International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.14, pp 276-280, 2017

Centrifugal Pump as Turbine: Experimental Report

K.Sekar[1], N.Krishna Kumar[2], P.Vasanthakumar[3]*

[1,3] Department of Mechanical Engineering, National Institute of Technology, Calicut, Kerala, India.
[2]Department of Mechanical Engineering, Himachal Institute of Engineering and Technology, Himachal Pradesh, India.

Abstract : In order to satisfy the needs of power demand, a suitable and attractive alternative of using centrifugal pump as turbine. Pump-as- turbine (PAT) is one of the most excellent alternatives for satisfying the energy demands and providing the electrical energy in isolated and rural areas. Financial growth through renewable energy and sustainable energy sector create more employment, which leads to communal improvement of the nation. One of the reasons for the micro hydro left immature is because of financial constraints. Although the running cost for micro hydro scale are very low, the initial capital cost are high particularly the turbines cost. Using pump-as-turbine (PAT) is an attractive and significant alternative. Currently, applications of PAT have been developed in villages, farms, irrigation systems and as small pump storage power stations.
Keywords : Centrifugal Pump, Pump as turbine, Hydropower schemes.

Introduction

Energy plays an important role in almost all areas of human and commercial activities, and it is particularly major contribution for those countries that are civilizing from economic point of analysis. The production of electrical power is necessary to elevate the economy's infrastructure of a country. Production of power through the non-renewable energy resource is relatively common[1]. Electrical power supply generated in world for about 20,053 TWh of installed capacity and that to hydro power contribute to approximately 16% in many countries it is the main source of power generation[2].

Chapallaz et al., investigated on conversion factors of PAT. Based on the specific speed of pumps, conversion factors graphs were developed. The conversion factors obtained from the graphs were set up to be within satisfactory limits even for the points far away from best efficiency point. Fernandez et al., explained the performance of a centrifugal pump in turbine mode at different revolving speeds with the help of experimental analysis in a hydraulic arrangement. The results showed that the turbine behaviour can be predicted to some extent from the pump behaviour and the performance curves were also obtained for PAT working at same speed and head.

Joshi et al., considered an easy approach to forecast PAT performance with a case study of a micro hydro location producing 25kW electric power from 5.5 meters of gross head. Then formulated a correlation between turbine and pump specific speeds to aid in pump selection for a particular hydro site.Derakhshan and Nourbakhshoffered some correlations to calculate the best efficiency point of a PAT based on pump hydraulic description using the experimental data. Four centrifugal pumps of industrial type with specific speeds from 14 to 56 (m,m3/s) were tested experimentally. The pumps with high specific speed needs lower ratios of discharge and head (for higher operating efficiency). But difference in power ratio were not relative to variations of pump‘s specific speed.

Suarda studied an experimental investigation by means of two small pumps to find out performances of pumps in turbine. It was accomplished that centrifugal pumps as hydro turbine was a more possible alternative solution. Singh and Nestmanninvestigated experimental study on three pumps with specific speeds of 18.2, 19.7 and 44.7. The prediction errors in the pump head at the maximum load position were significantly reduced, particularly for the lower specific speed PAT.

Nautiyal et al.,carried out an experimental analysis on a centrifugal pump having specific speed as 18. The best efficiency in turbine mode was set up to 8.53% inferior than best efficiency in pump mode. The experimental outcome of tested pump and other pumps were used to expand new correlations to attain turbine mode uniqueness of pump from pump mode characteristics by using their best efficiency point and specific speed in pump mode. Values obtained from the resulting correlations were compared with investigational results and outcome of other methods which showed very less deviation.

Experiments on PAT having specific speed range from 10 to 300 and developed a monogram to aid in the selection of a pump to be used as turbine for a particular site. This reduced the computation effort concerned in the choice of PAT [10].

End suction centrifugal pump (CALGON) type of 15.36 (m, m3/s) specific speed was experimentally tested to study the pump working in turbine mode characteristic. The experiment work showed that a centrifugal pump can acceptably be functioned as turbine without any mechanical problems. Compared to pump action, the pump operates at higher discharge and heads values in turbine mode. The BEP in turbine mode was found to be lower than BEP in pump mode. In the tested pump the BEP was only 39.0 % in turbine mode was with flow and head of 13.52 l/s and 30m respectively [11]. In global scenario electrification to rural areas, estimates huge initial capital cost especially in operating turbine. In order to satisfy the needs of power demand, a suitable and attractive alternative of using centrifugal pump as turbine[16-19].

