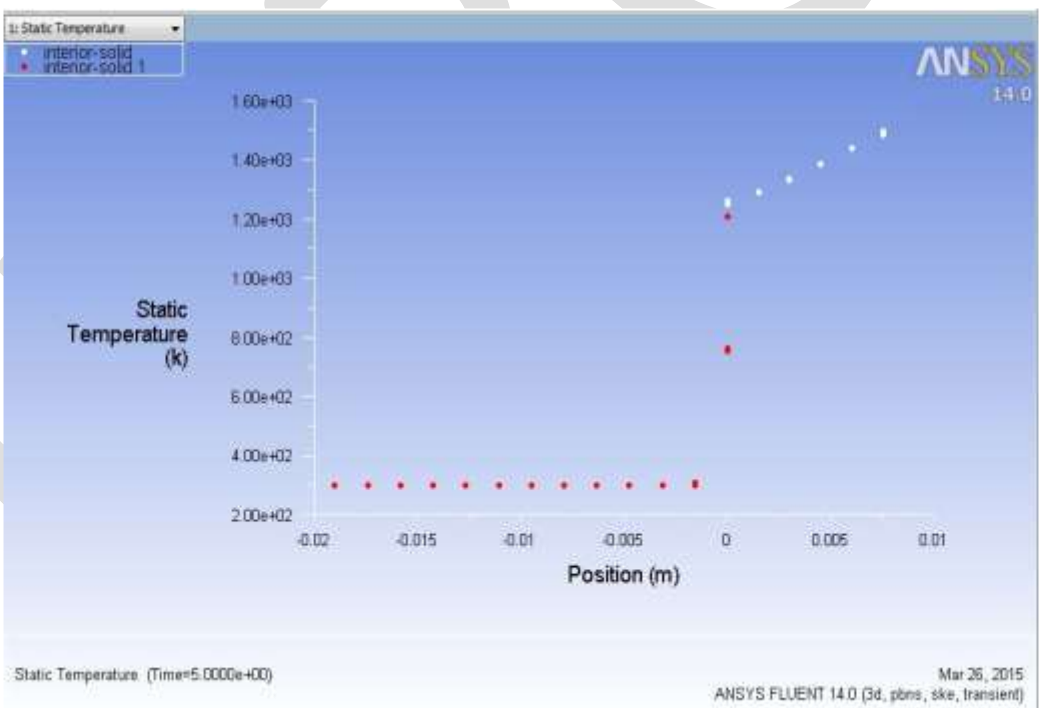


Fig 3 : Grey CI grade 60

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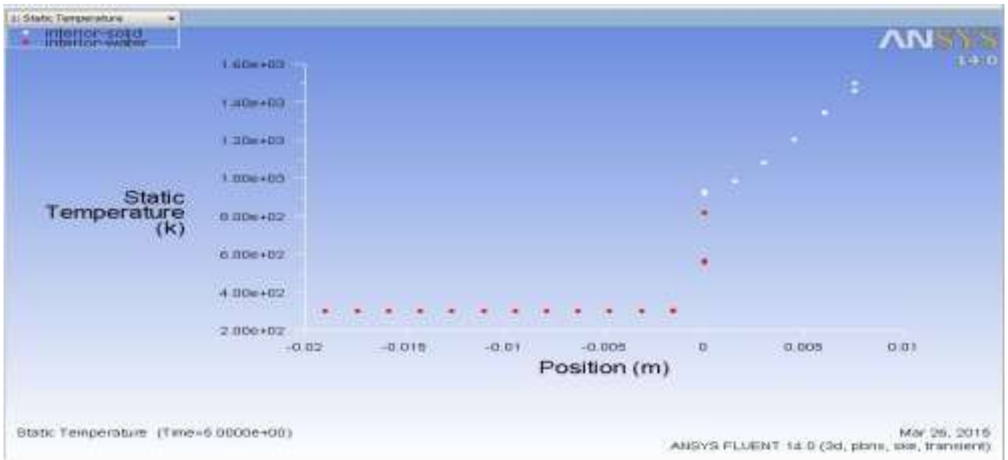

