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Static Analysis On Pelton Wheel Bucket

Structural Deformation and Material Property Study

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***Abstract*— To meet the energy demand dependence on renewable energy sources is becoming more popular these days. Pelton turbine is one such power source which develops electricity by converting kinetic energy of water into mechanical energy. Pelton wheel is the commonly used hydraulic turbine of the impulse type. The literature on Pelton turbine design available is scarce this project exposes the theoretical and experimental aspects in the analysis of a Pelton bucket. The project shows the analysis of the Pelton wheel bucket modelled using CATIA V5 software. The material used in the manufacture of pelton wheel buckets is studied in detail and these properties are used for analysis. The bucket is analyzed using ANSYS Workbench 14.0 .The bucket geometry is analyzed by considering the force and also by considering the pressure exerted on different points of the bucket. The bucket was analyzed for the static case and the results of structural deformation in both the cases are obtained. The so formed results are compared with the theoretical results and suitable interpretations are made.**

Keywords—initial jet impact; pelton bucket; ; static case; material properties; force; pressure

I. Introduction

Pelton turbines are hydraulic turbines which are widely used for large scale power generation. A micro hydel pelton turbine is miniature model of actual pelton turbine which can be used for small scale power generation. This type of turbines converts potential energy of water at height into kinetic energy by allowing the water to fall freely on the pelton runner. This water impact provides necessary torque required for the rotation the runner by overcoming its inertia forces. The rotation of runner develops a mechanical energy which is coupled to the alternator which converts it into electrical energy. To study the various characteristics of bucket for the first jet impact force of the water jet a bucket model is designed using CATIA V5 software.[2] The material used in the modelling of pelton bucket is CA6NM. When the bucket and hub assembly is at rest and a significant magnitude of force is necessary to put the runner into motion, the first impact of the water jet from the nozzle should be able to provide a force value not less than that is required. The water jet also exerts a pressure along the bucket profile. The ANSYS simulation of the bucket is done by considering the two cases of initial jet impact, first approach is by considering the first impact force along the splitter of the bucket and second approach is by taking the pressure distribution along the bucket profile. A study demonstrates a comparison of both the approaches. Theoretical validation of both the approaches is done using standard thumb rules and equations.[9]

II. Material Properties

For the industrial manufacturing of the pelton wheel turbines the material mainly used is CA6NM.[7] This is a combination of iron , chromium, nickel, and molybdenum which is hardened by heat treatment. This material has very high tensile strength and impact strength. This is not corrosive and thus it is used mainly in constructing structures formed in water. A major application of the alloy has been in large hydraulic turbine runners for power generation.

The major property of the material is listed below.

Property	**Value**
Density	1695 Kg/m^3
Young’s modulus	1.9995x10^5 MPa
Poissons’s ratio	0.27
Bulk modulus	1.4489x10^{10} Pa
Shear modulus	7.872x10^{10} Pa
Yield strength	689.43 MPa
Ultimate strength	827.37 MPa

III. Case Study

a. Analysis using ANSYS

The study only considers the initial jet impact condition and thus static analysis was considered in this study. The simulation of the bucket modeled in CATIA is done in two different methods which are as follows:[2]

1. By considering the first jet impact force along the splitter of the bucket
2. By considering the pressure distribution along the bucket profile

1. By considering the first jet impact force along the splitter of the bucket [2]. The assumptions made in this analysis are

a. The bucket is stationary
b. The bucket profile is uniform
c. Effects of external forces are negligible
d. The bucket fixed at its arm acts similar to a cantilever beam

The bucket is operated at a head of 6m and the mass flow rate is 6lps; the first impact force on the splitter is given by

F=349N

In real life situation the runner which is initially at rest is put to motion by the water jet impact force from the nozzle. The same scenario is replicated for the simulation in ANSYS. The force of magnitude 349N is directed at an inclination to the splitter of the bucket as a result of which the bucket deforms, the deformation characteristics is studied using ANSYS software.

