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Design and Static Analysis of Pelt on Turbine Bucket

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ABSTRACT:

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 buckets are often the limiting component of pelton turbines. To survive in this difficult environment, blades often use exotic materials In this project, pelton turbine bucket is designed and modelled in 3D modelling 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 steel, cast iron and fiber glass reinforced plastic. Optimization is done by varying these materials by performing coupled field analysis on the turbine blade for both the designs. The objective of this project is to perform coupled field analysis of pelton wheel bucket for various materials and varying the number of buckets on the pelton wheel for finding out the efficiency, high stress handling factors.

Introduction

Pelton turbines belong to the family of free jet turbines. A nozzle is placed at the end of the pressure line which converting the potential energy of the water into kinetic energy by forming a water jet. The jet is directed to the runner buckets, the hydraulically active parts of the turbine. At the entrance into the symmetrically shaped buckets the water jet is split into two parts, each developing a sheet of water on the bucket‘s curved surface. At the end of the working cycle, the water leaves the bucket in the opposite direction of the free jet. The rotational mechanical energy is then transferred through the shaft to the generator which is produced by momentum and pressure of water jet striking the buckets. Water jet falls with immense pressure on line dividing the two buckets. Jet pressure is controlled by spear which is further controlled by servomotor. Pelton turbine operates at high head (above 10 meters). This runner is further connected with the generator in which the rotor fixed with runner shaft rotates enclosed in between stator. Hence produce electricity. The pressurized water falls over the inside of blade and it generates stress on throughout section of blade. But the utilization of water jet to produce electricity is less as these turbines works at atmospheric pressure because of which splashing of water occurs makes it difficult to utilize the water jet fully for producing thrust, so we say these turbines are generally less efficient as compared to reaction turbines. The inside of the bucket should be as smooth so as the water does not loose speed at expense of outflow of water. If the jet speed is twice the speed of bucket, then water relative to bucket leaves at speed. Coupled-field analysis takes into account the interaction (coupling) between two or more disciplines (fields) of engineering. Examples of coupled-field analysis are thermal-stress analysis, thermal-electric analysis, and fluid-structure analysis.

PELTON WHEEL BUCKET

Pelton turbine buckets, single or two buckets together are generally manufactured by mould casting. The casting of buckets for Pelton turbines can be done by copying from other existing buckets. It is advisable to cast the single buckets and, after machining, to fix them to the rotor disk. In this manner complicated casting moulds can be avoided. It is not recommended to manufacture the buckets of halved pipe sections or other welding constructions of sheet metal sections, because of lacking strength and poor efficiency. The buckets can be made of different materials. This is also the case if the rotor is cast in one piece. On modern Pelton turbines the buckets are mostly of cast steel with 13% chrome. But other materials and methods are also used, including cast iron, or alloys such as bronze or aluminium, or injection molding with fiber glass reinforced plastic. Each material has its own properties, one of these being the allowable stress. The limits for application must be calculated carefully for each material. When calculating the allowable head for a certain turbine configuration not only the static forces must be calculated, but the fatigue stress and the centrifugal forces are also to be considered. Quick changing of the load on the buckets has an unfavorable effect on the admissible forces, especially when the stress is higher than normal. This could be caused by unequal distribution of the material, cracks at critical places, due to corrosion or due to welding.

One of the most important parameter of Pelton turbine design is number of buckets on the disk. If numbe

r of buckets is inadequate, this will result in loss in water jet. That means when one bucket departs from the water jet next bucket may not get engaged with the jet. This will result in loss in water jet for small time duration, thus sudden drop in turbine efficiency. Following figure illustrates what happens when the number of buckets is lowered. With lowering number of buckets at some point of operation, complete water jet might be lost (3rd figure). So there should be an appropriate number of buckets, which will make sure that no water is lost (1st figure).

This project deals with the analysis of the buckets made of different materials steel, cast iron and fiber glass reinforced plastic. The optimum material is the one that can withstand the high head flow is to be observed. Number of buckets on a pelton wheel turbine is calculated theoretically and is compared to that of the analysis results for an optimum number. Coupled field analysis (thermal and structural) is performed on a specific Pelton wheel bucket.