Fig 4 : Cast SS17 PH

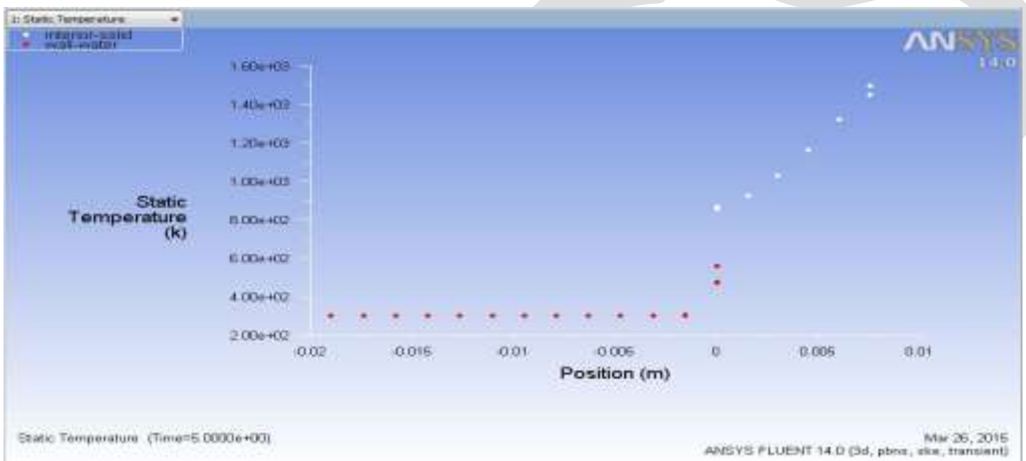

Fig 5 : Inconel 713C

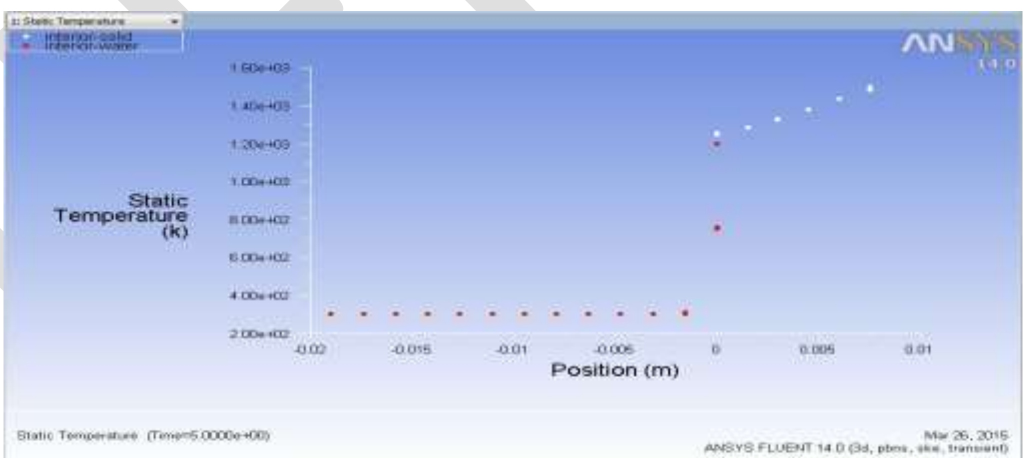

Fig 6 : Carbon steel AISI 1095

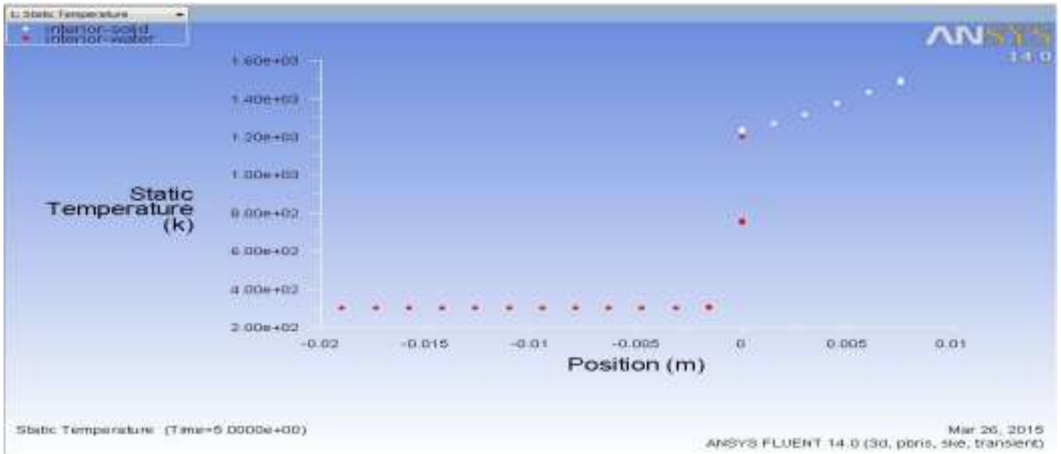

Fig 7 : Nickel Aluminium bronze alloy

From the above plotted result the Inconel 713C material transfer heat in lesser amount when compared to Grey CI grade 60 and Cast SS17PH , Nickel aluminium bronze alloy, Carbon steel AISI 1095materials.

Table 1. Comparison table for Different materials for temperature

Materials	Processing temperature	Convection Temperature
	°K	°K
Grey Cast Iron ASTM 60	1500	1128
Cast SS17 PH	1500	820
Inconel 713C	1500	610
Carbon steel AISI 1095	1500	1100
Nickel Aluminium bronze alloy	1500	1090

RESULTS

In table 1 comparison for five materials for temperature is shown. The counter plot images for component for three different materials are shown below

