DESIGN AND ANALYSIS OF PISTON IN HYDROGEN FUELED INTERNAL COMBUSTION ENGINE

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ABSTRACT

Hydrogen is a very efficient and clean fuel. Its combustion will produce no greenhouse gases, no ozone layer depleting chemicals, and little or no acid rain ingredients and pollution. In reciprocating piston engines or gas turbines of automobiles or aircraft. At the high reaction temperatures, which arise in such places, the oxygen and nitrogen in the air can combine to form nitrogen oxide. Energy stored in hydrogen would be available at any time and at any place on Earth.

To obtain a piston design with vanadium steel as the piston material and a computational model that incorporates the thermal aspects of hydrogen fueled internal combustion engine. The presence of cooling is modeled by assigning convection coefficient on cooling jacket. Material information and isotropic material properties are taken from published report. The transient heat transfer analysis is done for the instant of combustion. The model is validated by comparing the computed maximum temperature at the piston surface with the published result. The computed temperature gradient at the crucial parts are plotted and discussed. It has been found that the critical component likely suffered from thermal fatigue was the exhaust port near the cylinder head and the materials used to construct the engine parts strongly influenced the temperature distribution in the engine. The model is capable to analyze heat transfer in the engine reasonably and efficiently.

To design and analysis the piston with vanadium steel as the piston material for the hydrogen fueled internal combustion engine and compare it with the existing aluminium silicon alloy piston of hydrogen fueled internal combustion engine by PRO-E and Ansys software. The model would be useful to find out the information such as the temperature distribution, localized temperature, and critical part of the engine where thermal damage may occur. This analysis will be helpful for improving the piston materials for hydrogen fueled Internal Combustion engine.

Keyword: - *Pollution, Oxygen, Nitrogen, Temperature, Piston, Aluminium*

1. INTRODUCTION

Fossil fuels are not renewable. In addition, the pollutants emitted by fossil energy systems (e.g. CO, CO2, CnHm, SOx, NOx, radioactivity, heavy metals, ashes, etc.) are greater and more damaging than those that might be produced by a renewable based hydrogen energy system (Winter CJ. 1987). Since the oil crisis of 1973, considerable progress has been made in the search for alternative energy sources. A long term goal of planet. Many engineers and scientists agree that the solution to all of these global problems would be to replace the existing fossil fuel system with the clean hydrogen energy system. Hydrogen is a very efficient and clean fuel. Its combustion will produce no greenhouse gases, no ozone layer depleting chemicals, and little or no acid rain ingredients and pollution. Fossil fuels possess very useful properties not shared by non- energy research has been the seek for a method to produce hydrogen fuel economically by splitting water using sunlight as the primary energy source.

The use of hydrogen as an energy carrier is a long term option to reduce CO2 emissions. However, at the present time, hydrogen is not competitive with other energy carriers.

Energy, economic and political crises, as well as the health of humans, animals and plant life, are all critical concerns. There is an urgent need of implementing the hydrogen technology. Solar hydrogen is a clean energy carrier. Electrolytic hydrogen is made from water and becomes water again.

In reciprocating piston engines or gas turbines of automobiles or aircraft. At the higher action temperatures, which arise in such places, the oxygen and nitrogen in the air can combine to form nitrogen oxide. Energy stored in hydrogen would be available at any time and at any place on Earth.

Solar hydrogen has no need for the carbon atom, which makes the hydrocarbons almost infinitely storable at room temperatures, but is also the reason for their negative ecological impact. Hydrogen is a carbon-free fuel, which oxidizes to water as a combustion product. The generated water becomes, together with renewable primary energy for splitting it, a source of clean and abundant energy in a carbon-free, natural cycle (Gretz J. 1992).

The economies of rich nations and the lifestyle of most of their residents depend on cars and light trucks. These vehicles contribute most of the carbon monoxide (CO), carbon dioxide (CO2), volatile organic compounds (hydrocarbons, HC), and nitrogen oxides (NOx) emitted in cities. Importance goes well beyond the direct consumer expenditures and indirect (support) expenditures, such as roads, suburbs, oil wells, refineries, and service stations. Technology developments have created several challengers to the gasoline powered, internal combustion engine (ICE) vehicle. Short of some wonderful new technology emerging, the evolving gasoline fueled ICE will continue to be the choice of consumers and automakers.

