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Performance Assessment of Pelton Turbine with Traditional and Novel Hooped Runner by Experimental Investigation

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Abstract- Hydro turbomachines are used since long as a water wheel, even be- fore knowledge of fluid mechanics. A newly developed concept at runner i.e. hooped is considered here for investigation purpose. This paper mainly focuses on the performance comparison between traditional and hooped type Pelton wheel turbine runner. The performance characteristic of any hydraulic machines describes the behavior of the machine under operating conditions. The down comer jet impingement to the rotor buckets provides more velocity and thereby impulse to a runner. Efficient performance behavior of any turbo machine under consideration can be easily estimated from performance curves for that machine under specified conditions. In case of impulse type machines, it relies on the quality of jet and other aspects of jet-vane interaction too. In the present inves- tigation, the performance of two types of runner has experimented on the same setup and flow conditions. The main objective of this paper is to compare the performance of a regular runner with a novel hooped runner. It has been found that hooped runner exhibits same characteristics with some loss of efficiency due to overweight and loss of energy at buckets due to restricted passage creat- ed by a hoop (flanges) but on contrary, the reliability and safety of buckets can be ensured. In additions, less deflection of the bucket can also be ensured under heavy jet force.

Keywords: Impulse turbine, Hooped runner, Down comer nozzle, Performance curve.

I. INTRODUCTION

Impulse turbines are simplest form of all other class of hydro turbo machines. It involves simple construction and high hydraulic efficiency than any other counterpart. As Pelton turbines are suitable high to medium head application jet with tremendous energy strikes on bucket. The traditional buckets have cantilever arrangement as ends bolted or welded to runner [1], as shown in Figure 2. From analysis of traditional runner it was found that due to cantilever arrangement of bucket it is much stressed [2]. In the modified turbine runner, the flange can be provided on both the side of centroid as shown in fig .3 to hold bucket on it.

After, involving flanges, it is possible to reduce the stresses in the runner bucket. Such an arrangement is useful to sustain load as well as impart long life to buckets at nominal cost of efficiency shown by FE analysis [3]. From the literature review, t is observed that, the hydrodynamic perfor- mance comparison between traditional runner and hoop runner for identical geometric and operating condition is not investigated experimentally. Hence, In the present in- vestigation, the aim is set to compare the hydrodynamic performance investigation of traditional runner with hoop runner, with experimental investigation.

In the conventional turbine runner, the force is acting on the bucket and it is sup- ported at the other end to the rotor. Hence, it forms the cantilever beam type of ar- rangement. It results, more deflection of the bucket while impact of jet and more gen- eration of bending stress on the bucket support. The stress field is also become criti- cal, as it is generating the variable stress field in the bucket support. The deflection of bucket and the stress development in the support can be minimized, if bucket is sup- ported throughout at its back side using Hooped runner. In the present investigation, the performance of the Pelton turbine is investigated using both conventional and hooped runner, and results of power and torque development are compared.

II. EXPERIMENTAL SETUP

The laboratory test setup consists of a tank at the bottom side with leak proof ar- rangement act as sump. In order to create artificial head a 5 HP motor along with a pump is attached to the line. Bypass arrangement is kept in case of low discharge condition. A globe valve is kept in order to create variable head by rotating it. A mag- netic flow meter measures flow rate in m3/hr discharged from pump.

A cooling line of ½" with accommodates two flexible hose along with plastic nozzle at end which issues jet of water on back of rotating drum for rope bake type dyna- mometer. To carryout uniform cooling over rotating drum line is pointed in and over the circumference of drum. A rope along with dead weight is wound against the spring balance to find net force acting on drum. With the aid of known net force, power developed or brake power can be evaluated for different operating conditions.

At initial stages of experiment head valve is kept completely opened and load is var- ied. For different gate opening reading is taken and plotted to compare performance of both runner. A magneto electric flow meter is attached over the control panel as can be seen in fig.1 measures flow rate in m3/hr. works on Faraday's principle of moving conductor through electromagnetic field .The water is considered here to be as an electrical conductor on the passage digital meter shows discharge through it.

A jet is set such a way through down comer nozzle that it strikes exactly at the mid plane of bucket and bifurcated in streams gliding over bucket surface and come out. For a hooped runner this passage is reduced due to flanges compared to traditional runner.

