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Design and Thermal Analysis of Hydrogen Gas Turbine

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ABSTRACT:

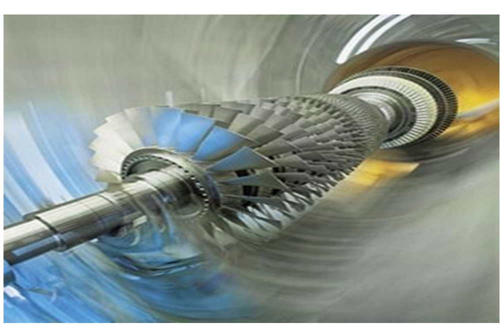
This study takes a look at the design process of the air intake system of the Hydrogen gas Turbine Inlet Manifold. Differences in turbine outputs and applications require different designs of intake-air manifolds in order to achieve the best volumetric efficiency and thus the best turbine performance. In the present work, the flow characteristics of hydrogen gas flowing in various designs of air-intake manifold will be studied. The study is done by three dimensional simulations of the flow of air within two designs of air-intake manifold into the turbine by using commercial CFD software, ANSYS. The simulation results are validated by an experimental study performed using a flow bench. The study reveals that the variations in the geometry of the air-intake system can result in a difference of up to 20% in the mass flow rate of air entering the combustion chamber.

The design will be done in a 3D software Catia and analysis carried in FEA software called Ansys.

I. INTRODUCTION

TURBINE

A turbine is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor. Early turbine examples are windmills and water wheels.



Turbine

Gas, steam, and water turbines have a casing around the blades that contains and controls the working fluid. Credit for invention of the steam turbine is given both to the British engineer Sir Charles Parsons (1854–1931), for invention of the reaction turbine and to Swedish engineer Gustaf de Laval (1845–1913), for invention of the impulse turbine. Modern steam turbines frequently employ both reaction and impulse in the same unit, typically varying the degree of reaction and impulse from the blade root to its periphery.

TYPES OF TURBINES

1. **Steam turbines**

These are used for the generation of electricity in thermal power plants, such as plants using coal, fuel oil or nuclear fuel. They were once used to directly drive mechanical devices such as ships propellers (for example the Turbine, the first turbine-powered steam launch) but most such applications now use reduction gears or an intermediate electrical step, where the turbine is used to generate electricity, which then powers an electric motor connected to the mechanical load. Turbo electric ship machinery was particularly popular in the period immediately before and during World War II, primarily due to a lack of sufficient gear-cutting facilities in US and UK shipyards.

2. **Gas turbines**

Gas turbines are sometimes referred to as turbine engines. Such engines usually feature an inlet, fan, compressor, combustor and nozzle in addition to one or more turbines.

3. **Transonic turbine**.

The gas flow in most turbines employed in gas turbine engines remains subsonic throughout the expansion process. In a transonic turbine the gas flow becomes supersonic as it exits the nozzle guide vanes, although the downstream velocities normally become subsonic. Transonic turbines operate at a higher pressure ratio than normal but are usually less efficient and uncommon.

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4. Contra-rotating turbines

With axial turbines, some efficiency advantage can be obtained if a downstream turbine rotates in the opposite direction to an upstream unit. However, the complication can be counter-productive. The design is essentially a multi-stage radial turbine (or pair of 'nested' turbine rotors) offering great efficiency, four times as large heat drop per stage as in the reaction (Parsons) turbine, extremely compact design and the type met particular success in back pressure power plants. However, contrary to other designs, large steam volumes are handled with difficulty and only a combination with axial flow turbines (DUREX) admits the turbine to be built for power greater than ca 50 MW. In marine applications only about 50 turbo-electric units were ordered (of which a considerable amount were finally sold to land plants) during 1917-19, and during 1920-22 a few turbo-mechanic not very successful units were sold. Only a few turbo-electric marine plants were still in use in the late 1960s, while most land plants remain in use 2010.

5. Stator less turbine

Multi-stage turbines have a set of static (meaning stationary) inlet guide vanes that direct the gas flow onto the rotating rotor blades. In a stator-less turbine the gas flow exiting an upstream rotor impinges onto a downstream rotor without an intermediate set of stator vanes (that rearrange the pressure/velocity energy levels of the flow) being encountered.

6. Ceramic turbine

Conventional high-pressure turbine blades (and vanes) are made from nickel based alloys and often utilize intricate internal air-cooling passages to prevent the metal from overheating. In recent years, experimental ceramic blades have been manufactured and tested in gas turbines, with a view to increasing rotor inlet temperatures and/or, possibly, eliminating air cooling. Ceramic blades are more brittle than their metallic counterparts, and carry a greater risk of catastrophic blade failure. This has tended to limit their use in jet engines and gas turbines to the stator (stationary) blades.