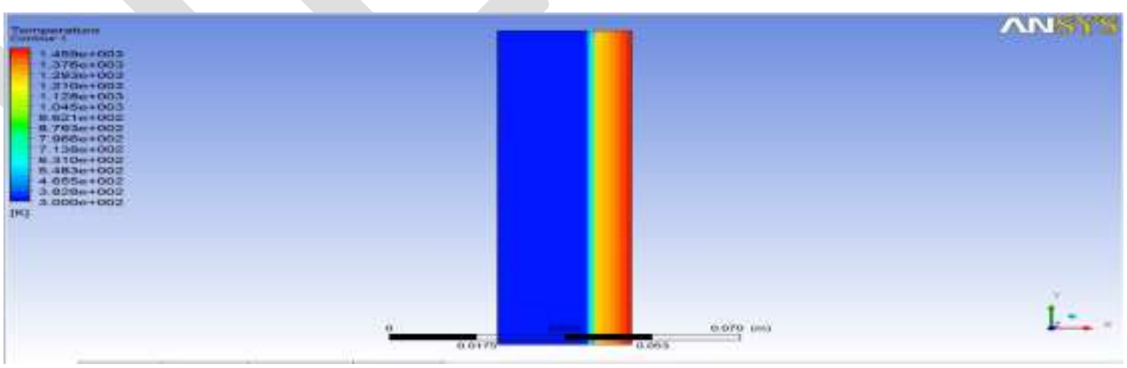

Fig 8 : counterplot for Grey CI grade 60

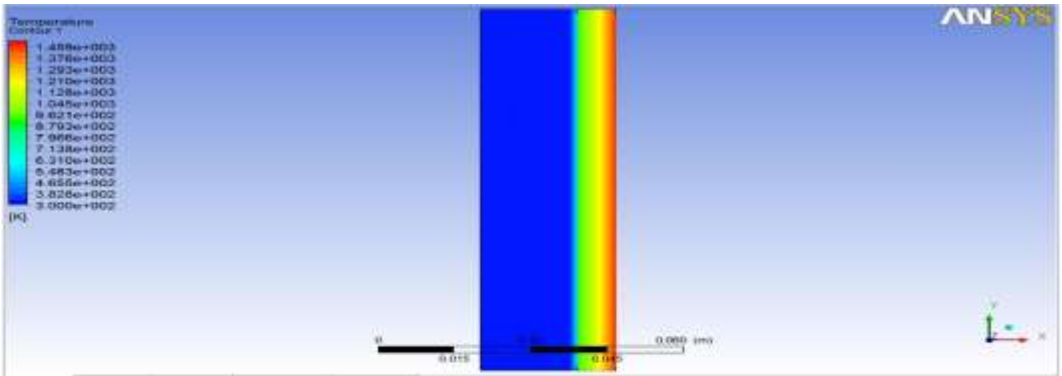

Fig 9 : counterplot for Cast SS17 PH

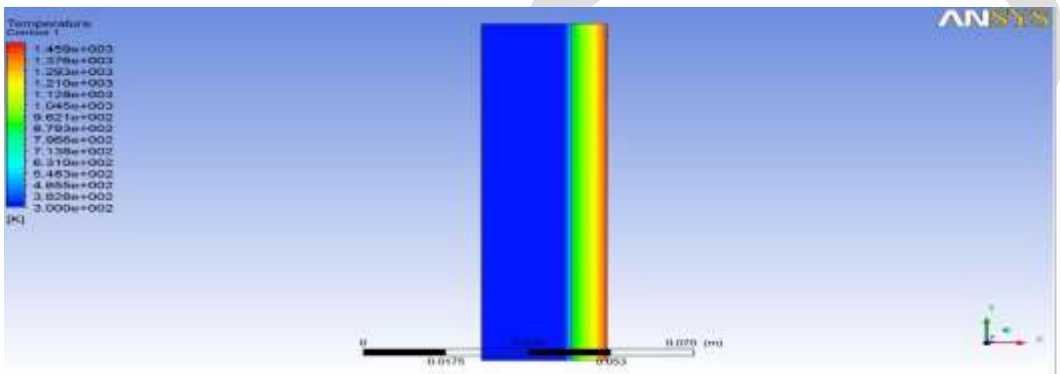

Fig 10 : counterplot for Inconel 713C

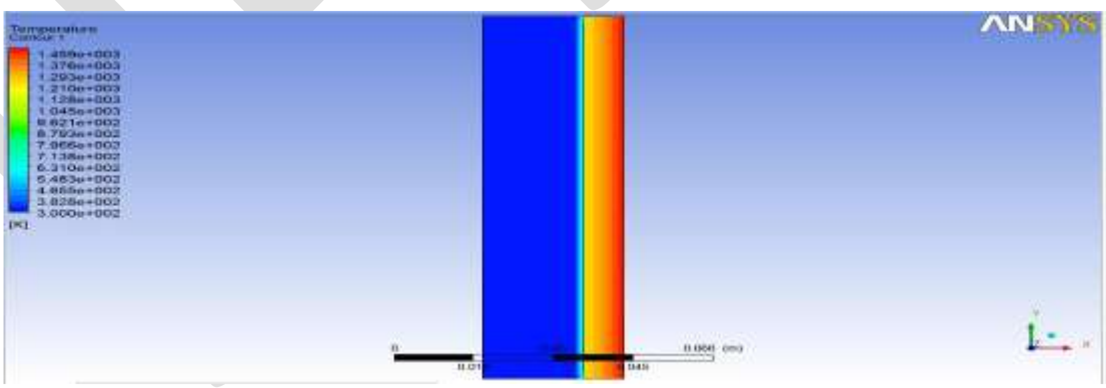

Fig 11 : counterplot for Carbon steel AISI 1095

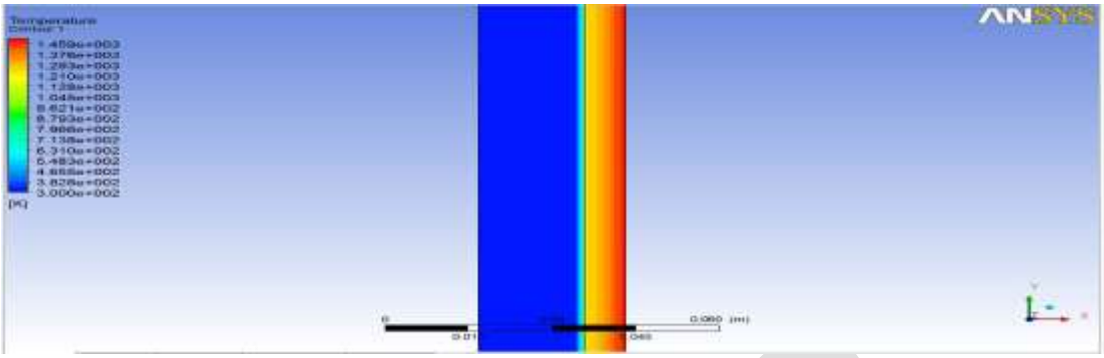

Fig 12 : counterplot for Nickel Aluminium bronze alloy

From the above fig's its is shown that the temperature distribution for Inconel 713C is minimum when compared to other two materials.

Table 2. Table of Mechanical and Thermal factors

Materials		Unit	Grey CastIron ASTM grade 60	Inconel 713C	Carbon steel AISI 1095	Nickel Aluminium bronze alloy	Cast SS17 PH
Mechanical factors	Tensile Strength	Mpa	430	990	1070	660	1000
	Yeild Strength	Mpa	276	900	635	360	914
	Youngs Modulus	Gpa	206	216	215	140	207
Thermal factors	Thermal Conductivity	W/mK	46	17	50	42	19
	Maximum service temperature	°C	551	982	1465	1100	320

Mechanical Factors

The normal operating pressure is around 5 Mpa to 9 Mpa, but this normal operating pressure depends on air fuel mixture also. In some extreme conditions, the pressure may also exceed 12 Mpa. So it is important that the cylinder should withstand the high pressure