Financial development through renewable energy creates more employment that leads to communal enhancement of the nation. Almost gifted non conservative energy for generating power in this condition is hydro machines. Hydro power is a non-conservative, non-polluting and environmentally being resource of power. The Ministry of Non-Conventional Energy Resources, Government of India documented various sites in North India, normally in the Himalayan Range for the growth of micro hydro power plants ranging from 15 to 50 kW [12]. In the present paper, the results of an experimental investigation of a centrifugal pump working as turbine was carried out. An ACH Monobloc Centrifugal Pump was tested in turbine mode at PAT test rig.

Experimental investigation of PAT:

Figure 1 show the experimental PAT Test rig. AnSouthern Agro Monobloc centrifugal pump of specific speed 23.5 (m, m3/s) was selected to function in the turbine mode. The centrifugal pump of 42 m head, 14.4 lps of discharge was tested in turbine mode. The pump functioning in turbine mode was experimented at the speed of 3500 rpm.

Results and discussion:

A number of modifications had been done so far in order to develop operation of centrifugal pump. But the investigation of pump using as turbine (Reverse mode of pump) was started in 1931. In this paper experimental investigation of radial flow ACH Monobloc centrifugal pump was carried out. From table.1 Best Efficiency points of turbine mode and pump mode was observed.From Fig.2 when discharge in the y-axis increases the head in the x-axis also increases and vice versa. The Best Efficiency point (BEP) of turbine operation was observed as maximum 9 m head at mass flow rate of 0.01cu.m /s and minimum 6 m head at mass flow rate of 0.009cu.m /s. The result shows that Head increases with discharge. From Fig.3 the result shows that maximum power of 0.182kW is achieved at Best Efficiency point (BEP) of 9m Head at mass flow rate of 0.01cu.m /s and minimum power of 0.086 kW at mass flow rate of 0.009cu.m /s.From Fig.4 the result shows that minimum efficiency of 15.08% at mass flow rate of 0.009cu.m /s. and maximum efficiency of 20.5% is achieved at Best Efficiency point (BEP) of 9 m Head at mass flow rate of 0.01cu.m /s. The power increases with discharge and head but potential energy is efficiently converted to mechanical energy at BEP only.

The dimensionless equations of Power number, Head number and Discharge number are considered for predicating pump as turbine. From table.2 PATs dimensionless BEP predicted by various researchers (Derakhshan& Nourbakhsh,2008) , (Stepanoff, 1947), (Sharma, 1998), (Alatorre-Frenk, 1994)) are tabulated and compared with experimental result when pump operated in reverse action.

Table.1 Experimental result of PAT- turbine mode

P	H	Q	N	T	I	O	η
Kg/sq.cm	**m of Water**	**Cu.m/sec**	**rpm**	**Kg**	**KW**	**KW**	**%**
0.6	**6**	**0.00981**	**1610**	**1**	**0.57**	**0.086**	**15.08**
0.7	**7**	**0.00981**	**1535**	**1.5**	**0.67**	**0.124**	**18.51**
0.8	**8**	**0.01009**	**1453**	**2**	**0.79**	**0.156**	**19.81**
0.9	**9**	**0.01009**	**1355**	**2.5**	**0.89**	**0.182**	**20.5**