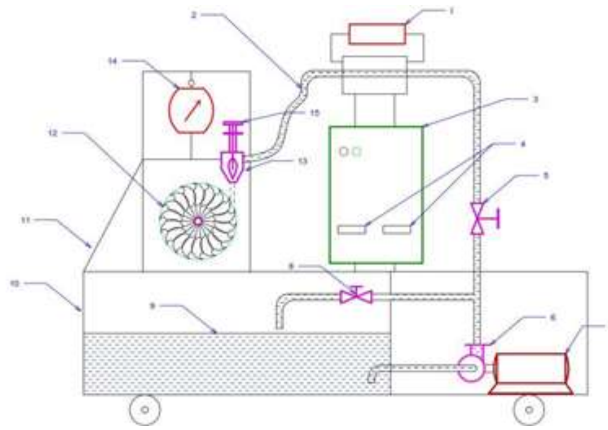

Fig. 1. Line diagram for experimental setup and flow path of fluid

Nomenclature of the components used in the set up

1. Electromagnetic flow meter 8. Bypass valve
2. Flexible hose for nozzle connection 9. Frame for setup
3. Control panel 10. Acrylic box for flow /process visual- ization
4. Speed and power input indicators 11. Turbine runner
5. Head control valve 12. Convergent hydraulic down comer nozzle
6. Centrifugal pump 13. Spring balance unit
7. Electric motor 14. Knob for gate opening

Fig. 2. Experimental setup with traditional runner

Fig. 3. Traditional Pelton wheel runner and bucket

The control panel accommodates display units for speed of runner and power indica- tor. It gives supply to electric motor which rotates the centrifugal pump in order to create specified head. Head can be varied by valve located at discharge line by open- ing and closing the same.

Figure 4 indicates the novel hoop type of runner. The same number of buckets with same design is used for better comparison. All other operating and design parameters are kept constant during experimentation with traditional and hooped runner cases.

Fig. 4. Novel hooped runner with bucket arrangement between two flanges

The electromagnetic flow meter, as shown in fig. 5, is used to measure the flow rate striking to the vane. The panel also indicates the runner speed in rpm and electric power input.

Fig. 5. Electric motor and electromagnetic flow meter with panel

III. NUMERICAL CALCULATION

Steel convergent down comer nozzle with inlet diameter of 40 mm and exit diame- ter of 17 mm is used for increasing kinetic energy of fluid different gate opening con- ditions.

For performance curve calculations carried out using Eq. (1) to (4) relations for both runner for different gate opening and as described earlier readings are taken at constant head of 45m with increasing dead weight cell in weight pan which intern de- crease the speed and there by power developed

Torque developed on the runner

$$T = \frac{(W - S) \times D_e \times g}{2} \tag{1}$$

Angular velocity of the runner in terms of rad/s

$$\omega = \frac{2\pi N}{60} \tag{2}$$

Mechanical power available on turbine shaft

$$P_d = T\omega \tag{3}$$

Hydraulic efficiency

$$\eta_h = \frac{P_d}{P_{in}} \tag{4}$$

IV. RESULTS AND DISCUSSION

The experiments have been done for both traditional and hooped runner. The ex- perimental results obtained are shown in Table 1 for traditional runner case and in Table 2 for hooped runner case. All experiments are performed with 100% gate open- ing with identical numbers of bucket.

Table 1.Observation table for Traditional Pelton wheel runner (D=320 mm , No of buckets =18,100% GO)

Volumetric flow rate (m^3/hr)	Speed of runner (rpm)	Dead weigh t (kg)	pring bal- ance Reading (kg)	Power input (kW)
9.01	1540	2	0.2	5.06
9.01	1489	4	0.6	5.08
9	1350	6	1.5	5.08
9.01	1278	8	2.5	5.08
9.04	1140	10	3.2	5.06
9.01	1116	12	4.5	5.05
9.06	1012	14	5	5.06
9.04	940	16	6.1	5.06
9.05	860	18	7.4	5.05

Table 2. Observation table for Hooped Pelton wheel runner (D=340 mm, No of bucke14ts =18,100% GO, No. of flanges =2)

Volumetric flow rate, Q (m^3/hr)	Speed of Runner, N (rpm)	Dead weight W(kg)	Spring balance Reading, S (kg)	Power input (kW)
9.0	1521	2	1	5.08
9.07	1416	4	1.5	5.08
9.0	1330	6	2.4	5.10
9.10	1256	8	3.3	5.13
8.99	1187	10	4.2	5.10
9.03	1112	12	5.4	5.10
8.92	1054	14	6.8	5.07
8.92	948	16	7.8	5.09
8.95	830	18	8.6	5.09

The comparison of power developed using hooped runner and traditional runner is shown in Fig. 6. Results indicate that, the power developed by hooped runner is rela- tively less compared to traditional runner. It may be because of flow restriction of the jet due to presence of side flanges. For a traditional runner maximum power devel- oped is 803.83W at 940 rpm. Whereas with hooped runner it is 673.92W at 830 rpm, so loss of power is not much significant here

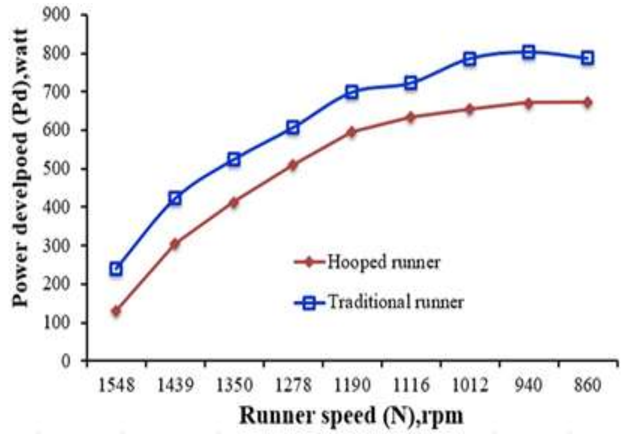

Fig.6. Variation of developed power at different runner speed

The water flow striking to the runner for traditional runner case and hooped runner case is shown in Fig. 7. For a traditional runner discharge remains almost constant but at lower speed discharge decrease for hooped runner.

