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Design and analysis of Pelton turbine buckets

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Abstract

The Pelton turbine can be used as a two-phase expander. The characterization of the Pelton turbine as two-phase expander consists in analyzing the power loss sources to evaluate the machine performance. The design of Pelton turbines has always been more difficult than that of reaction turbines, and their performances lower.

A Pelton turbine bucket is the individual component which makes up the turbine section of a pelton turbine.the blades are responsible for extracting energy from the high pressure water produced by the nozzle jet.the pelton bucket are very often the limiting componenet of pelton turbines. To survive n this difficult environment, blades often use exotic material.

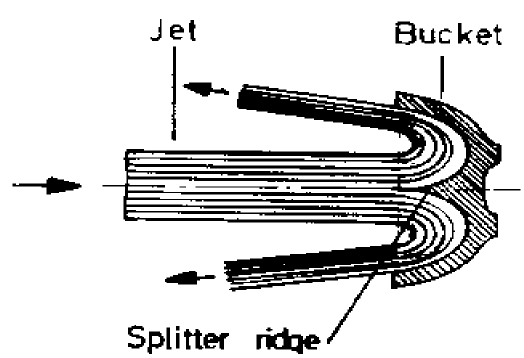
In this project,pelton turbine is designed and modeled in 3d modeling software CATIA V5.we know that the efficiency is directly related to material performance, making the material selection of primary importance.in this project,materials considered for turbine blade are structural steel,low carbon steel and maraging steel.Optimization s done by different material by performing coupled field analysis on the designs.the objective of this project is to perform coupled filed analysis of pelton wheel bucket for various material on the pelton wheel for finding out the efficiency,high stress handing factors, temperature distribution and thermal error.

The change in material will lead to changes in the values of Displacements, Stress, Strain, Max. Frequencies leading to resonance which will cause the failure of the equipment. Hence the CFD analysis is to be done. the proposed material is subjected with a certain velocity of water striking the buckets. The CFD analysis gives the distribution of Pressure, Temperature,density,velocity and stress.

INTRODUCTION

Energy may exist in various forms. Hydraulic energy is that which may be possessed by a fluid. It may be in the form of kinetic, pressure, potential, strain or thermal energy. Fluid machinery is used to convert hydraulic energy into mechanical energy or mechanical energy into hydraulic energy. This distinction is based on the direction of energy transfer and forms the basis of grouping fluid machinery into two different categories. One is power producing machines which convert hydraulic energy into mechanical energy like turbines and motors; the other is power consuming machines doing the reverse like pumps, fans and compressors. Another classification for fluid machinery can also be done based on the motion of moving parts. These are rot dynamics machines and positive displacement machines. A detailed chart is given below explaining the classifications.

The free jet turbine is used for heads up to 2000 m. Below 250 m, mostly the Francis turbines are given preference. Today the maximum output lies at around 200 MW.



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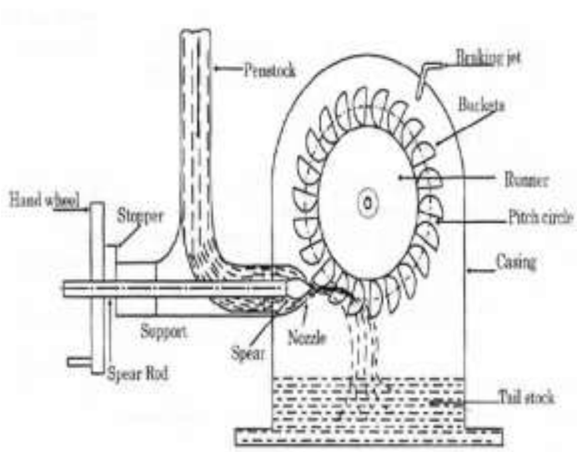
Depending on the discharge, head and quality of the water, Pelton turbines are installed with a horizontal shaft, with 1 or 2 jets per runner, as single or twin turbine, or with a vertical shaft with up to 6 jets. Generally the electrical generator is coupled directly to the shaft. The speed of small turbines may be adjusted by belt drives or gear boxes.

THEORY

In the impulse turbines, the total head available is first converted into the kinetic energy. This is usually accomplished in one or more nozzles. The jets issuing from the nozzles strike vanes attached to the periphery of a rotating wheel. Because of the rate of change of angular momentum and the motion of the vanes, work is done on the runner (impeller) by the fluid and, thus, energy is transferred. Since the fluid energy which is reduced on passing through the runner is entirely kinetic, it follows that the absolute velocity at outlet is smaller than the absolute velocity at inlet (jet velocity). Furthermore, the fluid pressure is atmospheric throughout and the relative velocity is constant except for a slight reduction due to friction.