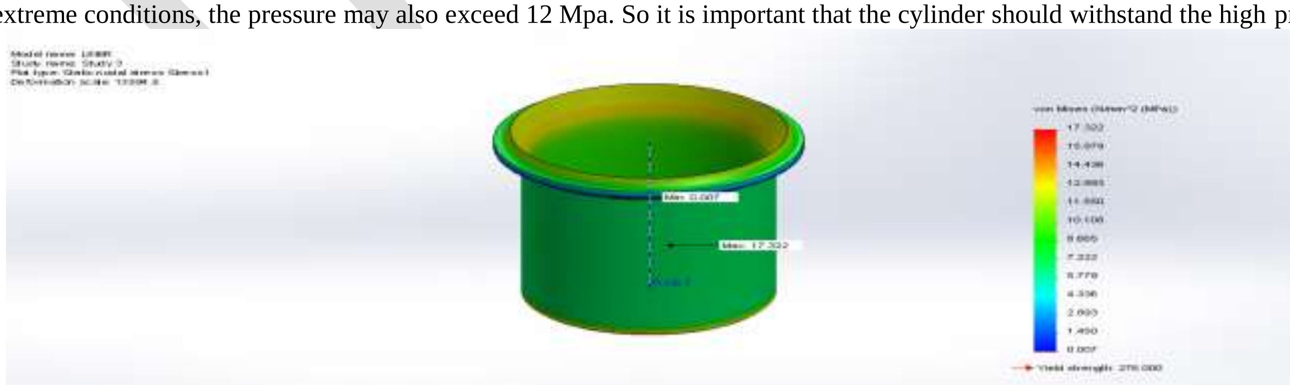

Fig 13 : Mechanical Factors for Grey cast iron ASTM 60

Fig 14 : Mechanical Factors for Cast SS17 PH

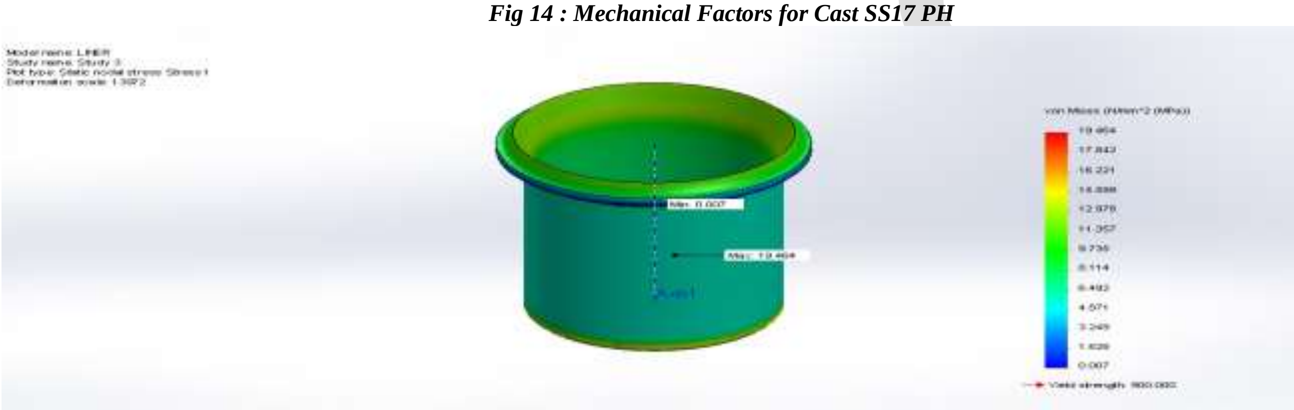

Fig 15 : Mechanical Factors for Inconel 713C

Fig 16 : Mechanical Factors for Carbon steel AISI 1095

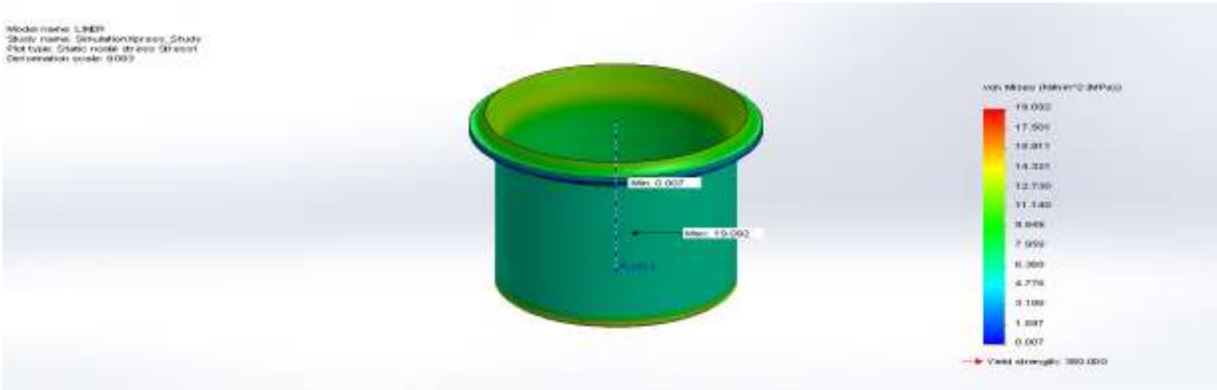

Fig 17 : Mechanical Factors for Nickel aluminium bronze alloy

The pressure analysis is done in solidworks 2012 for the selected materials and the result are tabulated below. According to the tabulation all the material is capable of withstanding the 12.5 Mpa maximum pressure. But when compared the thermal analysis also, then Inconel 713C is best suited material for liners.

Table 3. Result of minimum and maximum pressure

Materials	Minimum Mpa	Maximum Mpa
Grey cast-iron ASTM 60	0.0073	17.32
Cast SS17 PH H1100	0.0069	18.36
Inconel 713C	0.0065	19.46
Carbon steel AISI 1095	0.0070	18.011
Nickel Aluminium bronze alloy	0.0071	19.092