7. Shrouded turbine

Many turbine rotor blades have shrouding at the top, which interlocks with that of adjacent blades, to increase damping and thereby reduce blade flutter. In large land-based electricity generation steam turbines, the shrouding is often complemented, especially in the long blades of a low-pressure turbine, with lacing wires. These wires pass through holes drilled in the blades at suitable distances from the blade root and are usually brazed to the blades at the point where they pass through. Lacing wires reduce blade flutter in the central part of the blades. The introduction of lacing wires substantially reduces the instances of blade failure in large or low-pressure turbines.

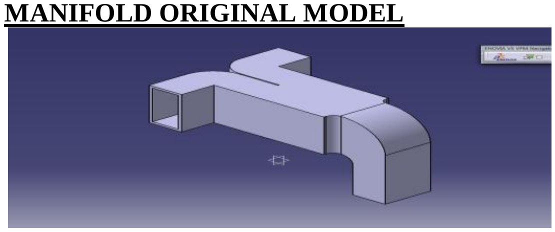
8. Water turbines

a. Pelton turbine, a type of impulse water turbine.
b. Francis turbine, a type of widely used water turbine.
c. Kaplan turbine, a variation of the Francis Turbine.
d. Turgo turbine, a modified form of the Pelton wheel.
e. Cross-flow turbine, also known as Banki-Michell turbine, or Ossberger turbine.

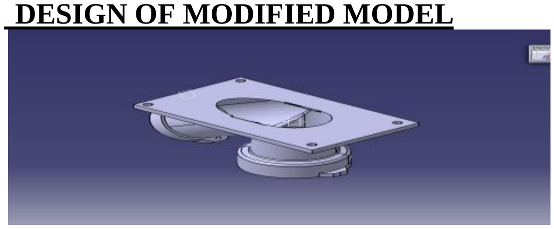
9. Wind turbine

These normally operate as a single stage without nozzle and interstage guide vanes. An exception is the ÉolienneBollée, which has a stator and a rotor.