Pelton Bucket - Design & Features

Most vital component of Pelton wheel is its bucket. Buckets are casted as single solid piece, in order to avoid fatigue failure. You can note that force acting on the turbine bucket is not constant with time. If you follow one particular bucket, it will have high force for small time duration (at the time of jet impingement) after that a larger idle period where no jet interaction takes place. So the force acting on the bucket is also not constant. It varies with the time but it is having a cyclic nature. If bucket were made using pieces by welding attachment such cyclic fore will easily lead to premature fatigue failure.

Buckets are Held Stationary

If Pelton wheel buckets are held stationary, there will be a huge impulse force produced. But power extraction will be zero since buckets are not moving.

Bucket Speed Same as Jest Speed

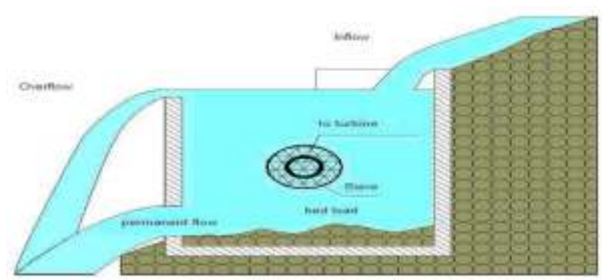
If buckets are moving with same speed of jet, water jet won't be able to hit the bucket. This will lead to zero impulse force. Again power extraction will be zero.

Working of pelton wheel turbine:

In the pelton wheel turbine the water from the nozzle straightly strikes the buckets arranged to the circumference of the wheel. In the middle of the bucket we can see the splitters. The water jets are divided into two equal watercourses. The watercourses are also known as streams. The water flows along with the internal curve of the bucket. The water leaves from the opposite direction of the incoming jet. With the help of the high speed water turbine the pelton wheel must be worked. The pelton wheels are expanding with the help of high pressure water through the nozzle to the atmospheric pressure. It receives the high pressure water jet from the water body which was situated at the high level to flow the water downwards.

Water Intake

In many cases the Pelton turbine is used with spring water. In certain cases the penstock is already available and there is no need to take a residual amount of water into consideration.



When taking water from public creeks and rivers a residual amount of water has to be guaranteed. This constant water quantity is also called permanent flow. It is

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also important to stop larger particles (sand, etc.) that can be found in the penstock entering the turbine. The following construction is proposed

The water of the creek flows into a settling tank (for ebay) having in his lower part a notch as outlet. The size of the notch and the difference in height between notch and overflow determine the residual water quantity.

Applications

Pelton wheels are the preferred turbine for hydro-power, when the available water source has relatively high hydraulic head at low flow rates. Pelton wheels are made in all sizes. There exist multi-ton Pelton wheels mounted on vertical oil pad bearings in hydroelectric plants. The largest units can be up to 200 megawatts. The smallest Pelton wheels are only a few inches across, and can be used to tap power from mountain streams having flows of a few gallons per minute. Some of these systems utilize household plumbing fixtures for water delivery. These small units are recommended for use with thirty meters or more of head, in order to generate significant power levels. Depending on water flow and design, Pelton wheels operate best with heads from 15 meters to 1,800 meters, although there is no theoretical limit.

