Design and Modelling of a Pelton Wheel Bucket

Theoretical Validation And Software Comparison

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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 work exposes the theoretical and experimental aspects in the design and analysis of a Pelton wheel bucket, and hence the designing of Pelton wheel bucket using the standard thumb rules. The bucket is designed for maximum efficiency. The bucket modeling was done by using CATIA V5.**

***Keywords*—impulse turbine; pelton turbine; jet impact; maximum efficieny.**

I. INTRODUCTION

Turbines can be generally classified as steam and hydraulic turbines. The hydraulic turbines are rotary machines which convert the potential head of the water into useful forms of energy such as mechanical energy and electrical energy. The hydraulic turbines are again sub divided into impulse and reaction turbines. The pelton wheel turbine which is dealt with in this journal is an impulse type of turbine and to be very precise this is a Micro hydro turbine. Micro hydropower plants are a major source of energy in the rural areas of northern India and Nepal. The pelton turbine consists of mainly the following parts: - 1) buckets 2) nozzles 3) governors 4) valves. The bucket is of the form of a double hemispherical cup fitted onto a runner. The water jet strikes the splitter at the interface of the two halves. The water jet after striking the splitter it moves through the bucket profile outwards. The splitters deflect the water at an angle between 165^0-175^0. The impact energy is converted into mechanical energy which is used to rotate the runner which will be connected to a generator to produce the required AC current.

The details on the design and analysis on the turbine is very scarce because the details available are kept as a closed corporate secret. The literature about the pelton wheel turbine is very scarce, this journal sums up the basic important parameters needed for the design of a pelton wheel bucket which can be considered to be the prime moving part of the bucket which makes the power production possible. The design is done using the thumb rules and the so formed design is brought to life using CATIA V5 design software.

FIG 1. *Pelton Runner model*

II. DESIGN STEPS OF A PELTON BUCKET

Considering the initial operating condition of the turbine; the runner bucket assembly is stationary at initial stage. The water jet leaves the nozzle at a very high velocity and strikes the bucket with high kinetic energy. During the normal running of a pelton turbine a continuous jet of water at varying speed is maintained for the uninterrupted rotation of the runner. However it is the first jet of water that strikes the bucket which has the maximum impact on the bucket profile, this is because the first water jet has to overcome the inertia forces of the runner. In fact it is the first water jet impact which produces the rotational momentum and torque required for the rotation of the runner. This journal deals with the construction of a pelton bucket for considering first impact force of water jet.

A. Assumptions:

1) Net head is taken as 45 m, 2) Rotational speed is taken as 1200 rpm, 3) Flow rate is taken to be 6 liters per second, 4) the bucket is stationary, 5) the bucket is designed at maximum efficiency.

B. Bucket design procedure:

Calculations:-

BASIC BUCKET DESIGN

Bucket is made of elliptical section as in figure. The longitudinal section of the one half of the bucket is an ellipse with axes 52mm and 29mm, similarly the middle transverse section is an ellipse with axes 58mm and 29mm.[2]

Calculations:

Velocity of jet (V_{jet}) $= \sqrt{2gH}$

$= \sqrt{2 * 9.81 * 45} = 29.7\ {}^{m}/_{s}$

Bucket speed (U) $= 0.46\ V_{jet}$

$= 13.6\ {}^{m}/_{s}$

Runner diameter (D_{run}) $= \dfrac{60\ U}{\pi\ N}$

$= \dfrac{60*13.66}{\pi*1200} = 0.217$ m

Jet diameter (D_{jet}) $= {}^{D_{run}}/_{10} = 0.0217$m

Moment arm length $= 0.195\text{x}D_{run} = 0.04231$m

Depth of bucket (t) $=0.9\text{x}\ D_{jet} = 0.01953$m

Width of bucket (b) $=2.6\text{x}\ (D_{jet}) = 0.058$m

Height of bucket (h) $=2.4\text{x}\ (D_{jet}) = 0.052$m

Width of bucket opening (a) = (D_{jet}) =0.021m

The force of water jet on bucket=2 x 1000 x Q x (V_{jet})

= 349.32N [1]

III. COMPARISON OF THE CALCULATIONS WITH THE DESIGN SOFTWARE

The theoretically calculated result is checked using turbine design software used for small scale manufacturing and found out to be relevant. The results are tabulated as follows:

PARAMETERS	UNIT	DIMENSION
Head	Meter	45
Rotational speed	Rotations per minute	1200
Velocity of jet	Meter/second	29.7
Flow rate	Liters per second	6
Bucket speed	Meter/second	13.6
Runner diameter	millimeter	217
Jet diameter	millimeter	21.7
Shaft length	millimeter	42.31
Depth of bucket	millimeter	19.53
Width of bucket	millimeter	58
Height of bucket	millimeter	52
Force of water jet on bucket	Newton	262

TABLE NO 1. *Design parameters*

The observed results are compared using the software Turbin PRO and the analyzed results are also given as follows.