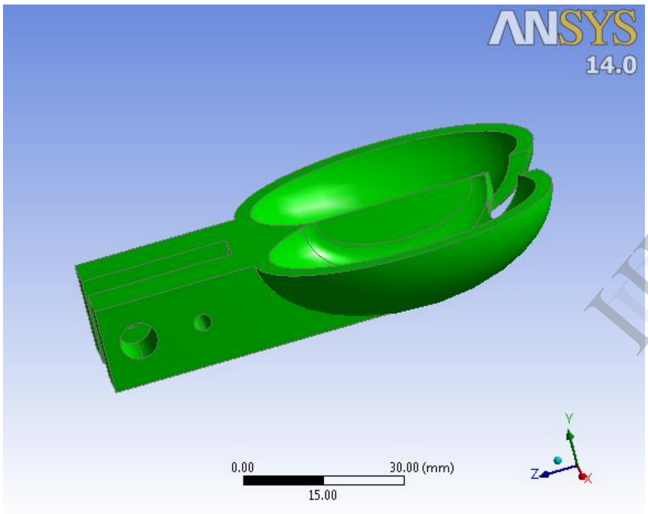

Fig1.Applying material properties for first case

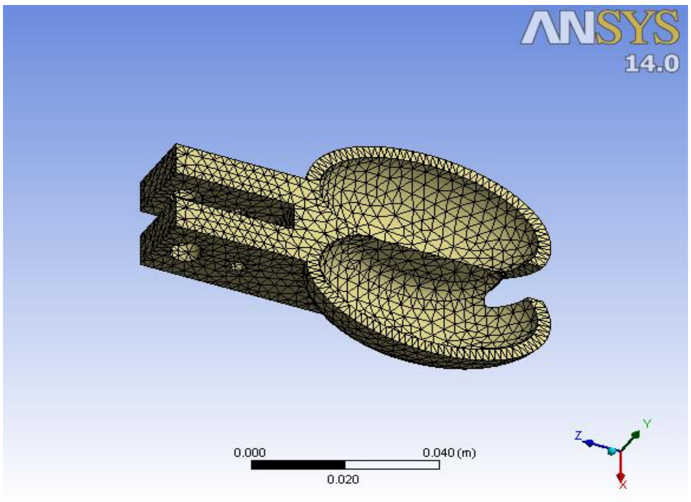

Fig2 Meshing

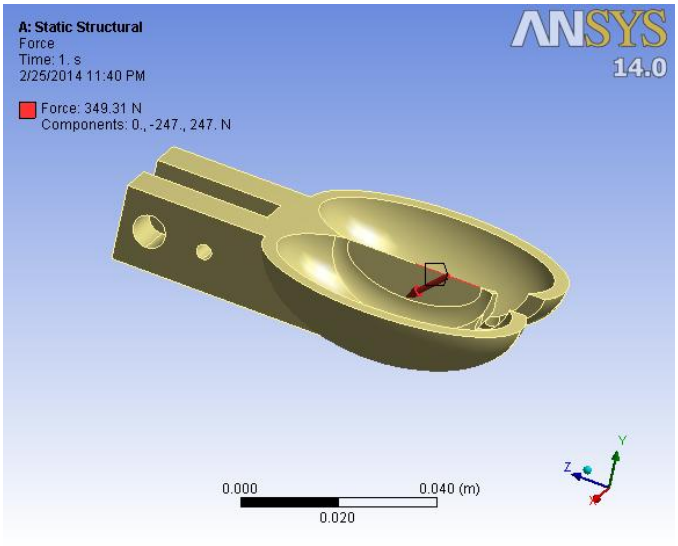

Fig3.Applying the load

2. By considering the pressure distribution along the bucket profile

The assumptions made in this analysis are

a. The bucket is stationary
b. The bucket profile is uniform
c. Effects of external forces are negligible
d. The fixed at its arm acts similar to a cantilever beam
e. The pressure distribution for crucial nodes are considered

Considering the actual case of first jet impact on the bucket from a nozzle it is observed that once the jet strikes the splitter water is distributed throughout the bucket profile. This aspect of the real situation is considered for the simulation in ANSYS by taking pressure distribution along the bucket profile. The pressure distributions at various nodes were referred from experimental data and this pressure values are applied to the predefined nodes modelled on the bucket profile. The deformation characteristics of the bucket were studied by the simulation in ANSYS.[4]