SURVEY:

Pelton turbines belong to the family of free jet turbines. A nozzle is placed at the end of the pressure line which converting the potential energy of the water into kinetic energy by forming a water jet. The jet is directed to the runner

buckets, the hydraulically active parts of the turbine. At the entrance into the symmetrically shaped buckets the water jet is split into two parts, each developing a sheet of water on the bucket's curved surface. At the end of the working cycle, the water leaves the bucket in the opposite direction of the free jet. The rotational mechanical energy is then transferred through the shaft to the generator which is produced by momentum and pressure of water jet striking the buckets. Water jet falls with immense pressure on line dividing the two buckets. Jet pressure is controlled by spear which is further controlled by servomotor. Pelton turbine operates at high head (above 10 meters). This runner is further connected with the generator in which the rotor fixed with runner shaft rotates enclosed in between stator. Hence produce electricity. The pressurized water falls over the inside of blade and it generates stress on throughout section of blade. But the utilization of water jet to produce electricity is less as these turbines works at atmospheric pressure because of which splashing of water occurs makes it difficult to utilize the water jet fully for producing thrust so we say these turbines are generally less efficient as compared to reaction turbines Hydropower is the longest established source for the generation of electric power. In this module we shall discuss the governing principles of various types of hydraulic turbines used in hydro-electric power stations.

Impulse Hydraulic Turbine **: The Pelton Wheel**

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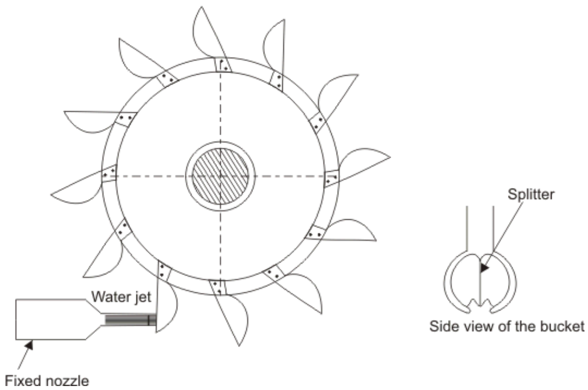
The only hydraulic turbine of the impulse type in common use, is named after an American



engineer Laster A Pelton, who contributed much to its development around the year 1880. Therefore this machine is known as Pelton turbine or Pelton wheel. It is an efficient machine particularly suited to high heads. The rotor consists of a large circular disc or wheel on which a number (seldom less than 15) of spoon shaped buckets are spaced uniformly round is periphery as shown in Figure 26.1. The wheel is driven by jets of water being discharged at atmospheric pressure from pressure nozzles. The nozzles are mounted so that each directs a jet along a tangent to the circle through the centres of the buckets (Figure 26.2). Down the centre of each bucket, there is a splitter ridge which divides the jet into two equal stream which flow round the smooth inner surface of the bucket and leaves the bucket with a relative velocity almost opposite in direction to the original jet.

For maximum change in momentum of the fluid and hence for the maximum driving force on the wheel, the deflection of the water jet should be 180^o. In practice, however, the deflection is limited to about 165^o so that the water leaving a bucket may not hit the back of the following bucket. Therefore, the camber angle of the buckets is made as $165^o (\theta = 165^o)$. Figure(26.3a)

The number of jets is not more than two for horizontal shaft turbines and is limited to six for vertical shaft turbines. The flow partly fills the buckets and the fluid remains in contact with the atmosphere. Therefore, once the jet is produced by the nozzle, the static pressure of the fluid remains atmospheric throughout the machine. Because of the symmetry of the buckets, the side thrusts produced by the fluid in each half should balance each other.

Analysis of force on the bucket and power generation Figure 26.3a shows a section through a bucket which is being acted on by a jet. The plane of section is parallel to the axis of the wheel and contains the axis of the jet. The absolute velocity of the jet V_1 with which it strikes the bucket is given by

$$V_1 = C_v \sqrt{2gH}$$

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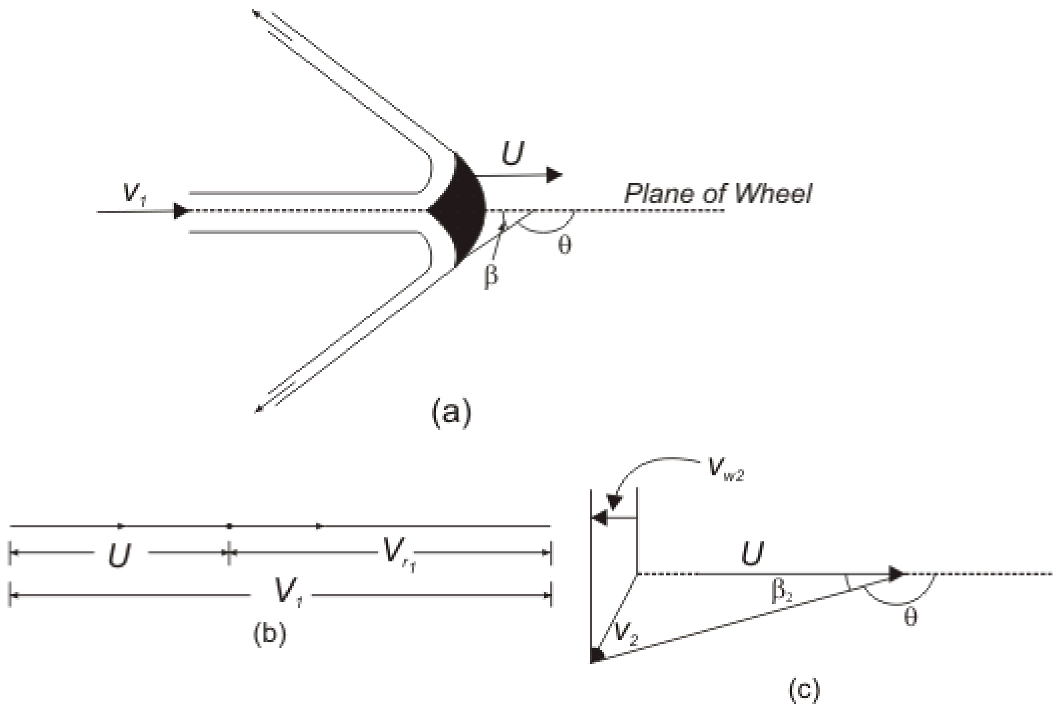