DESIGN OF HYDROGEN TURBINE INLET MANIFOLD ORIGINAL MODEL

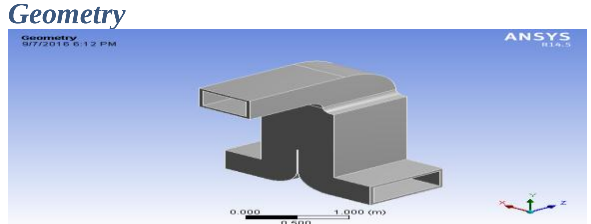


DESIGN OF MODIFIED MODEL

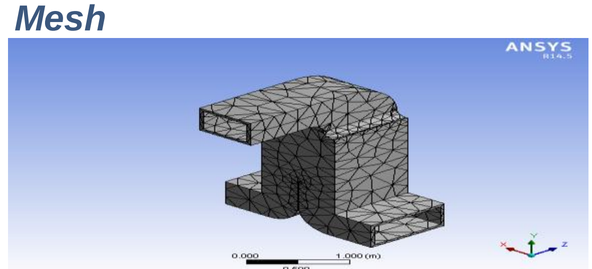


THERMAL ANALYSIS OF ORGINAL MODEL WITH CAST IRON

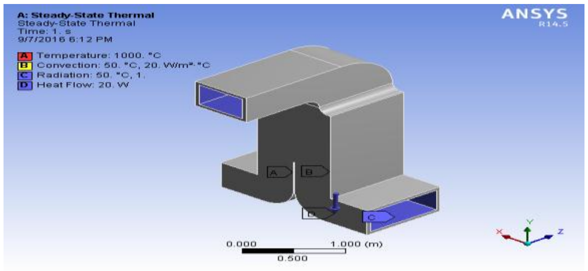
Geometry



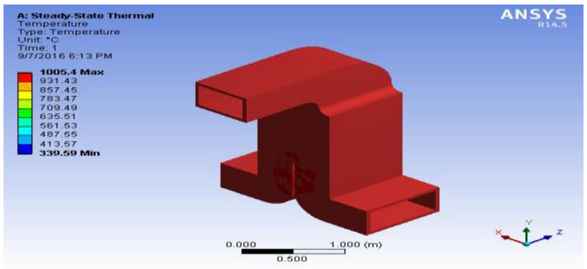
Mesh



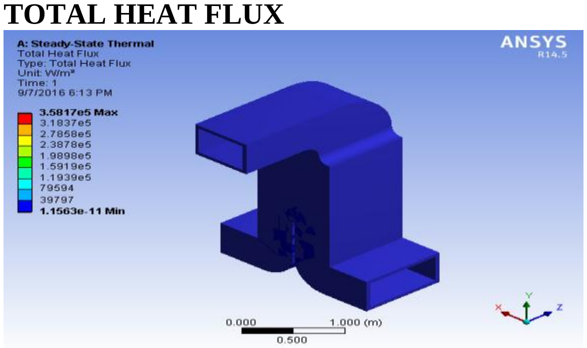
Steady-State Thermal (A5)