A brief statement and discussion of the positive features of hydrogen as a fuel and the associated limitations that are raising difficulties in its wide application as an engine fuel are both necessary and needed. Hydrogen gas has been in wide use as a fuel for quite a long time (Erren RA, Campbell WH. 1933).

Obviously, there is a need to be aware of what has been achieved in this field while focusing both on the attractive features as well as the potential limitations and associated drawbacks that need to be overcome for hydrogen to become a widely accepted and used fuel for engine applications. Hydrogen was also considered for use in powering airship engines. The gas used for buoyancy could also be used for fuel. Even if helium were used to provide lift, hydrogen gas could be used to supply additional buoyancy if stored at low pressure in a light container.

2.1 MODELING

In this analysis the piston model is created by using the PRO/E software. Pro/ENGINEER is a parametric, integrated 3D CAD/CAM/CAE solution created by Parametric Technology Corporation (PTC). It was the first to market with parametric, feature-based, associative solid modeling software. The application runs on Windows platform, and provides solid modeling, assembly modeling and drafting, finite element analysis, and NC and tooling functionality for mechanical engineers. Fig. 2.1 shows the designed piston model.

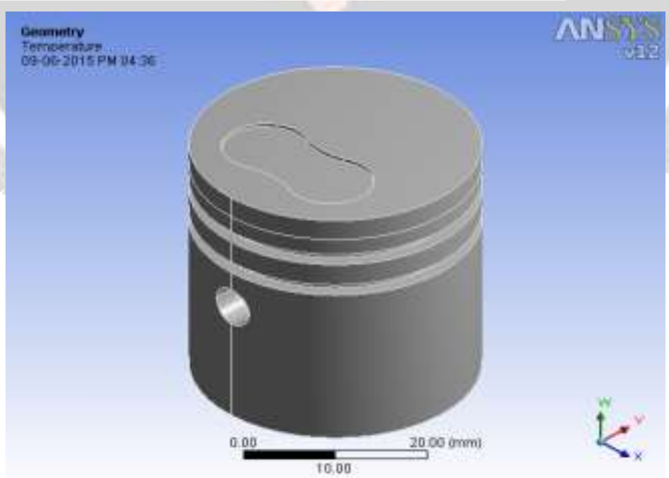

Fig.2.1 Piston Model

2.2 MESHING

The collection of nodes and elements form the finite element mesh. Each element is of simple shape for which the finite element program has information to write the governing equations in the form of stiffness matrix.

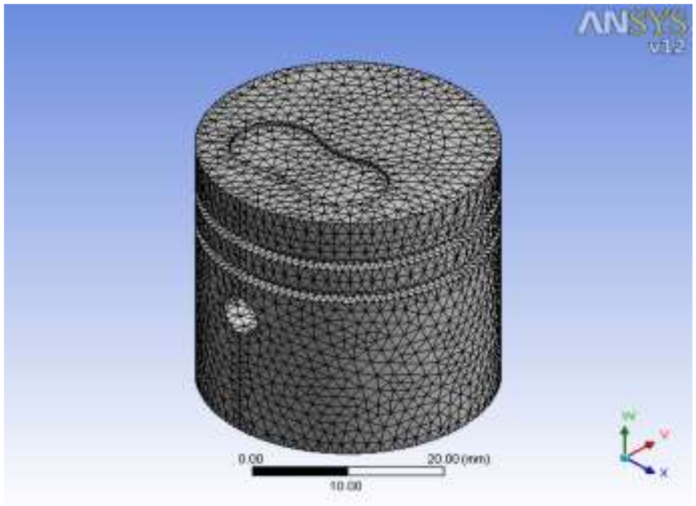

Fig.2.2 Meshing Model

The unknowns at each element are the stress and displacement at the node points, which are the points at which the elements are connected. The finite element program will assemble the stiffness matrix for the entire model. This stiffness matrix is solved for the unknown displacements, stress given the known forces and boundary conditions. From the displacements at the nodes, the stress in each element can be calculated.

