# DESIGN OF A PROTOTYPE HYDRO COIL TURBINE APPLIED AS MICRO HYDRO SOLUTION

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## Abstract

This study deals with the effort to release new revolution of renewable energy concept. Key issue in generating hydro power from low head, low flow sources until now has been impractical, expensive in efficient and complex technology. The idea of using Hydro Coil instead of turbine gives an economic advantage that it is relatively cheaper. The apparatus allows us to exploit sides that would not be practical at all for conventional small hydroelectric power.

Hydro Coil turbine in experimental prototype has been designed, built and tested. The turbine includes 4 inches acrylic with ribbon-like curved shape insert, which present a gradual curve of approximately 70 degrees from the axial flow of water progressing to a tightly curved angle perpendicular to the flow of water at the exit point. The gradual curve is used to reducing the axial velocity of water, thereby further as consequence of transfer energy from water to ribbon, thus the central axle and ribbon rotated. This rotation is initiated at the low frequency coil, with energy incrementally transferred as water, hitting the low frequency coil, turning the ribbon slowly, progressing gradually to higher frequency, tight coil where maximal energy to the transfer occurs.

Characteristics and efficiency of Hydro Coil turbine can be identified after laboratory experimental already finished. Turbine efficiency in 92.93% of this prototype exceeds expectation in the experiments. It thus demonstrates the promising potential of Hydro Coil technology to extract power from incoming water flow in low head sources.

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## 1. Introduction

The increase in population and industrial upgrading in Indonesia led an increase in energy demand. It is obvious that the dominant energy source used in the community is electric energy due to the ease of converting certain energy into other forms of energy. Meeting the needs of electricity which constitutes current problem in Indonesia is still not evenly distributed to all levels of society. Moreover, Indonesia geographically consists of thousands of islands spreading from Sabang to Merauke. This may lead to the more uneven spread of electrical loads in each area because of the high cost of the development infrastructure and the transmission of electric energy. Meanwhile, dependence on fossil fuel consumption is still very high for application of electric power generation. There are many disadvantages of fossil fuels such as global warming, environmental damage, disruption of biological balance, and etc.

The comparison between the demands for electrical energy needs and the availability of electrical energy is not balance, and hence creating a problem related to energy crisis. Sooner or later this energy crisis problem will increase and solutions for the problem should be proposed and implemented soon. Government policy is strongly needed here to support research, development, and the implementation of a field of science of environmental friendly renewable energy.

Renewable energy in Indonesia if addresses in micro hydro, it can help as little way to begin to correct global warming, air quality, and also burn fuel independency. Issues in generating hydropower in low head currently rise up due to impractical of low flow sources for generating electricity. Another reason it caused by expensive in efficient, complex technology, often deep drop water have been required.

Based on those complex problems, authors have eager to contribute Hydro Coil turbine as new concept of low head turbine to be applied in Indonesia. The Hydro Coil turbine has a single unique rotating coil with ribbon curved shape design that converts kinetic energy from flowing water into rotational energy. Because the coil blades are spaced at sequentially different amounts, the conversion process is more efficient than a standard coil, such as that in the Archimedes's screw design (see Fig. 1).

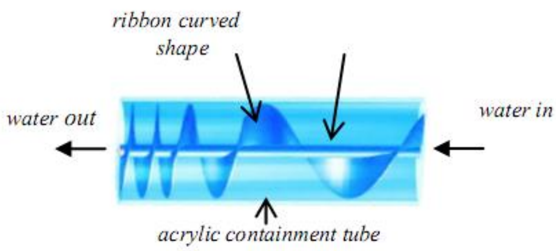


Fig. 1. Illustration of ribbon drive curved shape

Ribbon drive curved shape divided into three parts, which are curve coil A, B and C (see Fig. 2). It fixed in unitary single ribbon design or segmented into plural stages. Section coil A illustrated the staged embodiment that having an initial high frequency coil section, coil B for a medium frequency coil nearly perpendicular to the flow of water passing through the turbine, and coil C as a low frequency coil section which present a gradual curve approximately 30˚[8]. The progressively increasing frequency of the coils on the ribbons provide for efficient transfer of linear energy to rotational energy along the entire of the ribbon.

