Selection of Axial Hydraulic Turbines For Medium Head Micro hydropower Plants

[1]Santosh Chavan, [2]Vishwanath Panwar, [3]Rajkumar Rathod
[1]Assistant Professor, [2]Assistant Professor, [3]Assistant Professor

[1]Department of Mechanical Engineering Imperial college of Engineering & Research, Pune, India.
[2]Department of Mechanical Engineering, Rai Technology University Bangalore .India.
[3]Department of Mechanical Engineering Bhivarabai sawant Institute of Technology & Research, Pune. India

***Abstract* -** The creation of highly efficient hydro turbine for medium head micro hydro power plants is considered. The use of uncontrolled hydro turbines is a promising means of minimizing costs and the time for their recoupment. The model axial hydraulic turbine produced. The rotor diameter of this turbine is 200 mm. In the design of the working rotor, ANSYS CFX software is employed. Means of improving the efficiency of micro hydropower plants by optimal selection of the turbine parameters in the early stages of design are outlined. The energy efficiency of the hydro turbine designed for use in a micro hydropower plant may be assessed on the basis of the coefficient of energy utilization, which is a function of the total losses in all the pipeline elements and losses in the channel including the hydro turbine rotor. The limit on the coefficient of energy utilization in the pressure pipeline is the hydraulic analog limit, which is widely used in the design of wind generators. The proposed approach is experimentally verified at Engineering Institute. A model axial hydraulic turbine with four different rotors is designed for the research. The diameter of all four rotors is the same: 90 mm. The pipeline takes the form of a siphon. Working rotor R2, designed with parameter optimization, is characterized by the highest coefficient of energy utilization of the pressure pipeline and maximum efficiency. That confirms that the proposed approach is a promising means of maximizing the overall energy efficiency of the micro hydropower plant.

Keywords: Small hydropower, micro hydropower plant medium head micro hydropower plant, axial hydraulic turbine, siphons micro hydropower plant, pressure pipeline, hydraulic losses, and energy efficiency.

I. INTRODUCTION

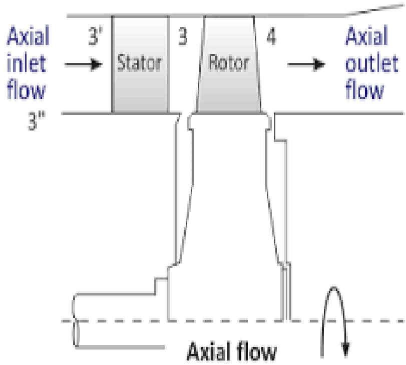
Globally, now a day's power requirement is more thus by using fossil fuels power cost becomes more but power generation at hydropower plants

[1] The cost of 1 kW of generated power at hydropower systems is among the lowest of fossils fuels and renewable energy sources with less environmental effects. Overall, the potential of small hydropower is very large around 33% of the total potential for hydropower [2] Most of this potential is represented by sources with a low head (1.1–2.8 m). At such sources, it is difficult to use large hydropower units. Therefore, mini hydropower plants are of most interest in those cases. At present, the large-scale introduction of low head mini hydropower plants is hindered by factors such as the following.

1. With low head, high energy efficiency of the mini hydropower plants is required. In other words, we must ensure the maximum efficiency of the mini hydropower plant as a whole, rather than simply its hydraulic components

The low power of the hydraulic system and hence the low power generation of micro hydropower plants extend the time for recoupment of their construction costs. That calls for minimization of the equipment costs. Hence, to address those concerns, we need simple and reliable mini hydropower plants. Uncontrollable hydro turbines and mass-produced asynchronous power generators are of interest for this purpose

[3] However, a problem arises here: mass-produced asynchronous generators are high-speed machines as a rule, whereas hydraulic turbines generate more torque at lower rotor speed. Accordingly, it is best to use an uncontrollable axial hydraulic turbine without an input guide for low head mini hydropower plants with a pressure pipeline [4]. An example of such a turbine—the propeller hydroturbine—was considered in[5]. A prototype (Fig. 1) has been created and investigated at Brno University of Technology. The design of the working rotor employs ANSYS Fluent software