Figure 26.3 **(a)Flow along the bucket of a pelton wheel**
(b) Inlet velocity triangle
(c)Outlet velocity triangle

where, C_v is the coefficient of velocity which takes care of the friction in the nozzle. *H* is the head at the entrance to the nozzle which is equal to the total or gross head of water stored at high altitudes minus the head lost due to friction in the long pipeline leading to the nozzle. Let the velocity of the bucket (due to the rotation of the wheel) at its centre where the jet strikes be *U* . Since the jet velocity V_1 is tangential, i.e. V_1 and *U* are collinear,

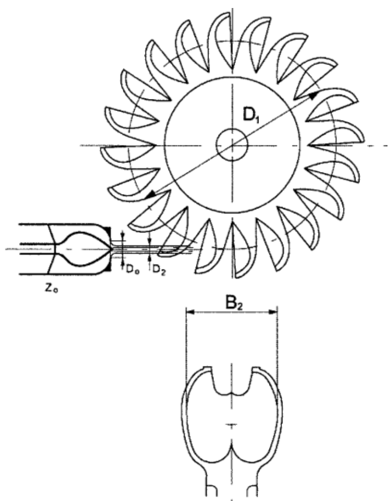
the diagram of velocity vector at inlet (Fig 26.3.b) becomes simply a straight line and the relative velocity is given by

$$V_{r_1} = V_1 - U$$

It is assumed that the flow of fluid is uniform and it glides the blade all along including the entrance and exit sections to avoid the unnecessary losses due to shock. Therefore the direction of relative velocity at entrance and exit should match the inlet and outlet angles of the buckets respectively. The velocity triangle at the outlet is shown in Figure 26.3c. The bucket velocity *U* remains the same both at the inlet and outlet. With the direction of *U* being taken as positive, we can write. The tangential component of inlet velocity (Figure 26.3b)

$$V_{w_1} = V_1 = V r_1 + U$$

Performance prediction of hydraulic machines, such as efficiency and dynamic behavior under different operating conditions,is of high interest to manufacturers. The design of Pelton turbines is mainly conducted from know-how and extensive experimental testing. In today's highly competitive market of turbine upgrading and refurbishment, the performance guarantees are often difficult to determine in the short term. the free surface, and surface tension modeling. Then, the numerical setup and the experimental techniques are presented. Finally, the results obtained from both approaches are analyzed, compared, and the momentum transfer in the bucket is discussed. **Two-Phase Homogeneous Model**



The flow model used for the numerical simulations is based on the generalized homogeneous multiphase flow model developed by Ishii _15_, with the additional sources of momentum for the effects of the Coriolis and centrifugal accelerations in a steady rotating frame of reference.

CONCLUSION

Our project is to design and analysis of both pelton bucket and pelton turbine on different material namely steel, cast iron and fiber glass reinforced plastic. We have designed piston using CAD software namely CATIA V5 and analysis is done using ANSYS 14.5 and the thermal and static analysis id drawn under required boundary conditions. Firstly we analyzed pelton bucket with steel, cast iron and fiber glass reinforced plastic and then followed by pelton turbine with 18 buckets under same condition and material properties. we have observed that fiber glass reinforced plastic shows good results when compared to other material and regular using material ie cast iron. In static analysis fiber glass reinforced plastic shows lower deformation and less affected to stress and strain factors when compared different materials even steel shows nearly equal results as fiber glass reinforced plastic which can be encouraged after fiber glass reinforced plastic. By this project we want to conclude that by using fiber glass reinforced plastic in place of cast iron shows good physical bearable properties. We even conclude that steel is also comparatively good material .

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