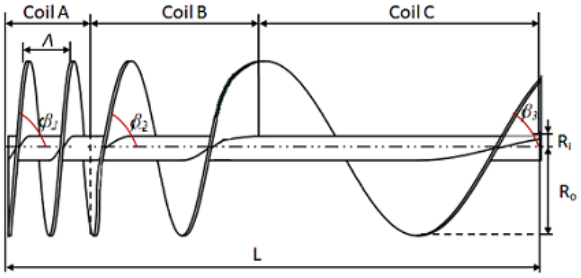


Fig. 2. Ribbon drive coil sections

Basic theory of the Hydro Coil turbine is very limited. The first reference is Ribbon Drive Power Generation Apparatus and Method came from Rosefsky [8]. This patent relates to an apparatus for producing hydroelectric power using a ribbon drive mechanism. Currently Rosefsky under company Hydro Coil Power Inc. is testing a Hydro Coil Turbine with 2kW in United State [9]. The prototype uses polymer components for the ribbon drive and 6 inches diameter for the turbine.

In 1970, Gutstein et al [1] investigated analysis flow inside a tube containing a helical-vane insert based on solid-body rotation. The fluid which passes through a tube into which a helical vane has been placed to rotate around the tube axis with a constant angular speed. Their simulations of the fluid helical velocity Vh was resolved into an axial component Vz and a tangential velocity Vɵ (see Fig. 3). The equation relating Vh, Vz, and Vɵ are expressed as:

$$V_Z = \frac{m}{A_C \rho} \tag{1}$$

$$V_\theta = \left(\frac{2\pi r}{Y}\right) V_Z = \left(\frac{l_\theta}{l_Z}\right) V_Z \tag{2}$$

$$V_h = \left\{ \frac{\left[Y^2 + (2\pi r)^2\right]^{1/2}}{Y} V_Z \right\} = \left(\frac{l_h}{l_Z}\right) V_Z \tag{3}$$

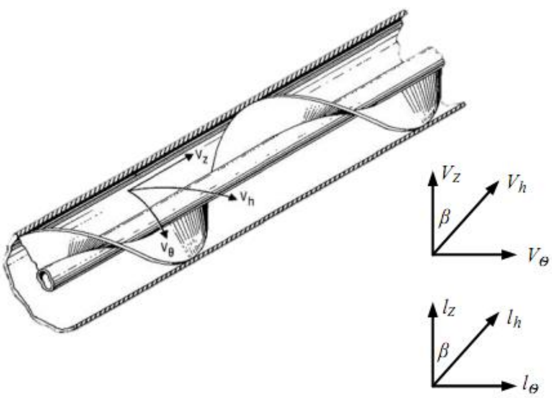


Fig. 3. Resolution of fluid helical velocity into axial and tangential components

The tangential and helical velocity was related to axial velocity by the geometry of the insert and both were functions of the radial displacement from the tube centerline. This paper describes the modified prototype tested, instruments and result obtained of Hydro Coil turbine.

## 2. Research Methodology

The research is conducted by two main activities:

1. Experimental study consists of system design and construct Hydro Coil turbine in laboratorium scale.
2. Installation proces, hydraulics water extraction system, start from February 2012 until July 2012 in Hydraulic and Piping System Laboratory, Vocational School of Civil Engineering, Gadjah Mada University.

Hydraulics concept is essential in Hydro Coil application, especially in determining an effective head, discharge and delivery capacity system. Hydraulic measurement, i.e discharge variation by varying valve opening, 30˚ until 90º. Respectively with 3 head variations; 1.2 m, 1 m, and 0.8 m from reservoir base (see Fig.4). Mechanical output of the Hydro Coil turbine also conducted in proof test. This is the measured, which is called a Prony brake dynamometer. The prime mover in Hydro Coil turbine is connected to pulley which can be loaded in such a way that the torque exerted by the turbine can be measured.