Table 2.1 : Material Properties

Material Properties	**Aluminium Silicon Alloy**	**Vanadium Steel**
Tensile Strength(Mpa)	165-415	490-760
Yield Strength(Mpa)	90-345	215-505
Melting Point(^oC)	660	1910
Young's Modulus(Mpa)	70000	138000
Thermal expansion(10^{-6}/K)	13.7	8.6

3.1 STEADY STATE THERMAL ANALYSIS USING ALUMINIUM SILICON ALLOY AS THE PISTON MATERIAL

3.1.1 Temperature

Since the melting point and tensile strength for aluminium silicon alloy is lesser compared to vanadium steel, it cannot withstand higher temperatures. The fastest burning characteristics of hydrogen fuel cause a very high temperature rise at the time of ignition. The existing aluminium silicon alloy can withstand this temperature but it will reduce the piston life. An analysis for temperature by Ansys software is done for the existing aluminium silicon alloy and the results are given below.

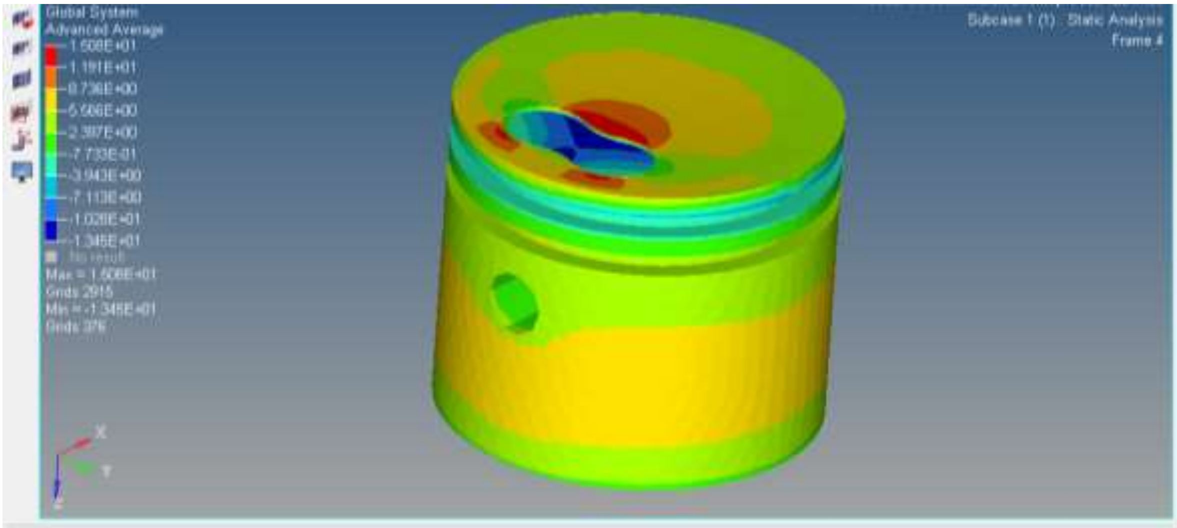

Fig. 3.1 Steady State Thermal Analysis- Temperature

3.1.2 Heat flux

The total convective heat flux for the aluminium silicon alloy piston is obtained by using ansys software and is shown below. Heat flux or thermal flux is the rate of heat energy transfer through a given surface. In SI units, heat flux is measured in [W/m^2]. Heat rate is a scalar quantity, while heat flux is a vectorial quantity. To define the heat flux at a certain point in space, one takes the limiting case where the size of the surface becomes infinitesimally small.The total heat flux is found to be higher in aluminium silicon alloy as compared to vanadium steel. The directional heat flux along the x direction is also analyzed using the Ansys software.