Fig.1 Experimental Set up of PAT

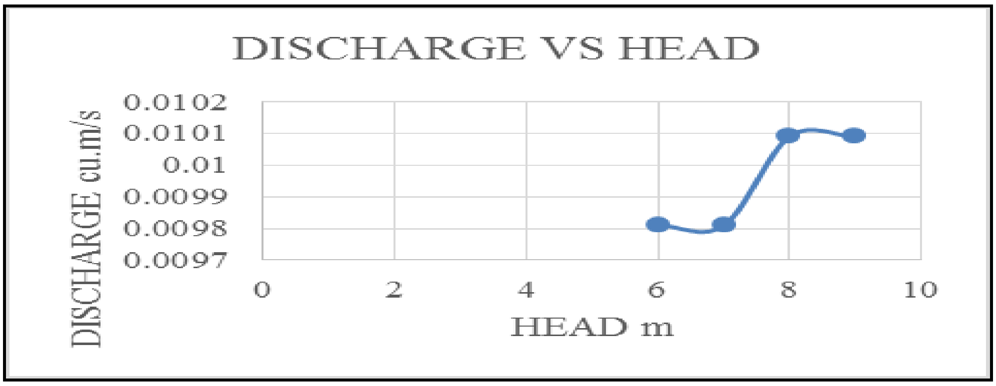

Fig.2 Discharge Vs Head – turbine mode

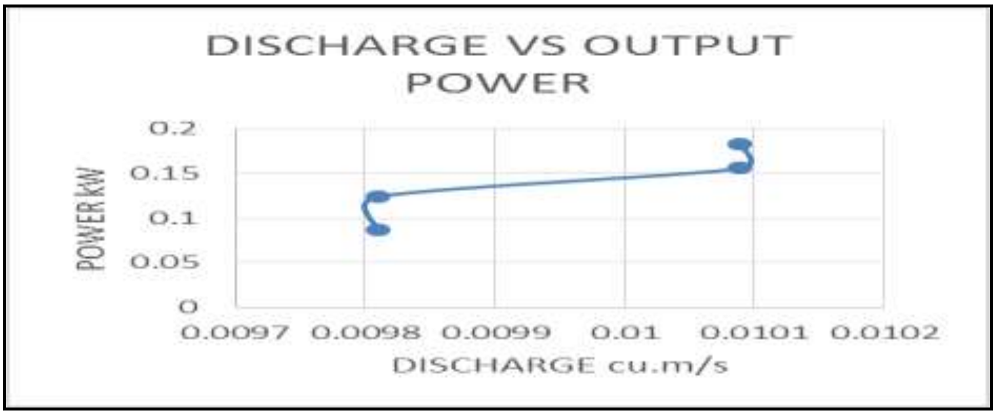

Fig.3 Power Vs Discharge – turbine mode

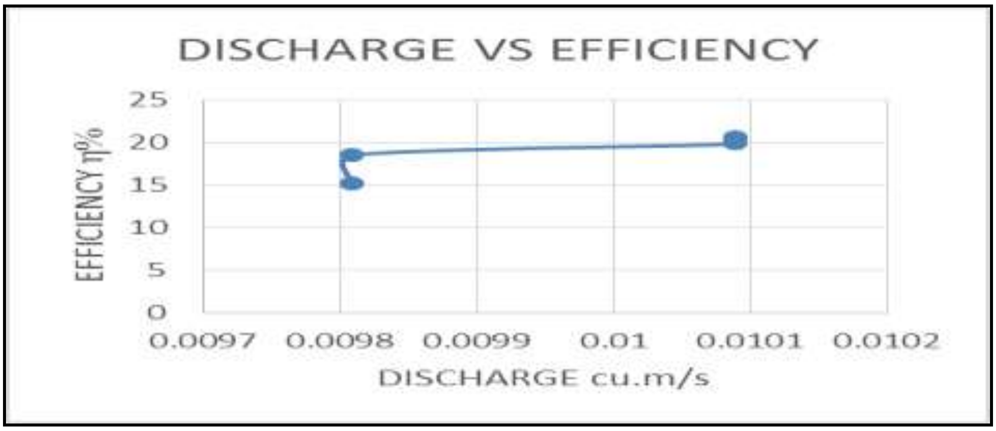

Fig.4 Efficiency Vs Discharge – turbine mode

Table.2 BEP predicted by various researchers

Pump $N_{s\,(m,\,m^3/s)}$ 23.9		
Experimental Results	ψ_t/ψ_p	1.05
	ϕ_t/ϕ_p	1.99
Derakhshan & Nourbakhsh 2008	ψ_t/ψ_p	1.31
	ϕ_t/ϕ_p	1.40
Stepanoff 1947	ψ_t/ψ_p	1.30
	ϕ_t/ϕ_p	1.14
Sharma 1998	ψ_t/ψ_p	1.37
	ϕ_t/ϕ_p	1.23
Alatorre- Frenk 1994	ψ_t/ψ_p	1.65
	ϕ_t/ϕ_p	1.63

Conclusion:

The Southern Agro Monobloc centrifugal pump of 23.5 (m, m3/s) specific speed was experimentally investigated to study the pump running as turbine. The experimental research clearly indicates that a centrifugal pump can reasonably be functioned as turbine without any mechanical troubles The BEP in turbine action was found to be lesser than BEP in pump action. In the tested pump the BEP was only 20.5 % in turbine mode was with head and flow of 9 m and 0.01cu.m /s respectively. The future works on PAT will be concentrated on modifications of impeller and volute casing to find the BEP of pump action and turbine action.

