Development and testing of in-stream domestic turbine at building scale

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Abstract : All In stream turbine may be a source of renewable energy that empower mechanical, metropolitan and rural areas to generate clean, dependable, low-cost power from their potential available. Here the core rotating part of the turbine is fabricated by 3D printing and fixed to turn axially inside a round and hollow pipe beneath the control of liquid streaming either heading there through the liquid will strike the edges of the turbine and in this way giving the rotating movement to the generator shaft. The edges of the turbine are turned in a plane that is slanted at a relative point to the rotational pivot of the central shaft. The edges of the turbine are outlined and analyzed by computational fluid dynamics considering the aero-foil section to optimize and decrease the resistance of the hydrodynamic flow also experimental work has done to find out the power output and electricity generation.

1. Introduction

Water possess a lot of kinetic and pressure energy flowing vertically through any pipe. H. Zainuddin et al emphasized on development of hydro generation system by using flowing water which is distributed to houses [1]. Vicente Leite et al researched on the design and implementation of a small hydropower plant against a run-of-river. It was designed for demonstration purposes which aimed to be a framework of wide spread dissemination of renewable energy sources and energy efficiency [2]. J. Chen et al studied to help water supply utilities improve water supply management. He helped in monitoring water pipeline leakage in order to provide clean water to residents, many instruments are installed to regulate hydraulic and water quality conditions along the water pipelines [3]. Shaleen Martin et al studied on the fact that India being a developing country is constantly in search of an alternative source of energy towards generating electricity [4]. Akhilesh Arvind Nimje et al researched on the fact that electricity is the most versatile and widely used form of energy. He concluded that global demand for electricity is continuously growing. As per survey report (January 2014), 7.5 crore Indian households don’t have access to electricity [5]. Vyom Pathak et al emphasized on a spherical turbine configured to rotate within a cylindrical pipe under the power of fluid flowing either direction through the fluid will strike the blades of the turbine and thus providing the rotary motion to the shaft coupled with a generator [6]. Sathit Pongduang et al researched on the helical turbine used for tidal energy. He has studied and reported its performance and characteristics for free water flow electric turbine development [7].

2. Design of the system

2.1. Selection of turbine blade profile:

From the previous works that we studied we found that NACA-0015 profile has given the best moment generation. The turbine named by Darrieus having NACA-0015 profile had a pressure increase of 1.4% against a 9% increase in moment. When the other turbine are examined, it was observed that the 20° twisted Gorlov turbine with NACA-0018 profile is the second highest in moment generation and it is the least in terms of loss of pressure [Evaluation of in-pipe turbine performance for turbo solenoid valve system]**.** Hence we have selected NACA0015 profile over other profiles for the turbine blade that is going to be created. The profile of NACA0015 was generated from NACA aero-foil plotter website. From the co-ordinate point data obtained the NACA0015 profile was generated as shown in figure below

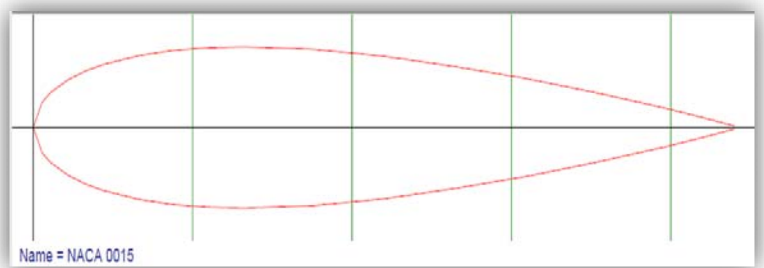

Figure 1. NACA0015 profile for turbine blade cross-section

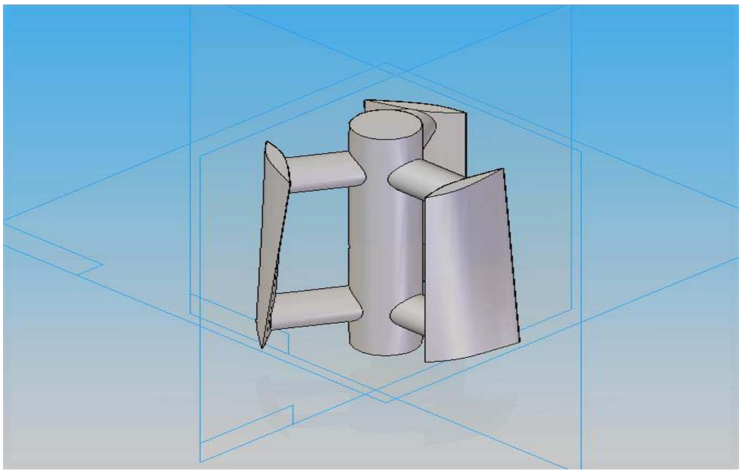

Figure 2. CAD model of Gorolov turbine

The created model later was stored in .igs file format which is the standard file format accepted by most of 3D printing machines.