CONCLUSION AND DISCUSSION

1) Mechanical factors

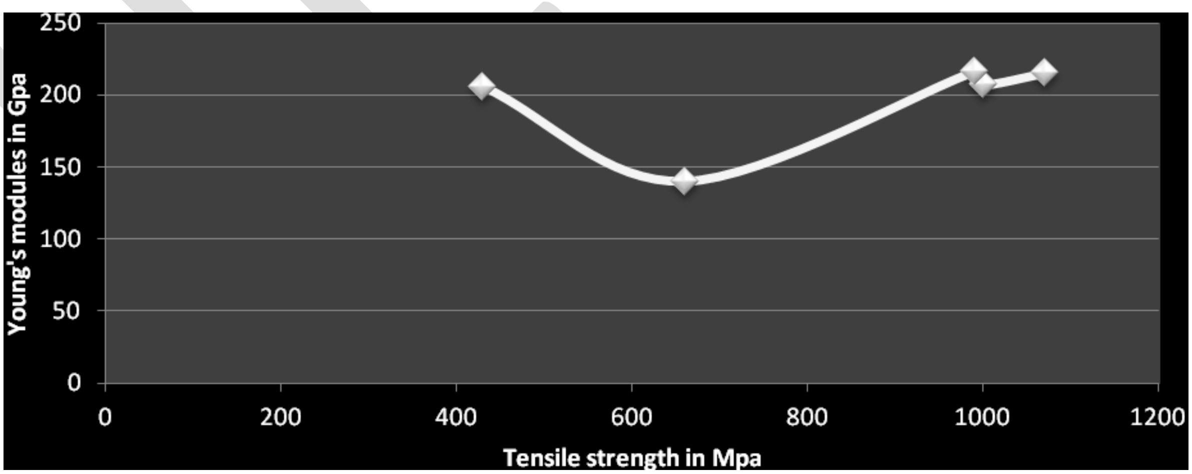

Fig 18 : Youngs modulus Vs Tensile strength

From the above graph and tabulation the tensile strength of materials Inconel 713C and carbon steel 1095 is higher than the grey cast iron Grade 60, nickel aluminum bronze alloy, and Cast ss17 PH, H1100 materials. So it is well shown that both the Carbon Steel and Inconel 713C can withstand the high pressure.

2) Thermal factors

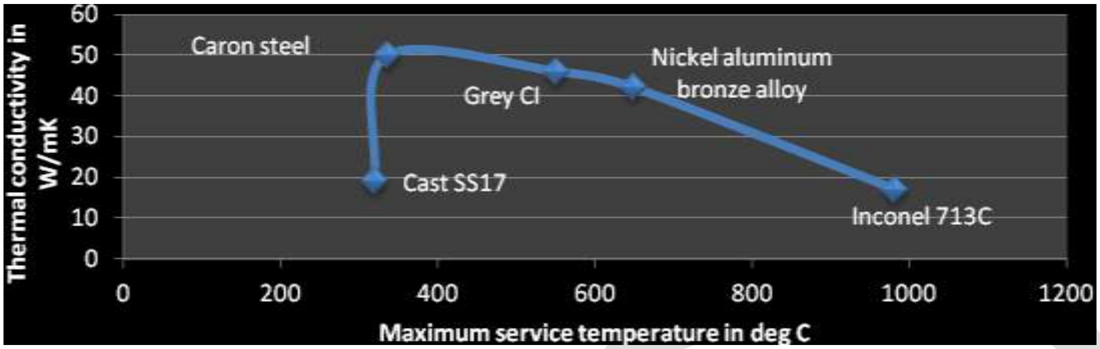

Fig 19 : Thermal conductivity Vs Maximum service temperature

It is observed that the operating temperature may vary from 550 °K to 1700 °K, so the material with higher service temperature can used. From the above graph it is shown that the Inconel 713C material has the operating temperature 850 to 980 °C with thermal conductivity of 17 W/mK, therefore Inconel 713C material will transfer the lesser amount of heat when compared to other materials.

It is concluded based on the above analysis that the Inconel 713C material can transfer lesser amount of heat energy, that means the excess heat energy may be converted into work done. In the mean while it should be noted that the other important component of the engine like piston, connecting rod ,cylinder head, etc should also be considerably designed.

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