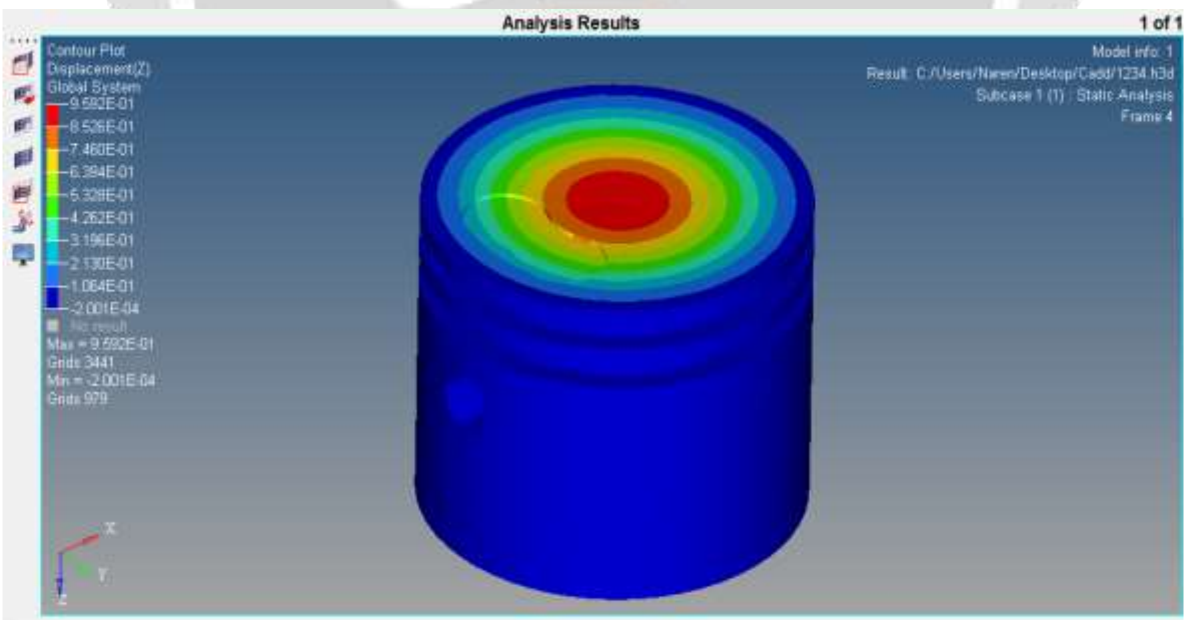

Fig. 3.2 Steady State Thermal Analysis- Total Heat Flux

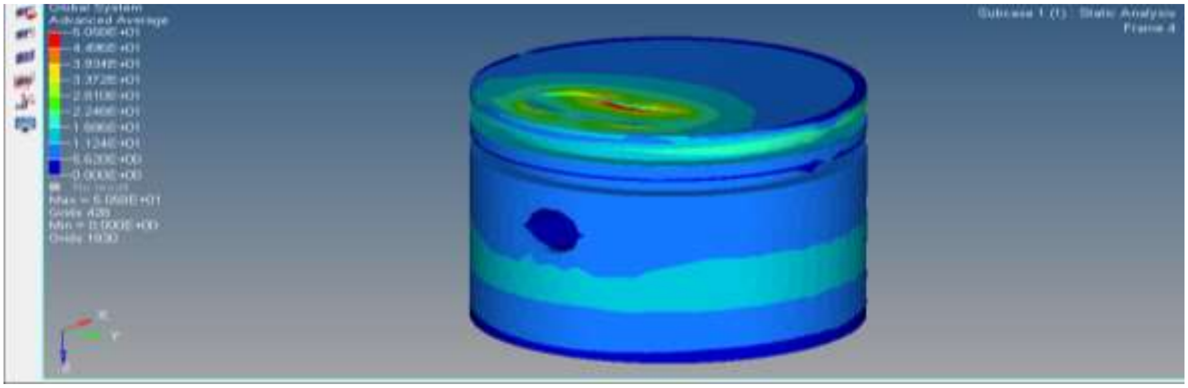

Fig. 3.3 Steady State Thermal Analysis- Directional Heat Flux

3.2 STEADY STATE THERMAL ANALYSIS USING VANADIUM STEEL AS THE PISTON MATERIAL

3.2.1 Temperature

The fastest burning characteristic of hydrogen fuel causes a very high temperature rise at the time of ignition. This high temperature rise may reduce the life of the piston on working. But due to the high melting point, tensile strength and thermal conductivity of the vanadium steel, it can withstand these high temperatures on working which will increase the life of the piston. The modeled piston is analyzed by using ansys software and results are obtained.

