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Review of Hydrokinetic Turbine Technology

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Abstract – Renewable energy can be produced by using kinetic energy of the flowing water such as rivers, ocean currents and tidal flows. The kinetic energy can be transformed to the power by hydrokinetic turbines. There are many different designs of hydrokinetic turbines for tidal applications, rivers and pipe. The working principle of the hydrokinetic turbines are similar with wind turbines. In this study, hydrokinetic turbine technology have been reviewed. Furthermore, turbines have been compared according to their working principle which are vertical and horizontal, and according to operating conditions such as open channel and pipeline. The hydrokinetic turbine in pipe is more predictable and environment friendly. This system can generate electric independent from nature because of closed system. It means that the velocity and discharge of the water can regulate manually. Another advantage of the hydrokinetic turbines is that, it can take replacement of the pressure breaker valves on the water supply network systems to produce power. Energy can be generated while pressure is reducing in the water distribution system. Moreover, Gorlov turbine is placed in the pipe than it is analysed by ANSYS Fluent software. Results indicates that, this new technology can be used in water distribution systems with pipes. But optimizing is needed to create more efficiency power.

Keywords – Hydrokinetic Turbine, Renewable Energy, Pipe, Water Network System, Open Channel

I. Introduction

Renewable energy is under investigation by many researches because of limited fossil fuels, greenhouse effect and increasing prices. The hydropower is the most efficient and largest renewable energy source relative to other energy sources. Furthermore hydropower is the most preferred energy source due to being predictable [1]. In addition, in- stream energy systems are less exposed to weather conditions unlike other energy conversion systems like wind and solar. [4]

Hydrostatic and hydrokinetic plants are two principal methods which applied for generate energy from water. In conventional approach is the hydrostatic plants which produce electricity by storing water in reservoirs to create a pressure head and extracting the potential energy of water [2]. Also there is need to dam, penstock and reservoir for the hydrostatic approach. On the other hand, hydrokinetic energy conversion system requires little or no elevation for generate power from flowing water [3]. Moreover there is no need to any massive construction for hydrokinetic turbines.

Hydrokinetic systems transform the kinetic energy to the beneficial energy by using flowing water like in canal, wave or etc. The system works same with the wind energy conversion systems except type of fluid because of using water [5]. These turbines are also named water current turbine, ultra-low or zero head hydro turbines [6]. Generally, turbines are categorized into two main subject horizontal and vertical axis turbines, according to their rotor axis.

The horizontal axis turbines have axis parallel to the fluid flow and they have propeller type rotors. They are also called axial flow turbine. Horizontal axis turbines generally use for in tidal energy converters and works with similar to wind turbines as concept and design.

If turbine rotating shaft is perpendicular to the flow, the turbine called as vertical axis turbine. Vertical turbine design begins with Darrieus turbine and it is operated by water drag force[11]. Vibration is the disadvantage for the vertical turbines while, independent direction of incoming water is the advantage.

Cross flow turbines have rotor axis perpendicular to the water flow, but parallel to the water surface [5]. These turbines are also known as floating water wheels. They are mainly drag based devices and are less effective than their lifting-based counterparts. The use of large amounts of material is another problem for these turbines. Darrieus turbines with cross flow arrangements may also fall under this category. Darrieus turbines are the preferred between from type of vertical axis turbines. H-Darrieus are the most prominent turbine but curved Darrieus turbines are not prevalent [5].

In this study hydrokinetic turbines were reviewed with respect to their operating axis. Also, Gorlov type turbine was analysed in pipe by ANSYS Fluent software.

II. Materials and Method

There are different types of hydrokinetic turbines according to their axis as, horizontal axis, vertical axis and cross-flow turbine. Different design of horizontal axis turbines are shown in figure1 [5].

According to study which analyzed with CFD simulation by L.T. Conteras at. al. was showed that inclined axis turbine with 30^o was exposed lower drag force but it generated lower power than horizontal turbine. The estimated reduction of the power was found almost 30% [7].