The characteristics of this hydraulic turbine, tested on the test bench in Fig. 2, are shown in Fig. 3, where the reduced flow is rate; and is the reduced rotor speed. Here Q is the actual water flow rate through the hydraulic turbine, m3/s ;n is the actual rotor speed,rpm; D1 is the external diameter of the hydroturbine rotor, m ;His the head, m (utilized at maximum hydroturbine efficiency). The rotor diameter of the hydraulic turbine is D1=194mm. The parameters corresponding to the maximum efficiency (85.57%) are as follows:

Head of water pipeline Hp, m 3.53
Reduced rotor speed rpm 250
Reduced flow rate m3/s 1.99

In tests, the measurement error is ±0.27% for the head and ± 0.2% for the flow rate, when using laser Doppler measurements. An analogous turbine, with similar characteristics and a rotor diameter of 350 mm, was created at Sigma Center for Hydraulic Research [6].It follows from similarity theory that, if hydrodynamic similarity is attained—if the Strouhal, Euler, Reynolds, and Froude numbers are identical, the reduced characteristics of kinematically similar hydroturbines will be identical [7–10]. In practice, toobtain a satisfactory result, with acceptable precision, all that is needed is identical values of the reduced tur bine parameters and , which are derivatives of the Strouhal, Euler, and Reynolds numbers [9]. However, this does not resolve the question of the energy efficiency of similar hydroturbines in different microhydropower plants

Assessing The Energy Efficiency Of An Axial Hydraulic Turbine In A Micro hydropower Plant

Usually, for axial turbines, the selection of the parameters—in particular, the theoretical head—is based on maximizing the head without preliminary assessment of the overall energy efficiency of the microhydropower plant [11]. In the present work, we assess the energy efficiency of the hydroturbine in the microhydropower plant on the basis of the coefficient of energy utilization KN proposed in [12

$$K_N\,(h,\eta_h)\text{-}\frac{N_t}{N}\text{–}h\sqrt{1-h(2-}\,\eta_h) \qquad 1$$

where
N is the available power of the flux in the pressure pipeline;
Nt is the hydroturbine power; ηh is the hydraulic efficiency of the hydroturbine;
h= Ht/Hav is the coefficient of head utilization; Ht is the theoretical head of the turbine;
Hav is the available head of the pipeline

The function uniquely characterizes the energy efficiency of the microhydropower plant, since it expresses the proportion of the available hydraulic energy in the pipeline that is utilized by the hydroturbine. The maximum of in Eq. (1) corresponds to maximum hydraulic efficiency ηh= ηmax and optimal h, corresponding to zero first derivative of the function

$$h_{opt\text{–}}\frac{2}{3(2-\eta_{max})} \qquad 2$$

(2) Note that, for an ideal hydroturbine with ηmax= 1,we find that hopt= 2/3, and (KN)lim= 2×27–0.5 ≈0.3849. Hence, the maximum for any real hydroturbine is (KN)lim. This limit is the hydraulic analog of the Betz–Joukowsky limit, which is widely used in the design of wind generators [13].

Views of the test bench with a siphon pipeline in the hydraulic laboratory at JSPM's BSIOTR Pune.