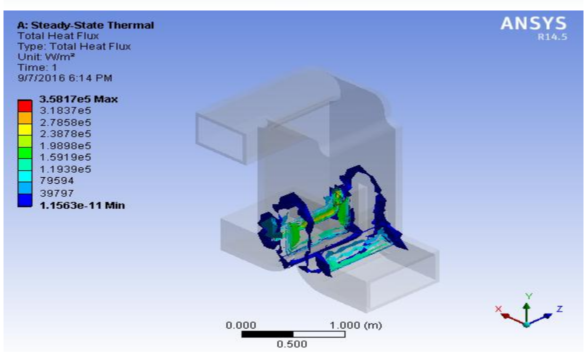


TEMPERATURE

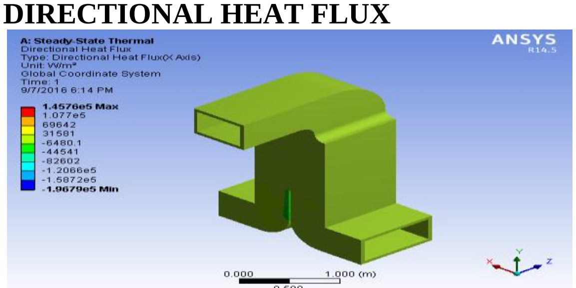


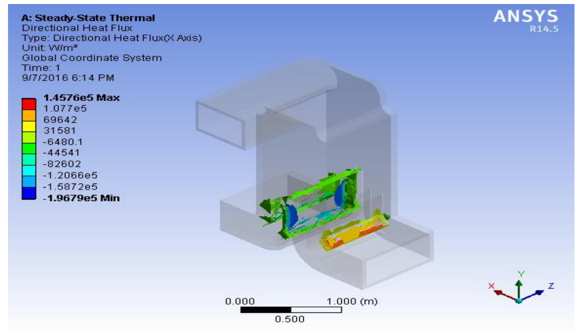
TOTAL HEAT FLUX





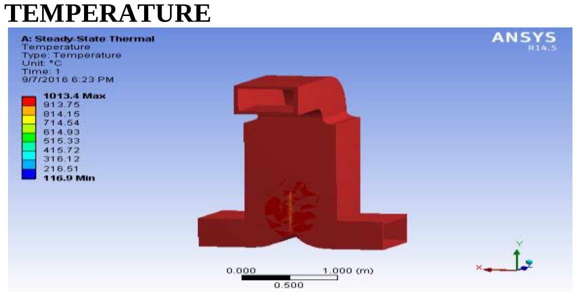
DIRECTIONAL HEAT FLUX



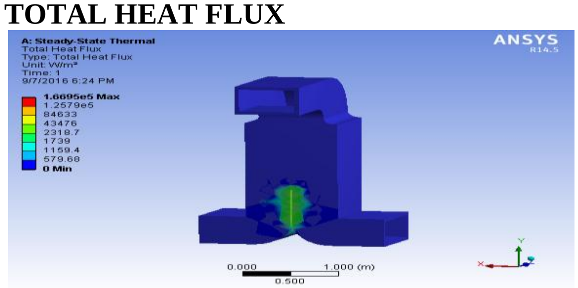


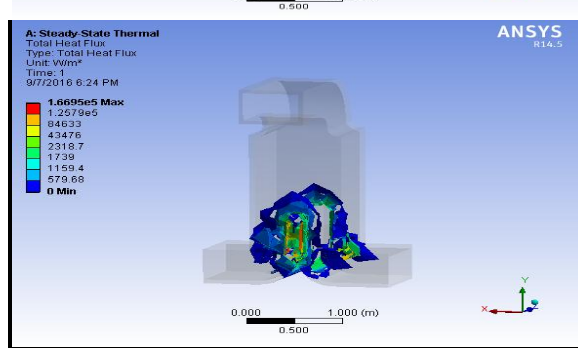
THERMAL ANALYSIS OF ORIGINAL MODEL WITH STAIN LESS STEEL

TEMPERATURE

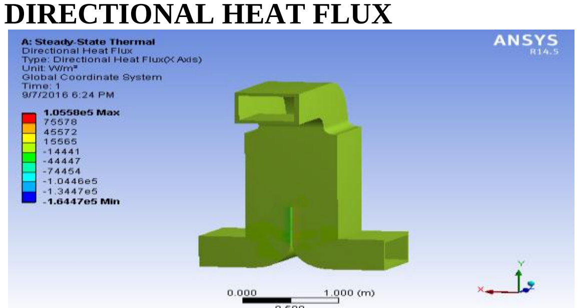


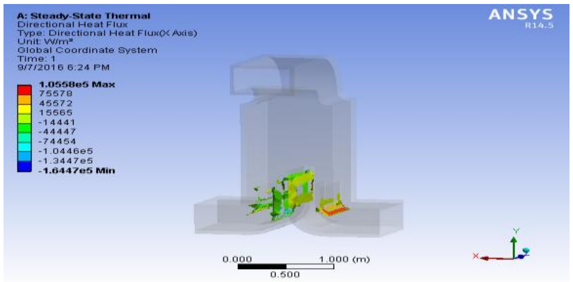