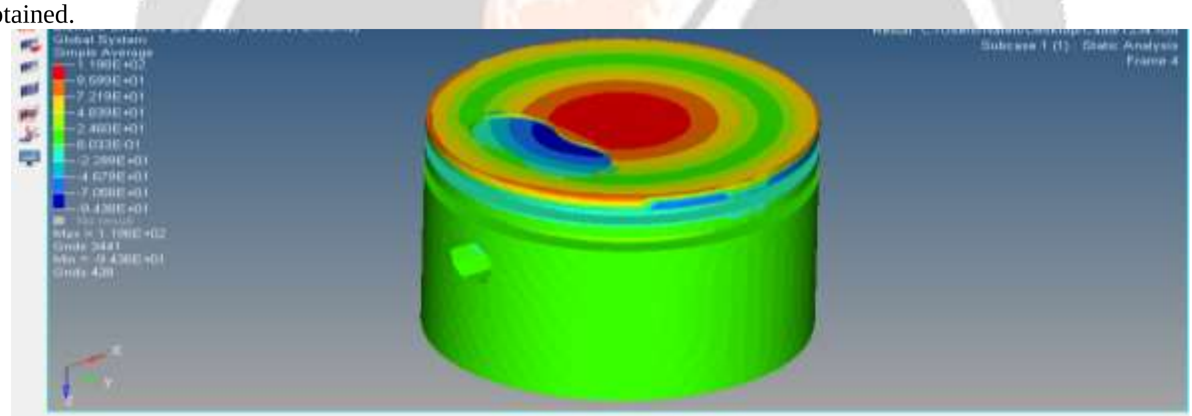

Fig. 3.4 Steady State Thermal Analysis- Temperature

3.2.2 Heat flux

The total convective heat flux for the vanadium steel piston is obtained by using ansys software. The total heat flux is found to be lesser in vanadium steel piston as compared to aluminium silicon alloy piston. The directional heat flux along the x direction is also analyzed using the ansys software.