3. CFD Analysis

The design and prediction capacity of the CFD has been confirmed to be effective and instructive in many areas, such as fluid machinery, aerospace and atmospheric environment and other fields. The CFD method also has been widely used in the design of vertical axis wind turbine. We have used the ANSYS CFD package, which is considered to be one of the best fluid design software packages nowadays, is applied to simulate the vertical axis water turbine. The stability of the chosen discretization is generally established numerically rather than analytically as with linear problem. Special care must be taken to make sure that the discretization handles uneven solutions gracefully. The Euler equations and Navier-Stokes equations both admit shocks and contact surfaces.

3.1. Post-processing:

After about 4200 iterations we observed the solution was converging and iteration was stopped at that point to obtain the results. we were able to obtain the simulation for 0.8s, the below figures show the flow of water around the turbine blades and position of turbine at different time intervals.

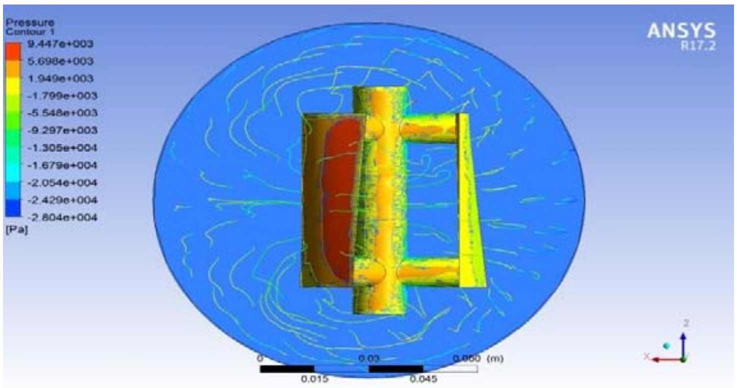

Figure 3. Pressure distribution on turbine body

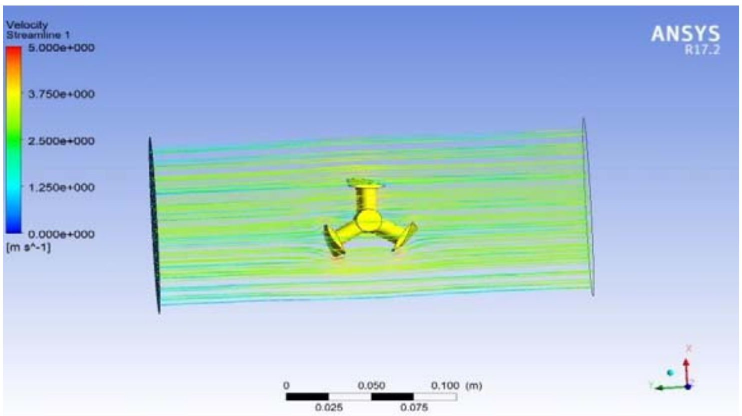

Figure 4. Position of turbine blades at 0.3s

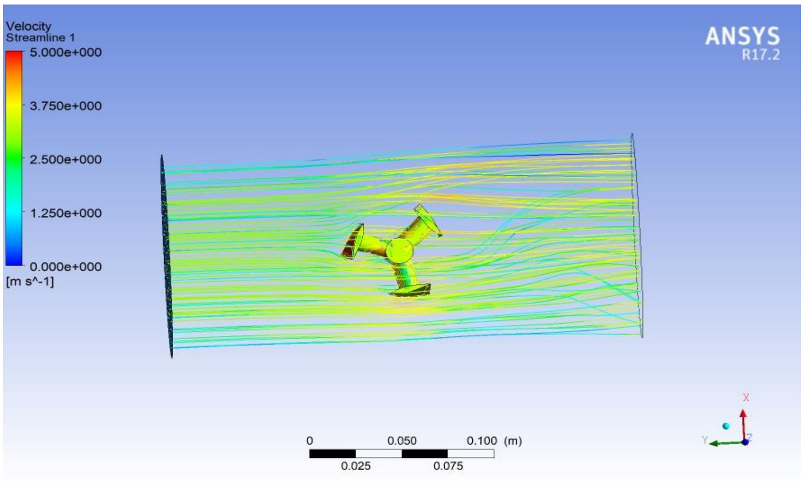

Figure 5. Position of turbine blades at 0.8s

4. Fabrication

The fabrication of the unit was started by selecting the suitable material for the turbine blades by comparing material properties of various materials such as aluminum, stainless steel, plastic etc. As the main importance of the fabrication process was to use a material which can handle water impact, pressure and resistant.
Material used: ABS (Acrylonitrile Butadiene Styrene)
Method used: Additive Manufacturing Technologies (AMTs, also known as 3D printing techniques)