TOTAL HEAT FLUX





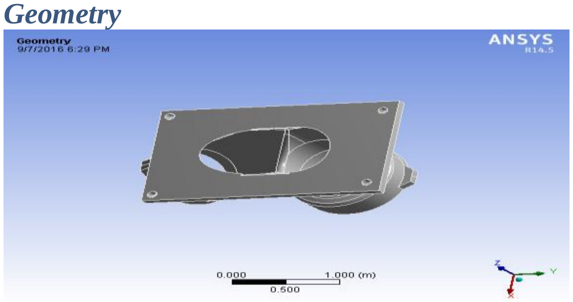
DIRECTIONAL HEAT FLUX





THERMAL ANALYSIS MODIFIED MODEL WITH CAST IRON

Geometry



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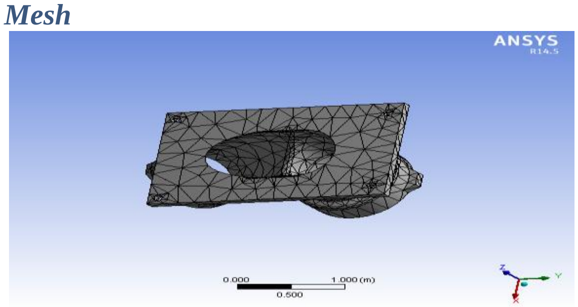

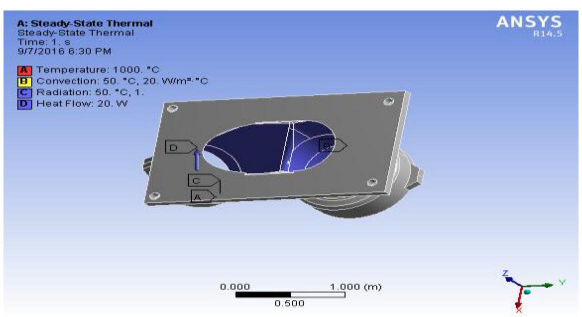

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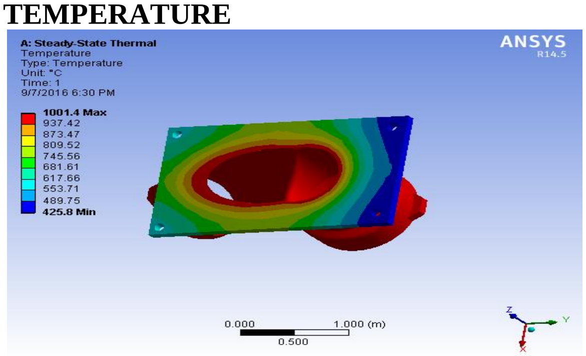
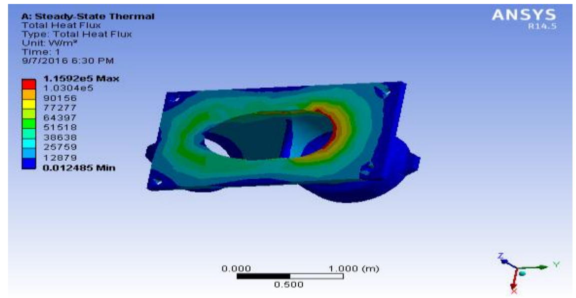
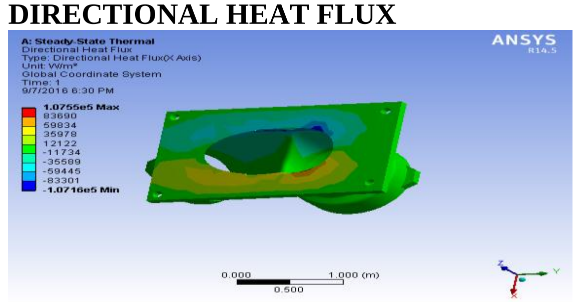