SELECTION OF AXIAL HYDRAULIC TURBINES

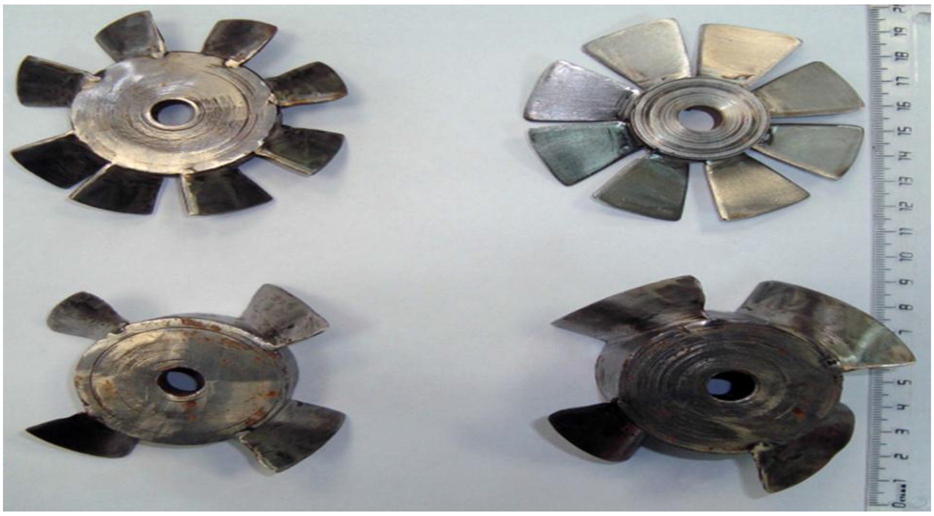
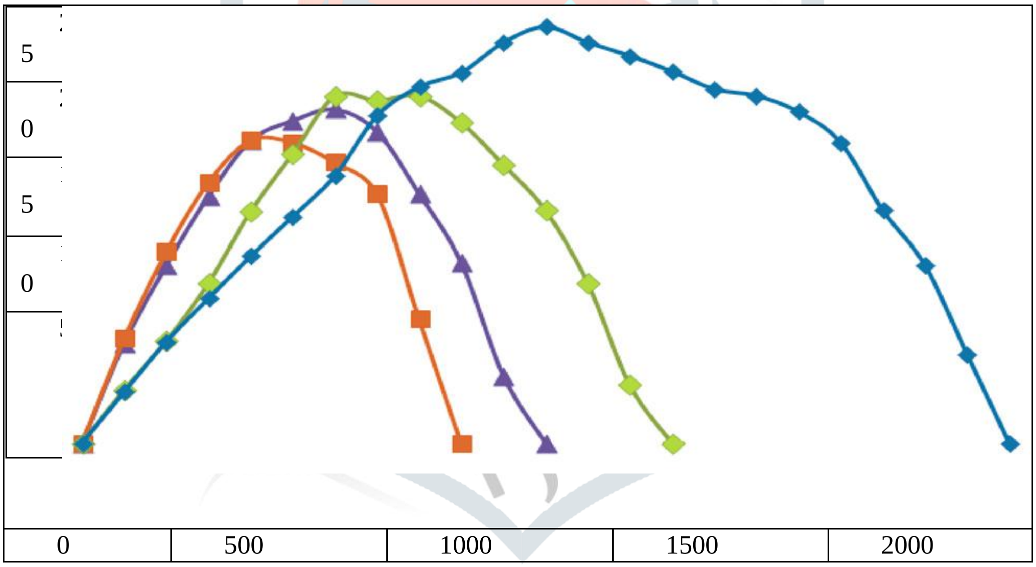


Fig.5 Working rotors R1, R2, R3, and R4 for the model propeller hydro turbine

In order to verify the proposed method of energy efficiency assessment, specialists at Moscow Power Engineering Institute have developed and produced several rotors (R1, R2, R3, and R4) with external diameter 85 mm but different hub diameter and different number of blades, for a model axial hydro turbine connected to the siphon pipeline in the test bench (Fig. 4).The siphon takes the form of a bent metal pipeline with conventional through cross section DN = 90. It is connected to the open upper hydraulic race, with a small height difference between the races Hav = 0.94 m. In the absence of the turbine rotor, the hydraulic loss coefficient is ξ = 6.52. The available hydraulic power of the siphon without the turbine rotor is N = 59.5 W. Like the hydro turbines in [5, 6], the model hydro turbine developed at Moscow Power Engineering Institute is designed without an input guide system.