Formula for determining the power of Hydro Coil TurbineThe research is conducted of two main activities, they are:

a. Primary data obtaining consists of topographical data and discharge data from November 2011 until December 2011 in Drainage and Waterways at Faculty of Engineering, Gadjah Mada University,Yogyakarta
b. Experimental study consists of system design, installation process, hydraulics water extraction system, and theoretical and practical research about water hammer phenomena, start from February 2012 until April 2012 in Hydraulics and Piping System Laboratory, Vocational School of Civil Engineering, Gadjah Mada University.

Hydraulics concept is so essential in micro hydropower application, especially in determining an effective head, discharge, and delivery capacity the system.

$$P = \omega . T \qquad (4)$$

Remark :
P = Power (*watt*)
ω = angle velocity (*rad/s*)
T = Torque (*Nm*)

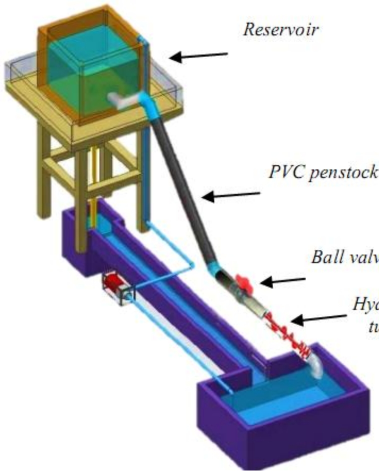


Fig. 4. Illustration of Hydro Coil turbine installation

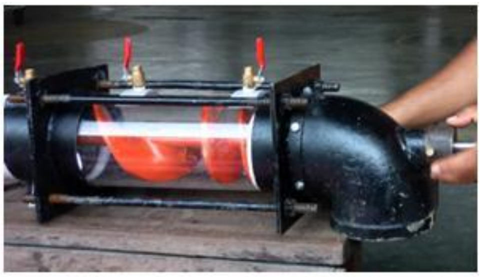

Fig. 5. Hydro Coil turbine

Table 1. Hydro Coil turbine parameters

| No | Specification | |
|---|---|---|
| 1 | Length Coil A (m) | 0.085 |
| 2 | Length Coil B (m) | 0.095 |
| 3 | Length Coil C (m) | 0.12 |
| 4 | $\beta_1$ in coil A (degrees) | 83˚ |
| 5 | $\beta_2$ in coil B (degrees) | 79˚ |
| 6 | $\beta_3$ in coil C (degrees) | 71˚ |
| 7 | $D_i$ ribbon drive (m) | 0.019 |
| 8 | $D_o$ ribbon drive (m) | 0.108 |

## 3. Results And Discussion

### Proof test without load

Proof test without load is to figure out the influence of variations in head constant and the variation of the valve opening of the turbine rotation speed when the turbine has not been loaded. Variations of the valve opening are 30˚,45˚,60˚and 90 ˚, with constant head varies are 4.2 m, 4 m and 3.8 m are represented discharges in each path of valve opening as per seen in Figure 6.

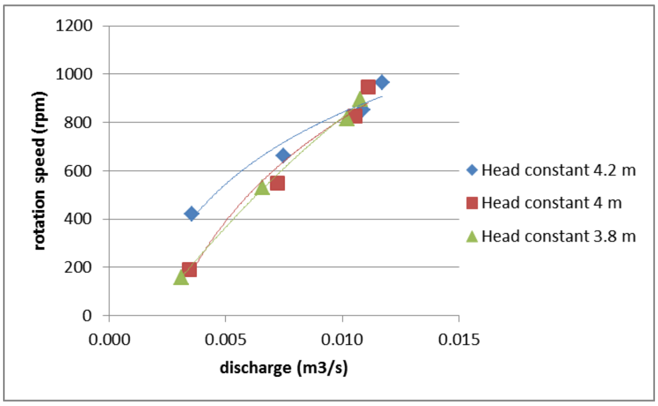


Fig. 6. Discharge versus rotational speed

Data above for each head constant figure out that rotation speed is increased along with the increasing of discharge. In head constant 4.2 m, maximum discharge is 0.0117 m3/s, generating speed rotation as much 965 revolutions per minute. More flow of water, the more energy possessed by the water flow which give effect to increase turbine rotation. In accordance with the law of conservation of energy, if the flow of water in the stream is passed through a turbine, the energy will be converted into other energy form which is turbine rotation.