TOTAL HEAT FLUX

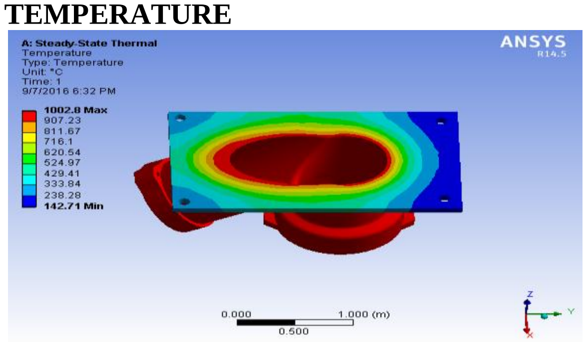


DIRECTIONAL HEAT FLUX

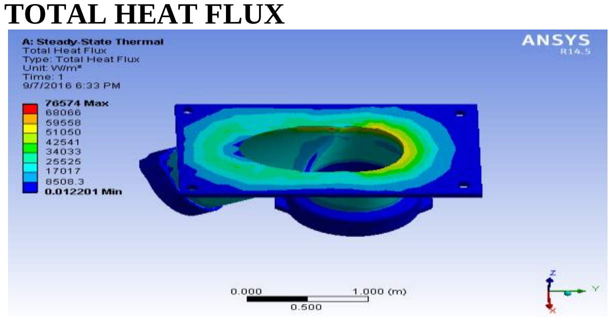


THERMAL ANALYSIS OF MODIFIED MODEL WITH STAIN LESS STEEL

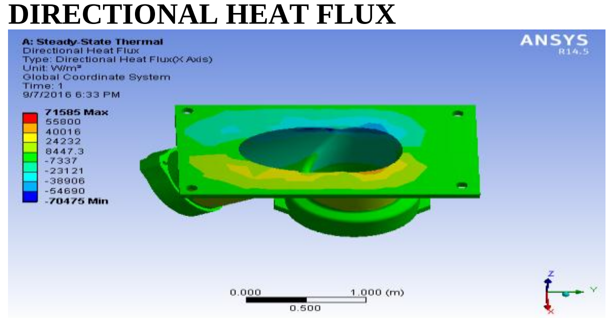
TEMPERATURE



TOTAL HEAT FLUX

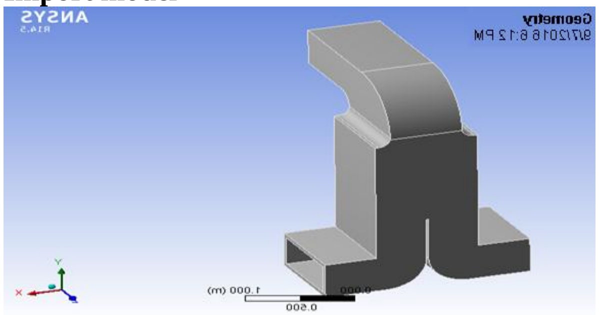


DIRECTIONAL HEAT FLUX

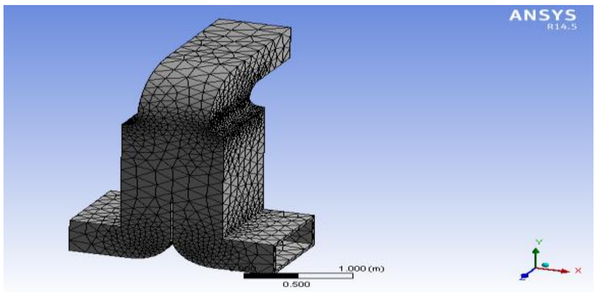


CFD ANALYSIS OF ORIGINAL MODEL

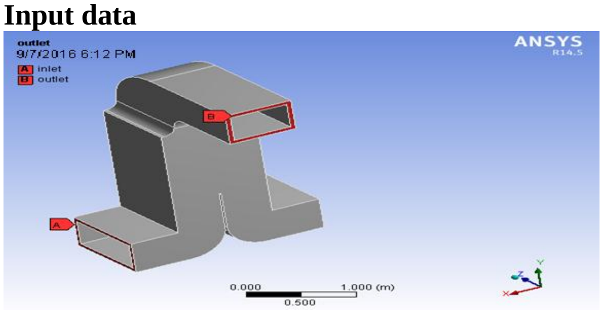
Import model



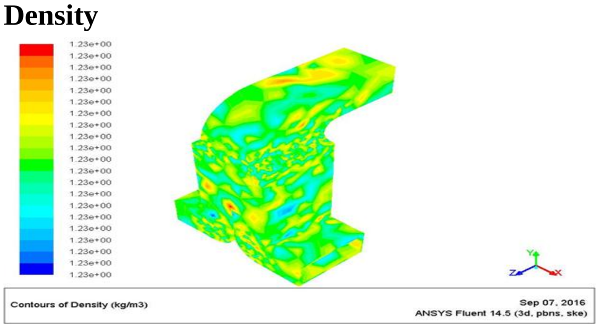
Mesh



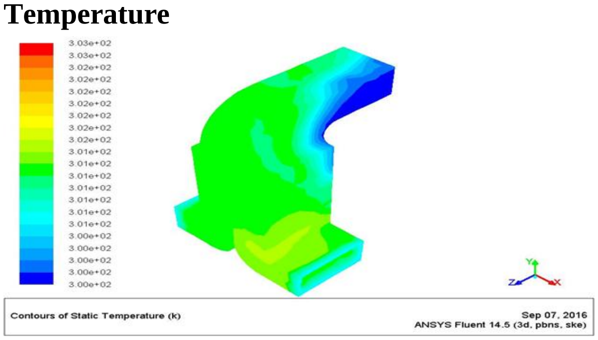
Input data



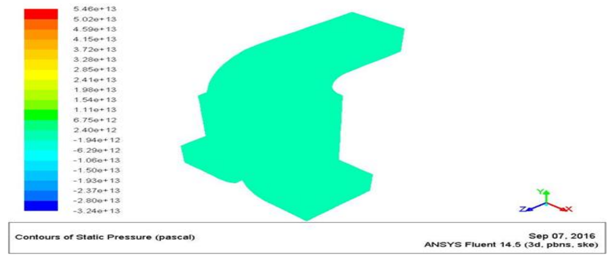
Density