Figure 6. 3D printed model of Gorolov turbine

By properly machining the nylon rods for required dimensions, turbine model was placed inside the 4 way joint where nylon caps serve as holding element of both turbine shaft as well as bearings. To one end extra stainless steel shaft was attached as an extension to the turbine shaft. Later this shaft is coupled to the generator via coupler, inside view of turbine assembly is shown below

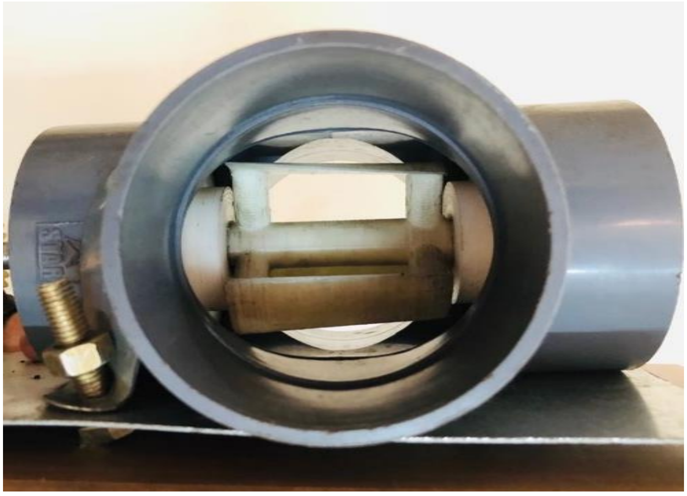

Figure 7: Inside view of turbine assembly

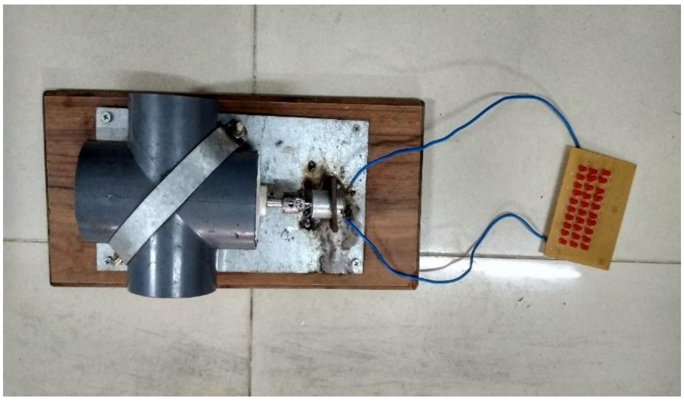

Figure 8: Final assembled model

5. Experimental Setup:

As the main aim of our project was to create in-stream turbine for water pipelines (3 inch) coming down from hill stations the same conditions were needed to be created , if not same at least similar conditions were needed to be created to check the better workability of model created. The flow of water coming down from hill stations will be constant most of the times. Hence to realize this condition a Sintex tank with approximately 1.2m height that could hold 1000 litres of water was used in our test. To regulate the flow gate valve was used. A PVC pipe of 5m long was used to channel the flow towards the turbine setup.

The tank was placed at approximately 1.7m height. Gate valve was connected to tank outlet. At the other side of gate valve a hose pipe was connected which is used to vary the angle of inclination of pipe. The hose pipe was inserted inside 5m long PVC pipe. Whose other end was connected to turbine setup. Later tank was filled completely, earlier to which gate valve was closed. The setup is shown in figure below

Figure 9: Experimental setup

6. Results and Discussions

The testing and analysis of in-stream Gorolov turbine was conducted for different conditions like varying the slope angle which in-turn varies the velocity, discharge and hence the power output. The power output thus obtained was compared against the theoretical calculated value. We found out that there was practical deviations compared to the calculated value, due to several factors like

1. Loss of head due to pipe losses which arises from resistance in pipe fittings, elbows and other structural attachments.
2. The 4 way joint used here created back pressure due to its structural restrictions.

The observations made from experimental and theoretical values are tabulated below:

Table 1: Tabular column of results

Sl. No.	Slope angle In degrees	Theoretical		Experimental	
		Discharge In L/s	Power output (Watts)	Discharge	Power output (Watts)
1	20	8.7	28	3.2	16
2	25	9.85	40	6.1	23
3	30	10.92	53	7.3	34

7. Conclusion

This turbine is now successfully capable of using gravity fed water to produce electricity within a pipeline with uninterrupted flowing fluid. Design and development of blade profile of the turbine was accomplished according to requirement which is a critical to validate its design. An inferior turbine design has also been fabricated by using a 3D printing technique (FDM). A Computational Fluid Dynamics (CFD) analysis was run on the final design of the turbine and the power output for given input conditions has been realized. This new system can be successfully used to produce low cost electricity which can be a boon to our society and ultimately the entire world.

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