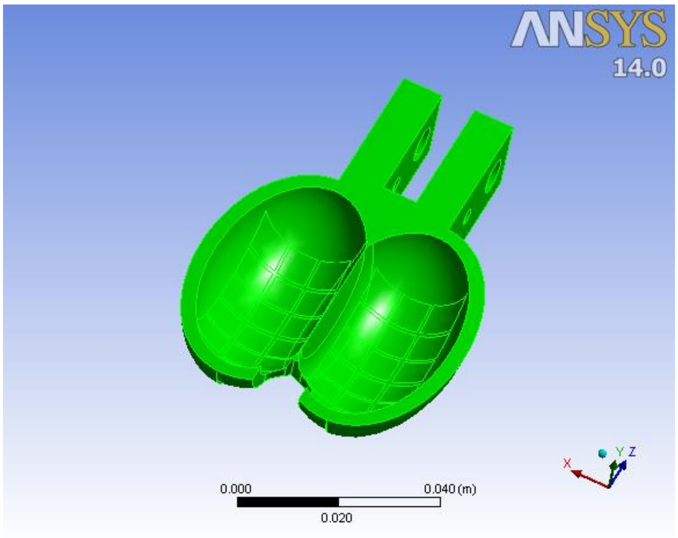

Fig4 Imprint faces

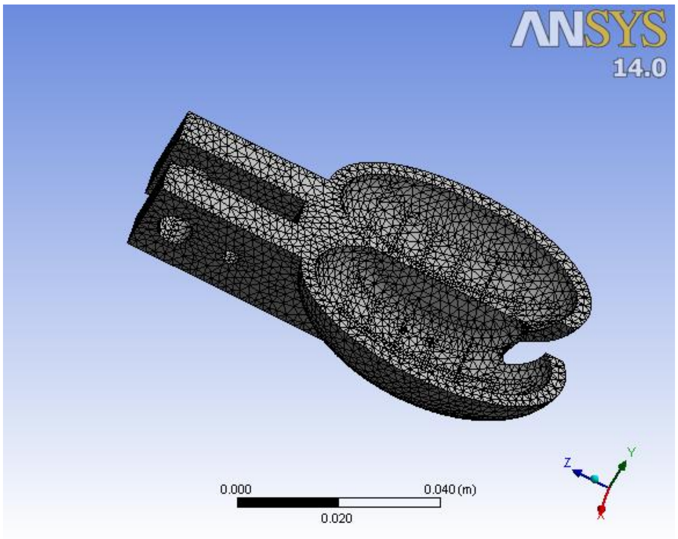

Fig5.Meshing

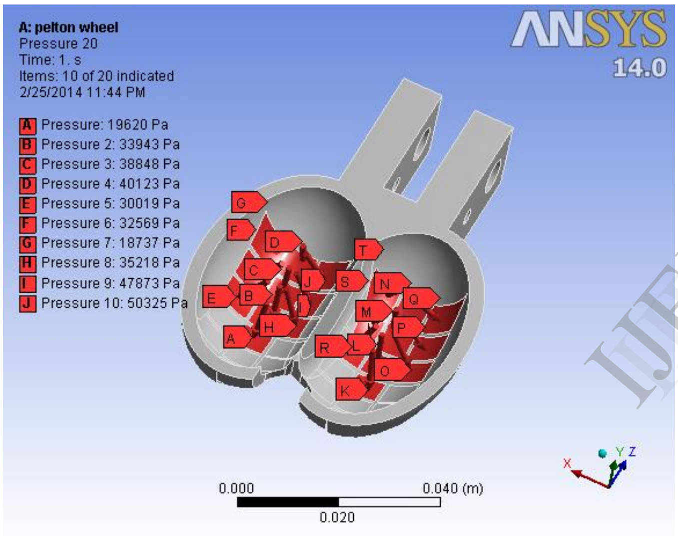

Fig6.Application of pressure on the faces

b. Structural deformation:-

One of the main phenomenon analyzed during the analysis done in ANSYS is structural deformation of the material for the loads applied. Its analysis results were found to concur with the theoretical calculations done. The structural deformation of the designed pelton wheel is as given below for both the force and pressure loading.