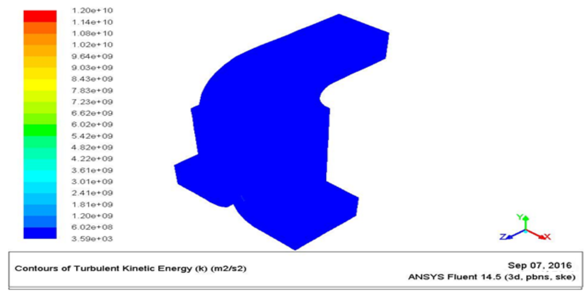
Temperature



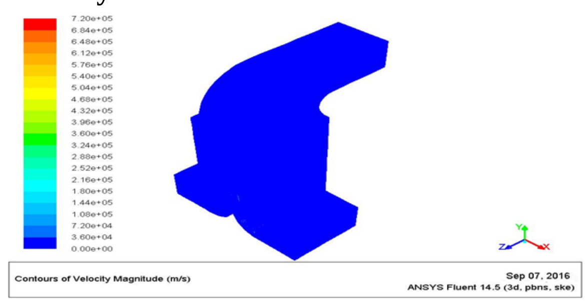
Pressure



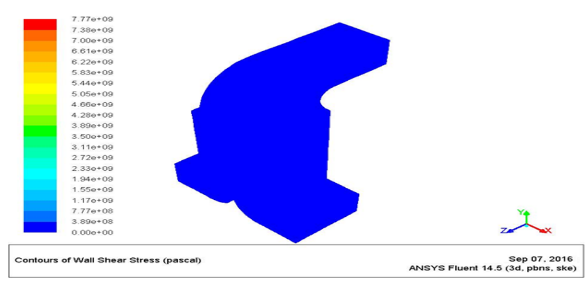
Turbulence



Velocity

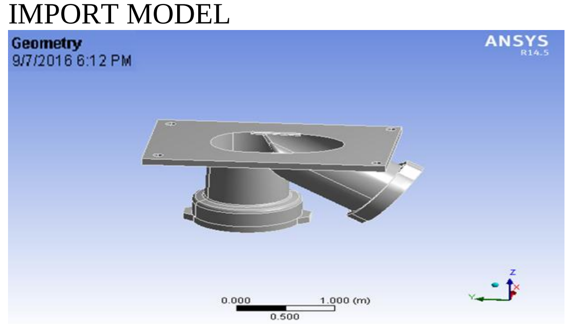


Stress



CFD ANALYSIS OF MODIFIED TURBINE MODEL

IMPORT MODEL



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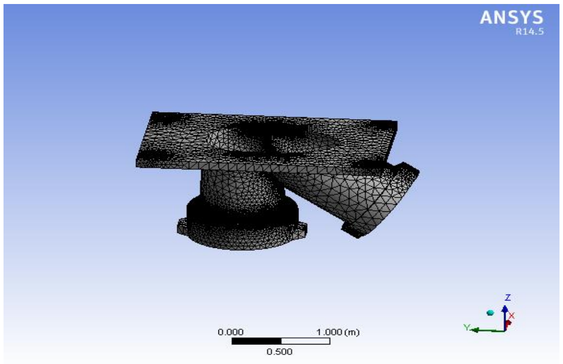

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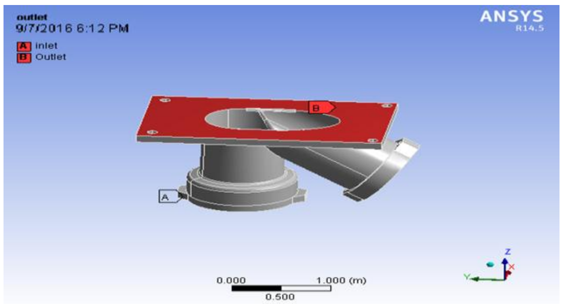

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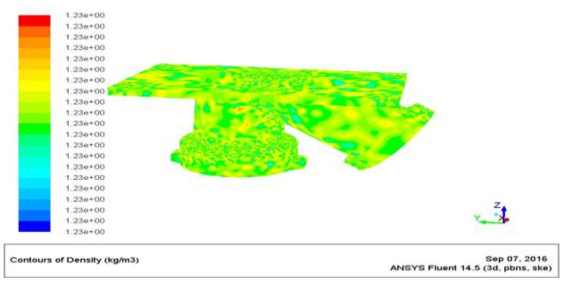
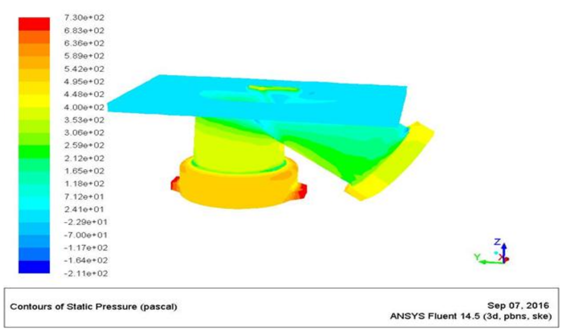
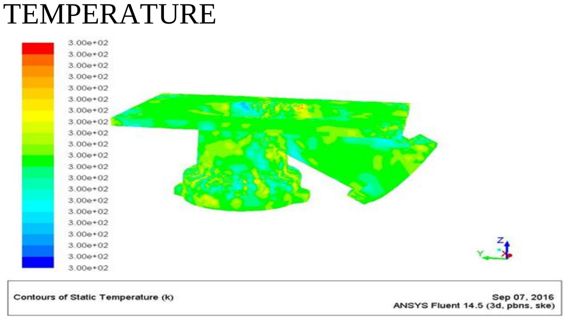