N rpm

Fig. 6. Dependence of the power Nt on the rotor speed for the model propeller hydroturbine

Torque Mt (with3% error) and a sensor measuring the rotor speed n. The flow rate is measured by a diaphragm type instrument (to within0.3% when the error in pressure measurement is 0.4%). The experimental characteristics of the model hydro turbine are presented.

DISCUSSION OF THE RESULTS

Analysis of the experimental characteristics of the model hydro turbine Engineering Institute indicates significant difference both in the maximum hydro turbine power and in KN for the different rotors. The hydro turbines with rotors R1, R3, and R4 are similar, despite their very different shapes). The hydro turbine with rotor R2 is evidently the most efficient. This may be explained in that rotors R1, R3, and R4 were designed so as to maximize Nt. The geometric parameters of the blades are selected so that which corresponds

to maximum power. (Here ω is the rotor speed.) Rotor R2 is designed on the basis of the method here outlined—that is, on the basis of in Eq. (5). In fact, the numerical data in the table show that the actual value of (KN)max for rotor R2 is almost the same as the calculated value, whereas these values are very different for the other rotors

CONCLUSIONS

(1) On the basis of, we may not only assess the energy efficiency of the hydro turbine and pipeline in the micro hydropower plant but also take account of the relationship between the head and the flow rate of working fluid through the pipeline in the early stages of design. That relationship determines the turbine power. Hence, we may optimize the turbine parameters in the design.

The hydro turbine here designed is able to operate effectively at any micro hydropower plant with similarity of the conditions. It may also be scaled up by a factor of at least 10 on the basis of similarity theory, without loss of energy efficiency The hydro turbine here designed is able to operate effectively at any micro hydropower plant with similarity of the conditions. It may also be scaled up by a factor of at least 10 on the basis of similarity theory, without loss of energy efficiency.

REFERENCES

[1] V. E. Fortov and O. S. Popel', Energetics in Contempo_ rary World, (Intellekt, Dolgoprudnyi, 2011).
[2] R. Taylor, "Hydropower," in Survey of Energy Resources, Ed. by A. C. J. Trinnaman, (Elsevier Science, Oxford, 2004) pp. 199–232. http://dx.doi.org/10.1016/B978_008044410_9/50012_7
[3] Manuals and Guidelines for Micro_Hydropower Devel_opment in Rural Electrification, (Japan Int. Coop. Agency, 2009), Vol.
[4] A. Date and A. Akbarzadeh, "Performance investiga_tion of a simple reaction water turbine for power gener_ ation from low head micro hydro resources," Smart Grid and Renewable Energy, 3 239–245 (2012).
[5] F. PoChylý, M. Haluza, P. Rudolf, and F. Šob, CZ Patent No. 292197, 2003.
[6] J. Šoukal and R. Kubí ek, "Turbines for small hydroelectric station with low gradient," Energetika, 65 (1), 26–30 (2015).
[7] L. Ya. Bronshtein, Hydroturbine Constructor Handbook (Mashinostroenie, Leningrad, 1971) [in Russian].
[8] G. I. Krivchenko, Hydraulic Machines: Turbines and Pumps (Energiya, Moscow, 1978) [in Russian].
[9] G. V. Viktorov, Resemblance and Simulation in Hydro_machines (MPEI, Moscow, 1980) [in Russian].
[10] G. V. Viktorov, Hydrodynamic Theory of Lattices (Vysshaya shkola, Moscow, 1969) [in Russian].
[11] M. Varchola, P. Hlbo an, and S. rep, "The simple tur_bine for very small gradient," in Proc. 22nd Int. Conf. on Water Energetics, (HYDROTURBO 2014), Bratislava,Slovenská Republika, 2014, pp. 223–232.
[12] A. G. Parygin, A. V. Volkov, and A. V. Ryzhenkov, "Com_mentary on the efficiency of selected structural designs oflow head micro hydraulic power plants," Modern Appl.Sci. 9, 116–125 (2015). doi: 10.5539/mas.v9n4p116