Another investigation for horizontal hydrokinetic turbine was studied in river current by T. T. Rajaonary. Turbine was placed in a duct to increase the power of turbine. According to results, the power of turbine with ducted higher than bare turbine about 40% [10].

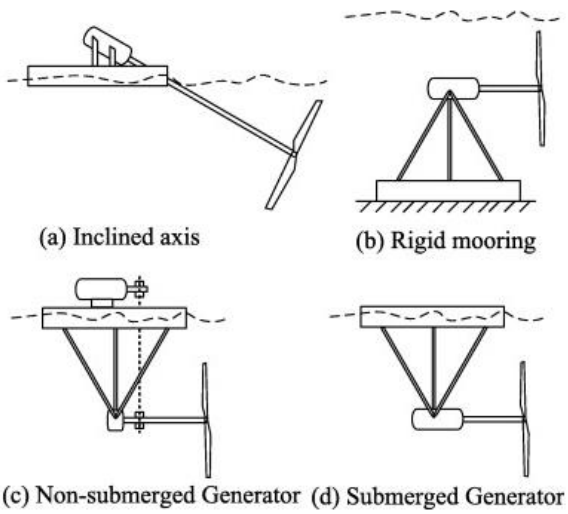

Fig. 1 Horizontal axis turbines [5]

If the rotational axis of turbine is perpendicular to the flow direction, the turbine is called vertical axis turbine. Darrieus(a.b,c), Gorlov(d) Savonius(e) turbines are the most common turbine types for vertical axis which are showed in figure 2.

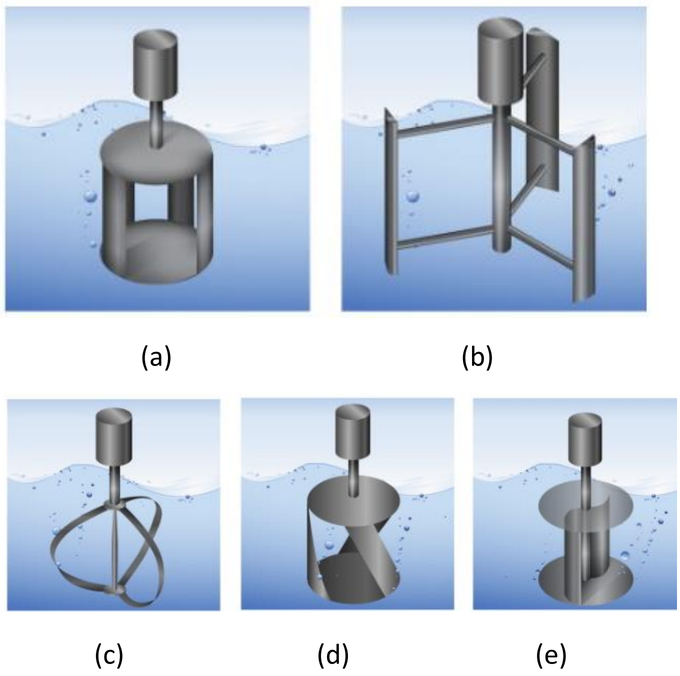

Fig 2 Vertical Axis Turbines [8]

The experimental and simulation with ANSYS Fluent study for vertical axis turbine in pipe was carried out by J. Chen at. al to water pipeline data monitoring. Turbine was designed for 100mm pipeline and water velocity was 1.5 m/s. In study 20 different types of turbines were tested. Then, the maximum power output was found 88.2 W between all attempts but the results were found different for experimental and simulation [9].

The tip speed of the blades over flow velocity is called tip speed ratio (TSR). Tip speed ratio is the important parameter to estimate the power coefficient (Cp). It is defined as equation(1).

$$\lambda = \frac{\Omega\, R}{v} \qquad (1)$$

λ is the TSR, R is the sweeping area radius (m), Ω is the rotational velocity (rad/sec) and v is the velocity of stream (m/s).