### Proof test with load

On proof test with load, initially research focus in relationship among rotational speed; torque and mass flow rate. It can be seen that by loading method, rotation of turbine’s shaft decreasing along with increasing load, thereby torque value is rising up. An example to describe the graph is by increasing radial displacement of shaft. The suction force of fluid is getting high which leads mass flow rate into higher value. Otherwise, if radial displacement declines there will be no suction force of fluid, thereby mass flow rate falls off, as per seen in Fig. 7.

The variation of mass flow rate with rotational speed is almost linear and the effect of supply head on mass flow rate vanishes at high rotational speeds. It is also seen that for a practical situation with fluid frictional loss the simple reaction turbine will never experience the runaway condition of infinite speed.

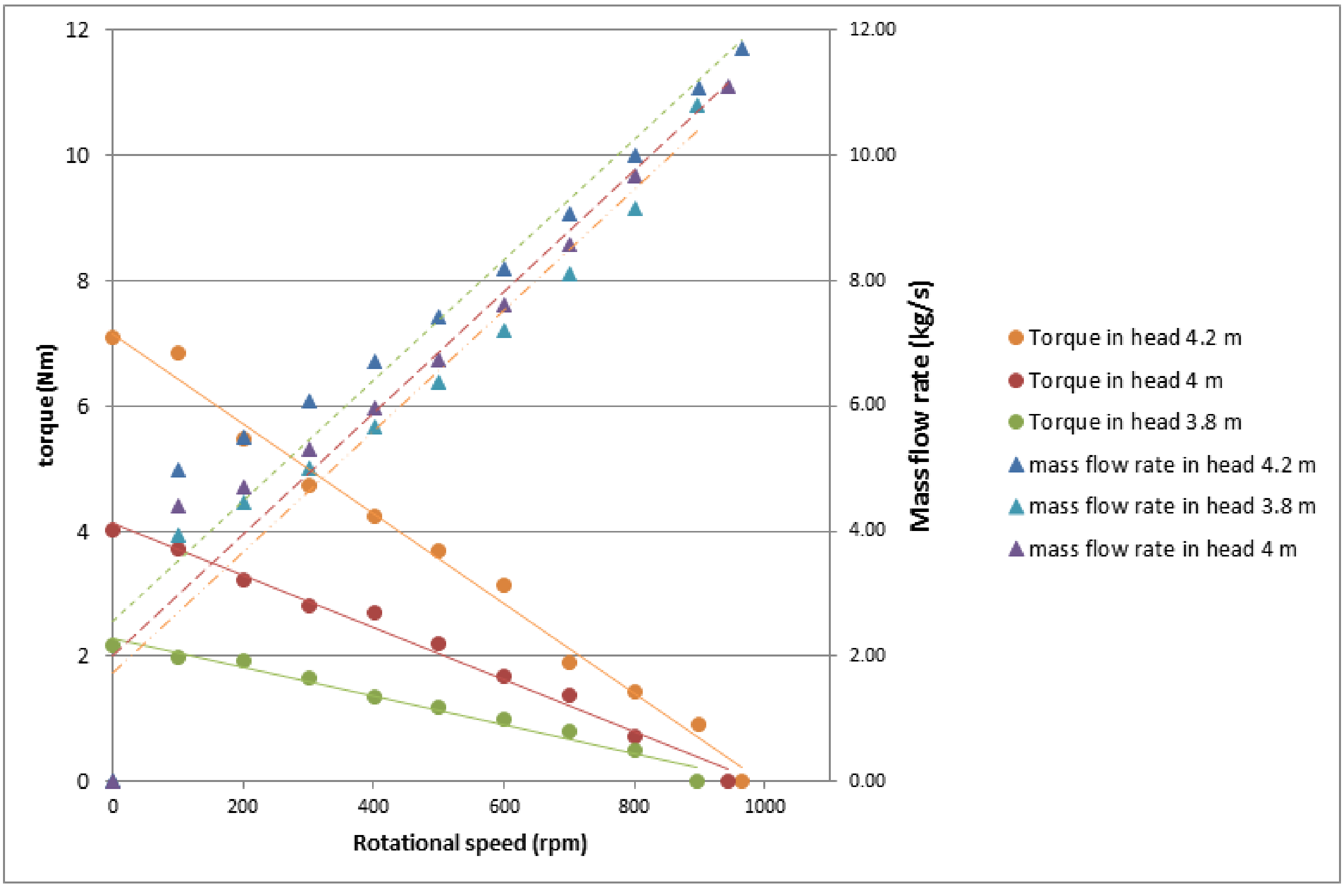


Fig. 7. Variation of rotational speed versus torque at different supply heads

The graphic below explain about correlation among rotational speed towards mechanical output power of Hydro Coil turbine. It has performed the greater magnitude of output turbine along with increased rotational