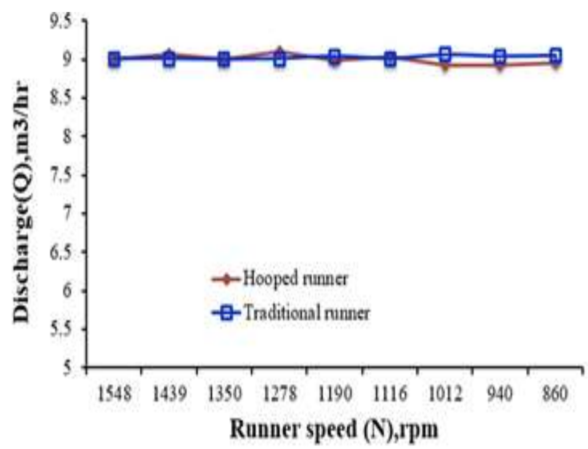

Fig. 7. Variation of discharge (Q) at different runner speed (N)

Experiments indicate a traditional runner provides maximum hydraulic efficiency of 72% at 940 rpm .Whereas that of hooped runner it is 61.40% at 830 rpm. So loss of power is not much significant here. The variation of hydraulic efficiency at various runner speeds is shown in Fig. 8.

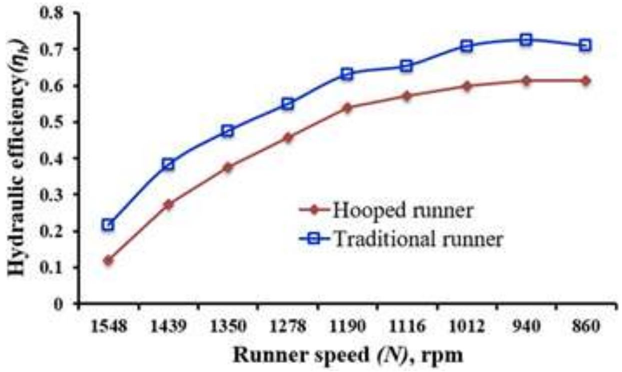

Fig. 8. Variation of hydraulic efficiency at various runner speed

From the experiments it is observed that, the torque development at the runner shaft is continuously decreases with runner speed. The maximum torque of 8.745 Nm is achieved at runner speed 860 rpm for traditional runner, and that of hooped runner is 7.755 Nm at 830 rpm. The variation of torque available at different runner speed is shown in Fig. 9.

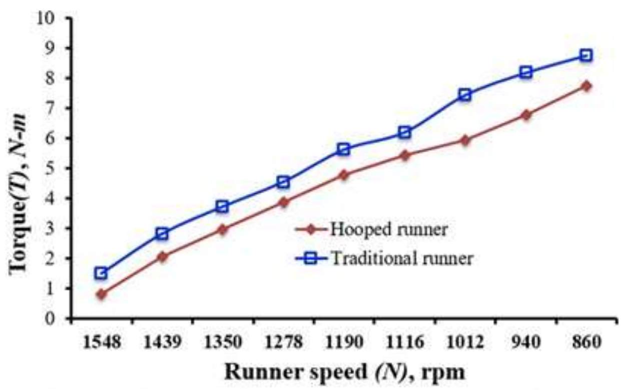

Fig. 9. Variation of torque available at different runner speed

V. CONCLUSION

From the experimental observation the nature of the graphs is observed almost same with no irregular pattern. There is little variation in hooped case compared to tradi- tional runner as flanges are attached additionally results in heavy weight of runner. So, more force is required to move heavy inertia. Secondly the flow passage is re- stricted due to flanges so fluid moves with wheel instead of gliding through buckets. In spite of less efficient behavior the other side is positive that makes it more useful for high head application. The strength of bucket is enhanced and more endurance of bucket is achieved under high head. Least maintenance cost is associated with such runner which is ultimately beneficial at over all stage instead of short term negative results.

The results indicate that the hydraulic efficiency and torque development using hooped runner is partially lower compared to the conventional rotor. However, the major advantage of the hooped runner is the improvement in the strength of the tur- bine runner. The conventional turbine buckets are supported at the one end, the water jet develops the force at other end. This condition created the bucket structure as a cantilever type of arrangement. Ultimately it results in higher stress development due to greater bending moment and more deflection of the bucket at free end. Also, it will develop variable stress field in the bucket structure, results in higher possibility of rotor maintenance. On other hand, due to continuous support with the use of Hoop, the deflection and variable stress development on the bucket support can be mini- mized.

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