The power of coefficient (C_p) indicates the efficiency of the turbine and it is defined as;

$$C_p = \frac{P_t}{P_W} = \frac{T\Omega}{0.5Av^3} \qquad (2)$$

P_t is the turbine power and P_w is the flowing water turbine. Torque, angular velocity, area, and velocity of flow are expressed as T, **Ω**, A and v respectively.

Gorlov type 4 bladed turbine is analysed as horizontal in pipe by using ANSYS Fluent software at the present study. The distance of inlet and outlet of the pipe are estimated 4 and 8 times of the turbine diameter from the middle of the turbine.

Blades of turbine are helical and their cross section is NACA0018 airfoil shape which shown in Figure 3. Pipe diameter and length 1.3 m and 12 m respectively. Furthermore, the flow velocity (v) is equal to 1m/s and radius of blades (R) is 0.5 m for the simulated design.

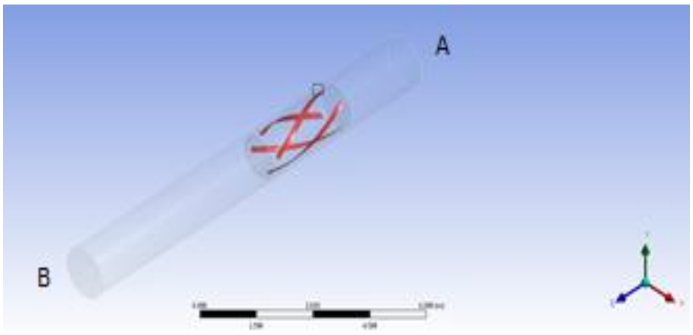

Fig. 3 Hydrokinetic Turbine in Pipe

Face and body mesh are generated to create elements and nodes on the geometry. Also inflation is placed to take precise results at the around of blades. To evaluate the quality of mesh skewness, element quality and aspect ratio are presented at table 1 with number of elements and nodes.

Table 1. Mesh Statistics

Elements	**Nodes**	**Skewness (Avg)**	**Element quality**	**Aspect ratio(max)**
12604547	2729570	0,24	0,78	69

Mesh body is generated as figure 4. As seen in the figure, grids are dense at the zone which placed the blade. Dense meshes created to estimate more accuracy results by using body mesh tool.

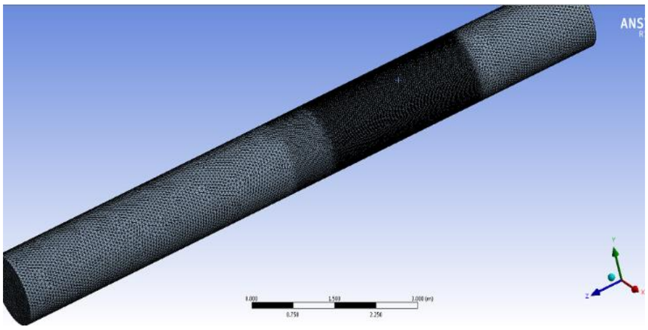

Fig 4 Mesh Body of Domain

III. Results

In table 2 shows the torque and Cp value for simulation of turbine which placed in pipe. Cp value is get from the equation(2). Torque is calculated by ANSYS Fluent software directly.

Table 2. Input and Output Values of Simulation

Flow Velocity(m/s)	TSR	T (N.m)	Cp
1	2	47,37	0,13

Velocity distribution in the pipe is demonstrated in figure 5 as m/s. The flow in the pipe is come from –Z direction to the +Z direction. Velocity distribution is top view of the middle of pipe.