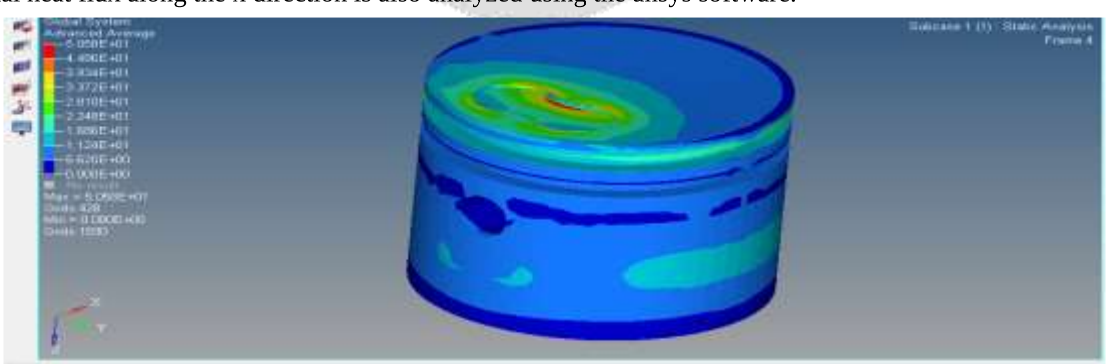

Fig. 3.5 Steady State Thermal Analysis- Total Heat Flux

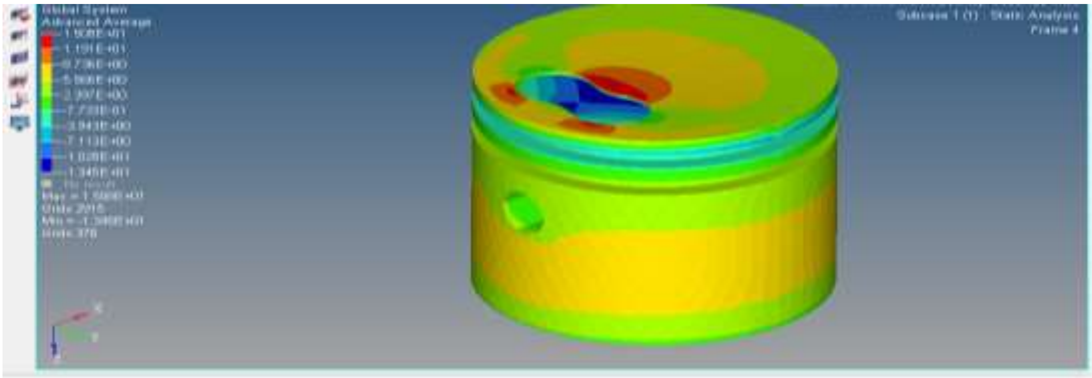

Fig. 3.6 Steady State Thermal Analysis- Directional Heat Flux

3.3 TEMPERATURE DIFFERENCE BETWEEN AL AND VANADIUM STEEL

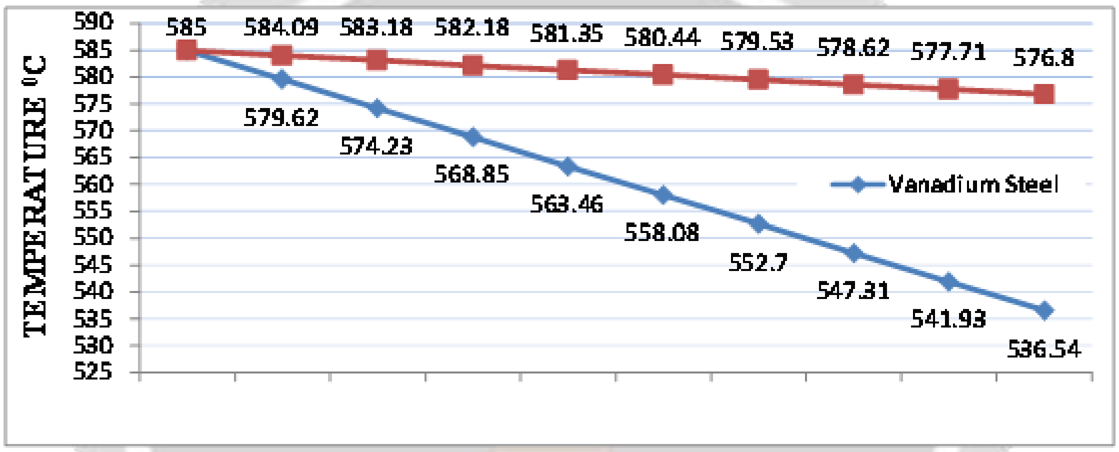

Fig. 3.7 Temperature difference between Al and Vanadium steel

The temperature difference graph shows that the vanadium steel have less temperature distribution throughout the body when compared it with the Aluminium silicon alloy. So, that the Vanadium steel is material is good for the piston when compared to Aluminium silicon alloy.

3.4 TOTAL HEAT FLUX

The rate of heat energy transfer through a given surface is higher in Aluminium silicon alloy and lesser in the Vanadium steel. This shows that the vanadium steel is better than the aluminium silicon alloy.