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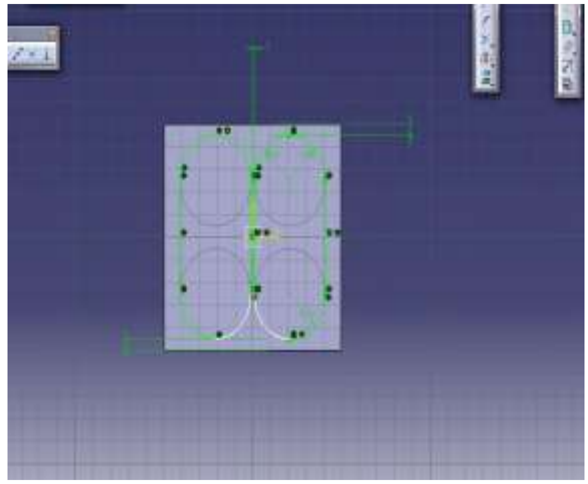
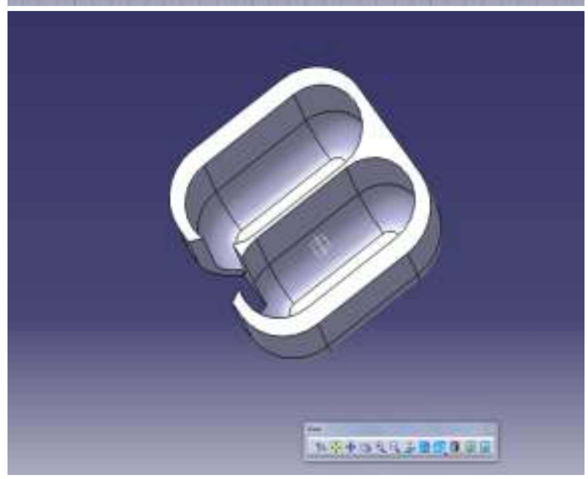
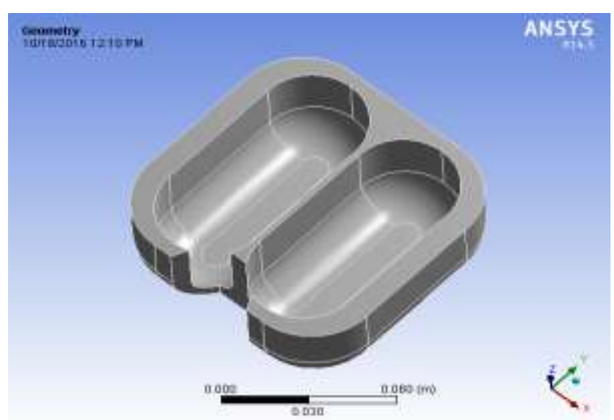
DESIGNING





Model (A4)

Geometry



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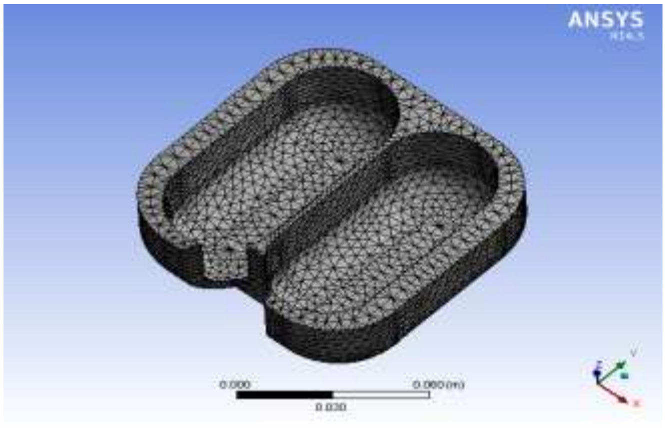
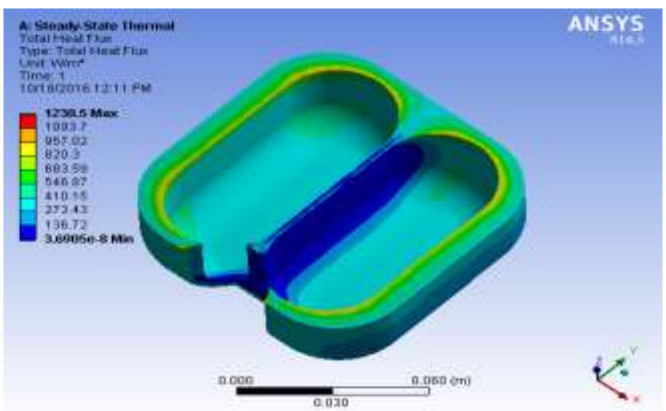
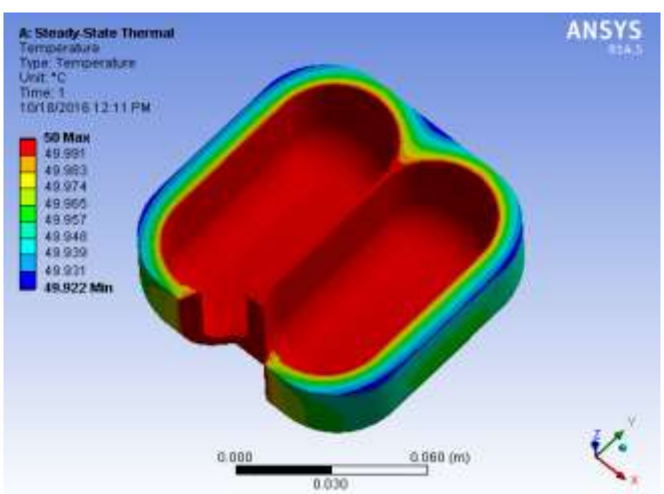
Mesh