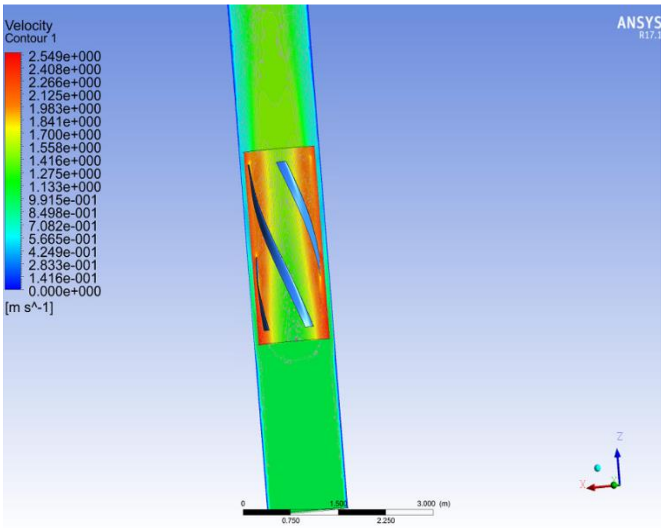

Fig 5 Velocity Distribution

The pressure distribution at blades is showed in figure 6 as isometric view of the pipe. Colours indicates from red to the blue as highest from lowest magnitudes in unit of Pascal. Plane, is the cross section of the pipe, at the beginning of the blades.

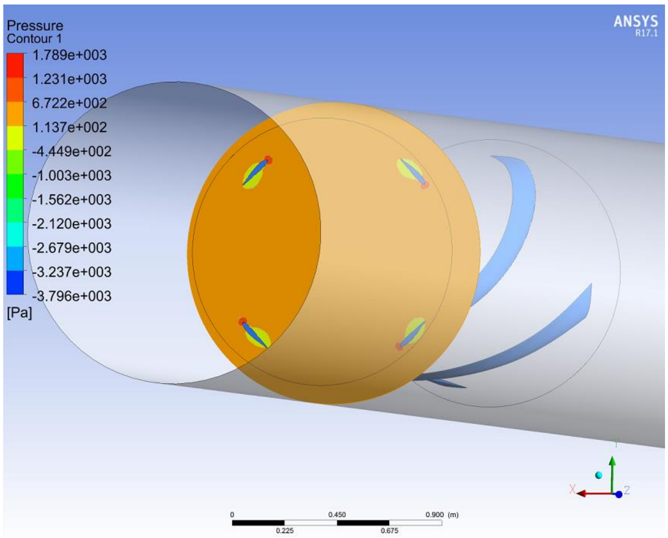

Fig 6 Pressure Distribution

IV. Discussion

Results at the table show that, power coefficient is even if small amount of power, water can use to generate power with hydrokinetic turbine in pipe. Velocity of water can be increased to generate more power.

Also velocity distribution on blade zone is higher than input flow velocity. Than it returns to initial velocity as shown in figure 5.

Pressure is higher at leading edge than trailing edge as expected. This situation provides rotational motion to the turbine as counter clock wise.

V. Conclusion

In this study, general properties of hydrokinetic turbines is presented. Also types of hydrokinetic turbines explained briefly and some studies are explained. Thereafter, Gorlov type hydrokinetic turbine is placed in the pipe than it is analysed. ANSYS Fluent is used for analysis. According to results the power can be generated by using this system. However it is needed more proper design to get more efficiency results. Also more turbines can be place in the pipe as serial to generate more electricity.

This system also provides to decrease the pressure in the pipe like a pressure break valve. Therefore it can be use for water distribution systems, so the energy waste is prevented. Because pressure break valve absorb the energy but turbine converts to electrical energy.

Moreover, velocity and discharge can be adjusted by manually because of closed system. Open channel, tidal flow and channels doesn't have like this possibility. Their discharge depends on climate rainfall etc. There is no any external effect like sediment, fish and trash for the pipe system.

Hydrokinetic turbine is new technology to produce clean and renewable energy. However, it is needed to optimizing for generate more and beneficial power. Also different cases, as flow velocity and TSR, can be tried to get best power coefficient.

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