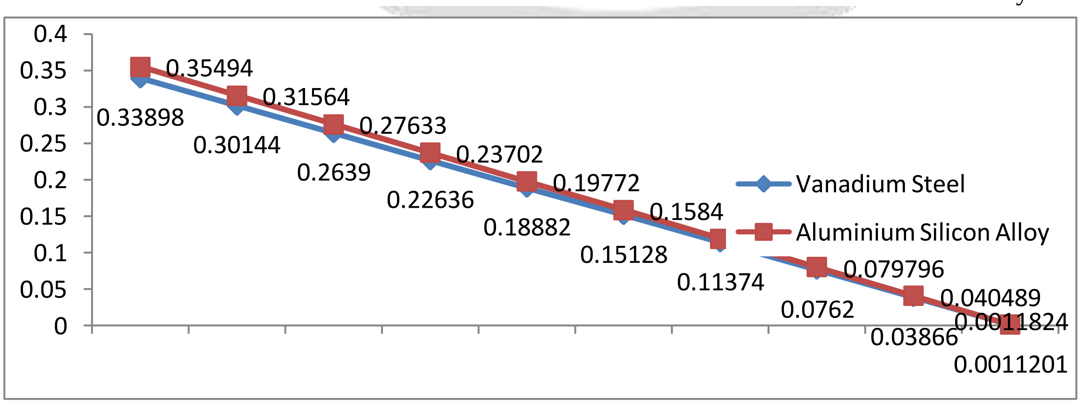

Fig. 3.8 Total Heat Flux

3.5 DIRECTONAL HEAT FLUX

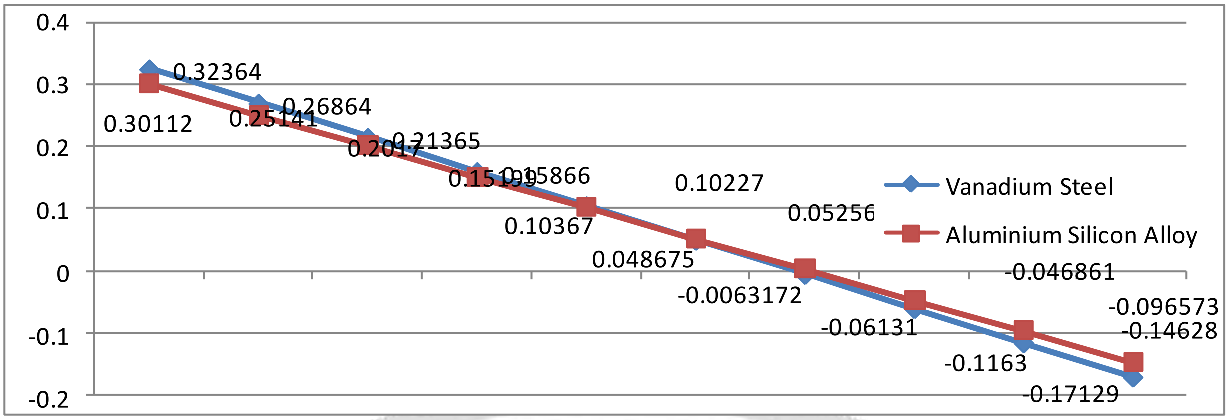

Fig. 3.9 Directional Heat Flux

The directional heat flux of the given two materials is shown in the graph. Thus, the Vanadium steel x – directional heat flux is lesser when compared to the aluminum silicon alloy. Its shows that Vanadium steel is a better material for piston.

4. CONCLUSION

The use of hydrogen as an energy carrier is a long term option to reduce CO2 emissions. However, at the present time, hydrogen is not competitive with other energy carriers. Global utilization of fossil fuels for energy needs is rapidly resulting in critical environmental problems throughout the world. Energy, economic and political crises, as well as the health of humans, animals and plant life, are all critical concerns. There is an urgent need of implementing the hydrogen technology. A worldwide conversion from fossil fuels to hydrogen would eliminate many of the problems and their consequences.

Now a days many manufacturers have introduced hydrogen fueled internal combustion engines as a basis for the environmental problems that are arising in the world today. This work concentrated on the piston design of the hydrogen fueled internal combustion engine. The existing material for the hydrogen engine piston is aluminium silicon alloy of its good material properties. The fastest burning characteristic of hydrogen fuel causes a very high temperature rise at the time of ignition. The existing aluminium silicon alloy can withstand this temperature but it will reduce the piston life. By using vanadium steel instead of aluminium silicon alloy, it can absorb large amount of thermal shock due to its high melting point and tensile strength there by increasing the life of the piston. So due to fast burning characteristics of the hydrogen, Vanadium is the most suitable material for the hydrogen piston design.

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