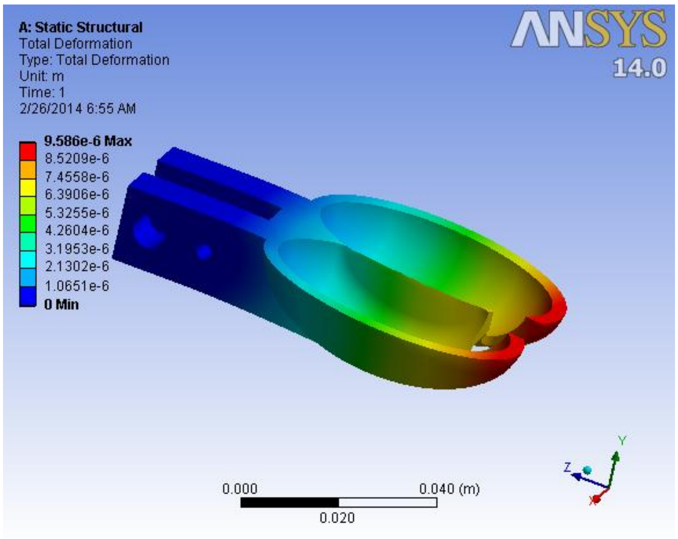

Fig7.Structural deformation in the case of point load

From the analysis it was observed that it is the tip of the bucket which experience maximum deformation of 0.0095mm.

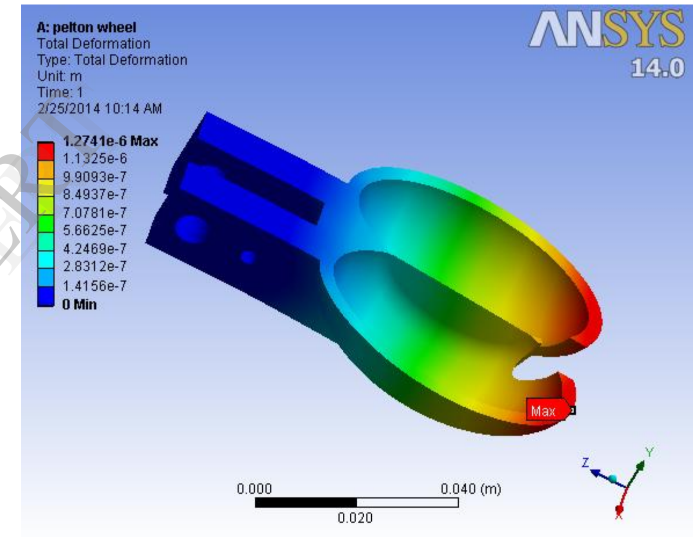

Fig8.Structural deformation in the case of pressure loading

From the analysis it was observed that it is the tip of the bucket which experience maximum deformation of 0.00127mm.

c. Theoretical calculations:

The above observations are compared with the results theoretically obtained. The theoretical calculations are done on the assumption that the bucket is roughly in the form of a cantilever beam and then the equations for finding out the deflection acting in a cantilever beam is used to theoretically validate the results obtained by ANSYS.[6]

Theoretical calculation of Deformation

Total length (L) = 88.97mm

Length of moment arm= (a) =42.077mm

Distance between the tip of bucket and point at which the water jet strikes = (L-a) =88.97-42.077 = 46.9 mm

Slope at distance 'a' $= \theta_c = \frac{Wa^2}{2EI}$

$= \frac{349*(42.077)^2}{2*(1.995*10^5)*20470.833}$ $= 7.5479*10^{-5}$mm

θ_c*(L-a) $= 3.5399*10^{-3}$mm^2

Deflection at point 'a'$= y_c = \frac{Wa^3}{3EI} = \frac{349*(42.077)^3}{3*(1.995*10^5)*20470.833}$

$= 2.1173*10^{-3}$mm

Deflection at the tip of the bucket, $y_b = y_c + \theta_c$*(L-a)

$= 2.1173*10^{-3}+3.5399*10^{-3}$

$= 5.6575*10^{-3}$mm

= 0.005675mm

Thus from the above calculations it is observed that the results obtained are similar to that obtained by using simulation in ANSYS.

IV. CONCLUSIONS

The study shows the effects on a pelton bucket under two loading conditions viz impact force along the splitter and the pressure load on the bucket profile. Simulations were carried out for both loading conditions and results were theoretically verified by hand calculations. Maximum deflection obtained by impact force along splitter 349 N, maximum deformation obtained by considering pressure load alone 0.00127mm, and that got from the force applied is 0.0095mm. The theoretically calculated value of deflection is 0.005675mm.The variation may be due to the assumptions made during the theoretical calculations. Of the two loading conditions theoretical values seems to be more related to simulation results of the force load.

V. NOMENCLATURE

L total length
a moment arm length
θ_c slope at distance a
y_c deflection at point a
y_b deflection at the tip of the bucket

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