References

1. H. Nautiyal and A. Kumar, "Reverse running pumps analytical, experimental and computational study: A review," Renewable and Sustainable Energy Reviews, vol. 14, pp. 2059-2067, 2010.
2. S. V. Jain and R. N. Patel, "Investigations on pump running in turbine mode: A review of the state-of-the-art," Renewable and Sustainable Energy Reviews, vol. 30, pp. 841-868, 2014.
3. J. Chapallaz, P. Eichenberger, and G. Fischer, "Manual on Pumps Used as Turbines; MHPG Series; Vol. 11; Friedr," Vieweg & SohnVerlagsgesellschaftmbH, 1992.
4. J. Fernandez, E. Blanco, J. Parrondo, M. Stickland, and T. Scanlon, "Performance of a centrifugal pump running in inverse mode," Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, vol. 218, pp. 265-271, 2004.
5. S. Joshi, A. Gordon, L. Holloway, and L. Chang, "Selecting a high specific speed pump for low head hydro-electric power generation," in Electrical and Computer Engineering. Canadian Conference on, pp. 603-606, 2005.
6. S. Derakhshan and A. Nourbakhsh, "Experimental study of characteristic curves of centrifugal pumps working as turbines in different specific speeds," Experimental thermal and fluid science, vol. 32, pp. 800-807, 2008.
7. M. Suarda, "Assessment Performance of Pumps as Hydro-Turbines," Jurnal Energi Dan Manufaktur, vol. 3, 2009.
8. P. Singh and F. Nestmann, "An optimization routine on a prediction and selection model for the turbine operation of centrifugal pumps," Experimental Thermal and Fluid Science, vol. 34, pp. 152-164, 2010.
9. H. Nautiyal, V. Varun, A. Kumar, and S. Y. Sanjay Yadav, "Experimental Investigation of Centrifugal Pump Working as Turbine for Small Hydropower Systems," Energy Science and Technology, vol. 1, pp. 79-86, 2011.
10. T. Agarwal, "Review of Pump as Turbine (PAT) for Micro-Hydropower," International Journal of Emerging Technology and Advanced engineering, vol. 2, pp. 163-168, 2012.
11. N. Raman, I. Hussein, K. Palanisamy, and B. Foo, "An experimental investigation of pump as turbine for micro hydro application," in IOP Conference Series: Earth and Environmental Science, p. 012064, 2013.
12. V. Patel, S. Jain, K. Motwani, and R. Patel, "Numerical Optimization of Guide Vanes and Reducer in Pump Running in Turbine Mode," Procedia Engineering, vol. 51, pp. 797-802, 2013.
13. SharmaR.L. 1998. Pumps as turbines(PAT) for small hydro. In:Proceedings of the international conference on hydropower development in Himalayas:137-46
14. A. Stepanoff, Centrifugal and axial flow pumps: John Wiley &Sons, New York, 1947.
15. C. Alatorre-Frenk, "Cost minimisation in micro-hydro systems using pumps-as-turbines," University of Warwick, 1994.
16. P.Vasanthakumar and A. Arulmurugu, "Investigation of Centrifugal Pump as Turbine: A Review Report," International Journal of Engineering Research and Technology, vol. 3, 2014.
17. A. Arulmurugu and P. Vasanthakumar, "Numerical Investigation of Centrifugal Pump as Turbine" Advances and Applications in Fluid Mechanics., vol. 17:147-163, 2015.
18. P.Vasanthakumar, Dr.S.Karthikayan, J.Krishnaraj, M.Palanisamy, T.Vinoth., 2015.Power Optimization of Rotodynamic Pump in Turbine Mode Operation for Pico Hydropower Plants. Advances in Natural and AppliedSciences.9(17); Pages: 291-295, 2015.
19. P. Vasanthakumar, J.Krishnaraj, S. KarthikayanT.Vinoth, S.K.ArunSankar “Investigation on Reverse Characteristics of Centrifugal Pump in Turbine Mode: A Comparative Study by an Experimentation and Simulation” Materials Today: Proceedings, 4:693-700, 2017.

*****