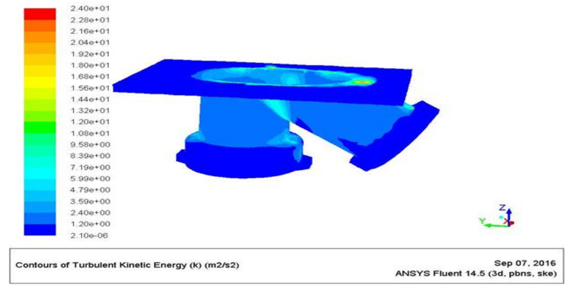
PRESSURE



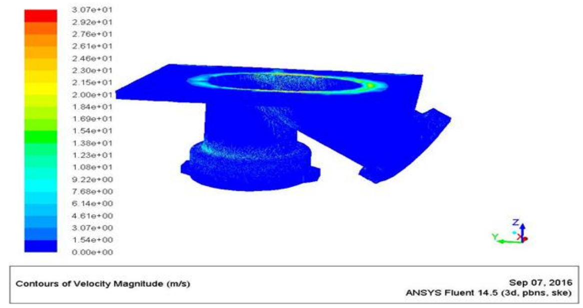
TEMPERATURE



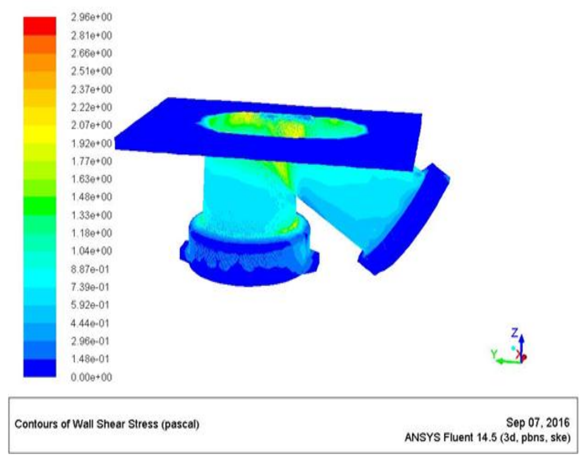
TURBULENCE



VELOCITY



STRESS



REPORT

Comparison Result tables:

<u>THERMAL ANALYSIS</u>

TABLES:

ORIGINAL MODEL

Materials	Temperature		Heat flux		Directional heat flux	
	Min	Max	Min	Max	Min	Max
Cast iron	339.59	1005.4	$1.1563e^{-11}$	$3.5817e^{5}$	$-1.9679e^{5}$	$1.4576e^{5}$
Stainless steel	116.9	1013.4	0	$1.6695e^{5}$	$-1.6447e^{5}$	$1.0558e^{5}$

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MODIFIED MODEL:

Materials	Temperature		Heat flux		Directional heat flux	
	Min	Max	Min	Max	Min	Max
Cast iron	425.8	1001.4	0.012485	$1.1592e^5$	$-1.0716e^5$	$1.0755e^5$
Stainless steel	142.71	1002.8	0.012201	76574	-70475	71585

CFD Analysis

	PRESSURE		DENSITY	TEMPERATURE		KINETIC ENERGY		VELOCITY MAGNITUDE	SHEAR STRESS
	MIN	MAX		MIN	MAX	MIN	MAX		
ORIGINAL	-3.24E+13	5.46E+13	1.23E+00	3.00E+02	3.03E+03	3.59E+03	1.20E+10	7.20E+05	7.77E+09
MODIFIED	-2.11E+02	7.3E+02	1.23E+00	3.00E+02	3.00E+02	2.10E-06	2.40E+01	3.07E+01	2.96E+00

CONCLUSION

This study takes a look at the design process of the air intake system of the Liquid Hydrogen Turbine Inlet Manifold. Differences in turbine outputs and applications require different designs of intake-air manifolds in order to achieve the best volumetric efficiency and thus the best turbine performance. In the present work, the flow characteristics of liquid hydrogen flowing in various designs of air-intake manifold will be studied. The study is done by three dimensional simulations of the flow of air within two designs of air-intake manifold into the turbine by using commercial CFD software, ANSYS.

Here we have done thermal analysis on the original model and even on the modified model with the materials cast iron and stainless steel, as if we compare the results obtained we have plotted them in a tubular form, so by the results we can conclude that modified model with stainless steel is the best material as it is having very low heat flux and even the directional heat flux.

As we observe here all the results which are obtained here are plotted in to tabular and graph form, as we can observe in all the variants here the modified model is considered as the best model as here there is a lot of difference in stress and velocity and temperature difference. As for the modified model it is very low, so here we can conclude that the modified model is the best model.

FUTURE SCOPE

Here, Thermal and CFD analysis is done the liquid hydrogen turbine intake manifold considering two models with two different materials i.e. -cast iron and stainless steel.

The study can be extended forward by conducting analysis on different available models of intake manifolds. Also, materials like composites, functionally graded materials can be used for the extended study.

Not only intake manifold but also many other components of turbine can be studied like turbine housing, propeller blades, hub, shaft and etc.

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1. **STUDENT**

2. **GUIDE 1**

3. **GUIDE 2**