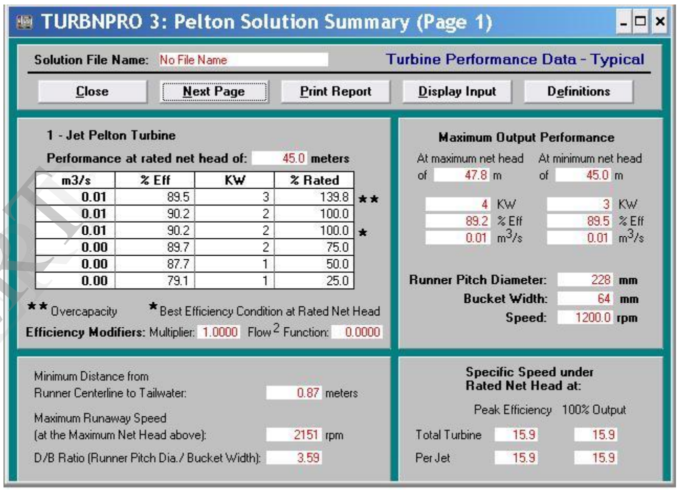

FIG 2. *Results from software analysis*

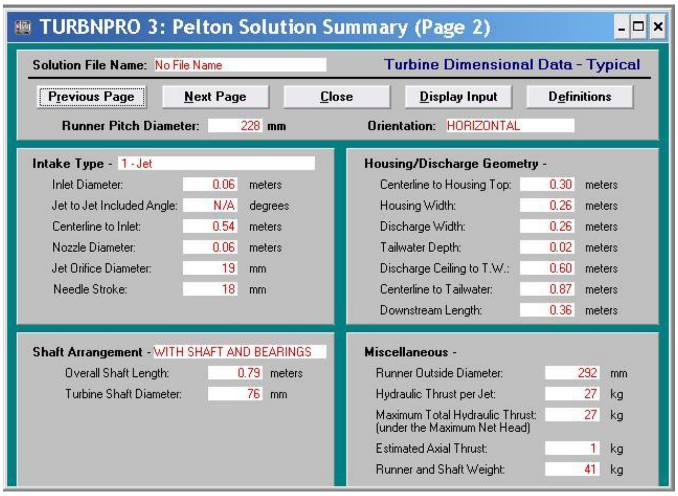

FIG 3. *Results from software analysis*

IV. MODELLING USING CATIA V5

The designed bucket specifications are used in modelling the bucket in CATIA V5. Using the various tools available in CATIA the bucket profile and the arms are modeled in a 3D view. This gives us a better picture of the bucket and the profile of the bucket. Some of the design steps are shown in the following figures.[8]

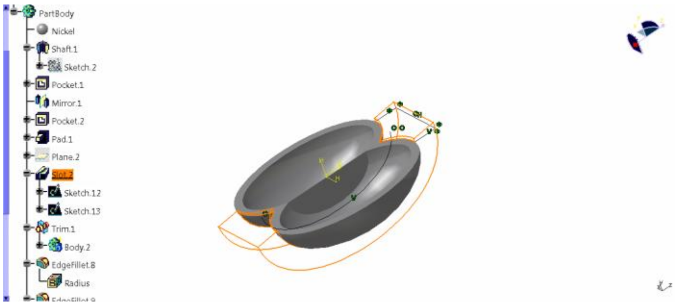

FIG 4. *CATIA drawing*

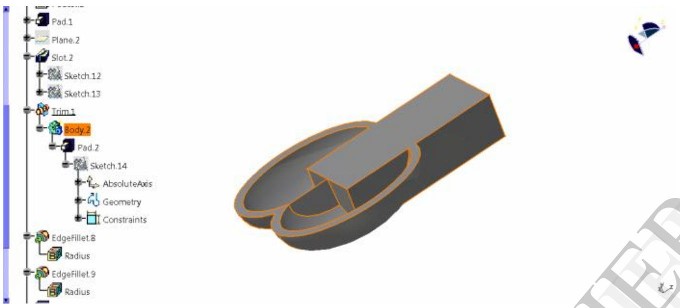

FIG 5. *CATIA drawing*

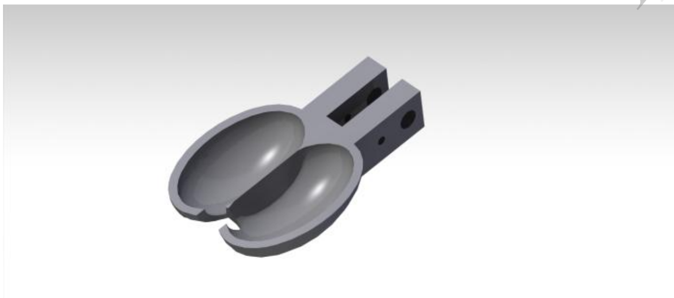

FIG 6. *CATIA drawing*

V. RESULTS AND CONCLUSIONS

A Pelton bucket model for micro-hydel applications was modelled in this study. The various design parameters where theoretically calculated using standard rules and equations. The calculated values of the design parameters were further verified with that of the values obtained by the design software TURBNPRO. The bucket of double ellipsoid profile and connecting arm is modelled using CATIA software. The study supports future works in this field of hydraulic turbines with provisions for further modification in the proposed CATIA design model.

VI. NOMENCLATURE

V_{jet}	Velocity of jet
H	Net Head
g	Gravitational constant
h	Height of bucket
U	Bucket speed
N	Speed of rotation in rpm
D_{run}	Diameter of runner
T	Depth of bucket
B	Width of bucket

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