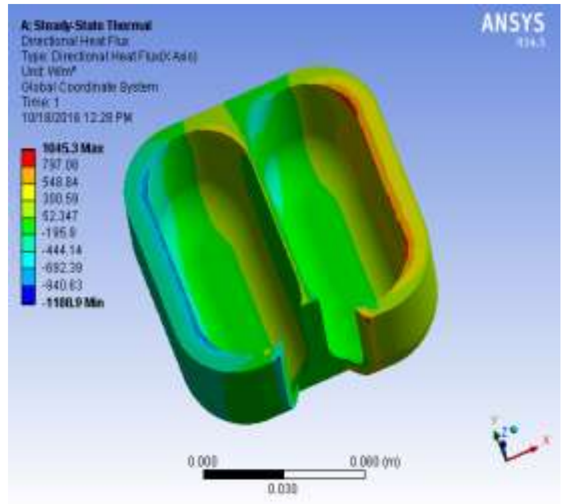
HEAT FLUX



Temperature



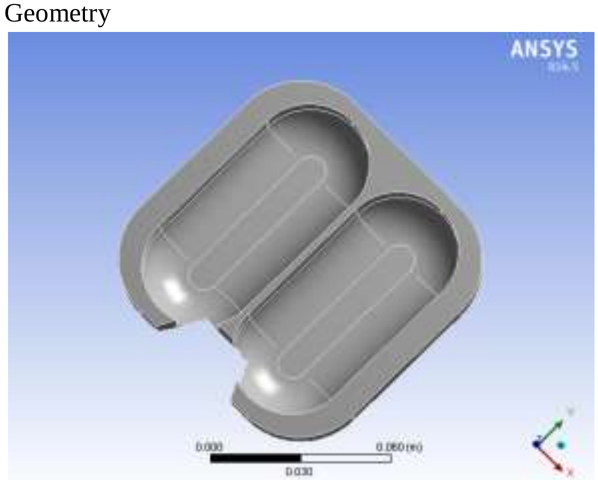
Directional heat flux



A heat flow rate can be applied to a vertex, edge, or surface. The load gets distributed for multiple selections. The magnitude plotted as contours: "Total Heat Flux". The magnitude & direction as vectors: "Direction Heat Flux". A rate equation that allows determination of the conduction heat flux from knowledge of the temperature distribution in a medium.

CFD ANALYSIS OF PELTON BUCKET

Geometry



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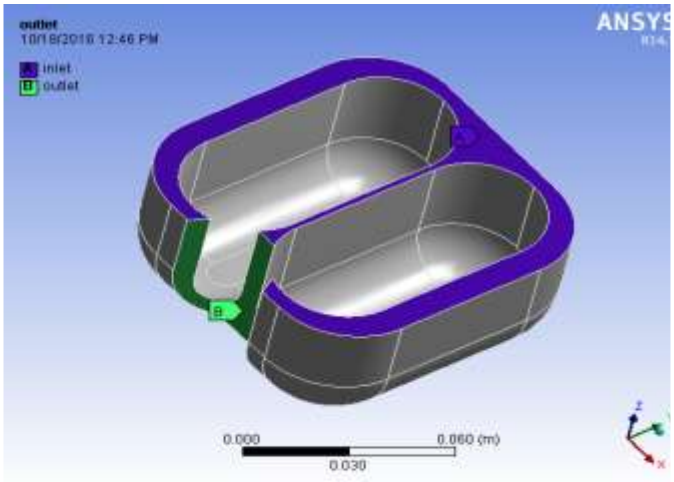
Boundary file



CONCLUSION

In this thesis we have designed a pelton turbine bucket using Catia V5 software and then the thermal analysis is done in Ansys software. And even CFD analysis is also done to the pelton turbine to find out the flow of liquid. As here the materials considered structural steels, maraging steels and low carbon steel.

As if we see the results of the thermal analysis cleared mentioned in the tabular form, total heat flux and the directional heat flux is low for the maraging steels other than the two materials, as maraging steels has the best output in the life parameters and the life efficiency.

So as per the results we can conclude that he maraging steels is the best suited material for the pelton turbine bucket.

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