speed of turbine until maximum, while flow rate of water is also increase. Maximum rotational speed occurred if turbine not rotating with load. In calculating torque, load increased in order to reach constant speed during proof test that effected to decrease rotational displacement and then stop as consequence of maximum load. Accordance to the result in Fig. 8 explains maximum value of output power is 196.65 watt with flow rates as much 0.0117 $m^3$/s.

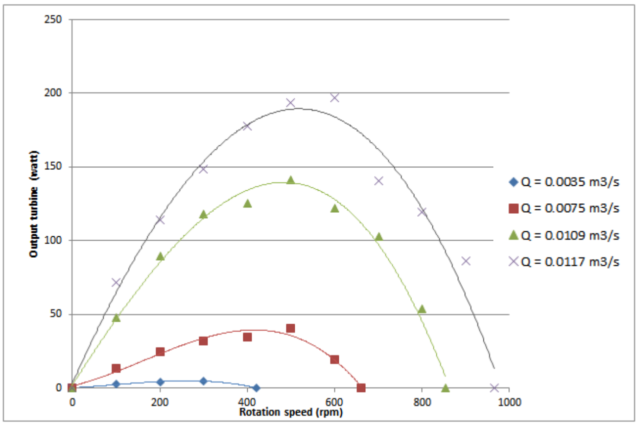


Fig.8. Curves of rotation speed towards output power of Hydro Coil turbine at head constant 4.2 m

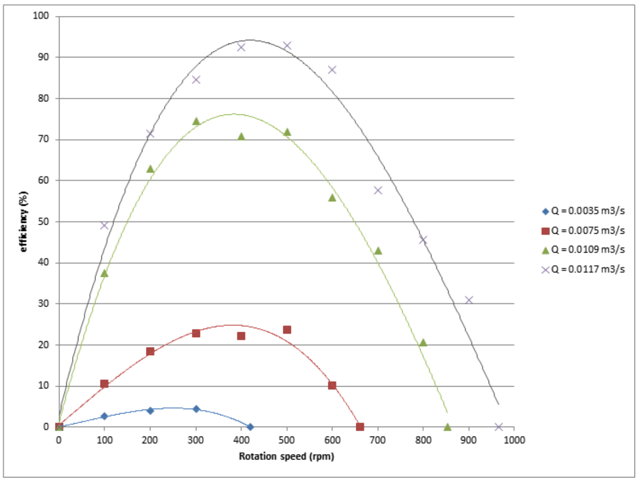


Fig.9. Curves of rotation speed towards efficiency of Hydro Coil turbine at head constant 4.2 m

Accordance to Fig. 8, shows that maximum efficiency of the turbine is 92.93% with also has the output as much 193.45 watt at head constant 4.2 m.

Comparison of theoretical concept about velocity vector based on equation (1); (2) and (3) towards experimental result, has been obtained closest result. In proof test radial displacement for head constant 4.2 m with full open valve was 965 rpm, while theoretical concept obtained 1012 rpm. It can be figure out that conversion energy has been occurred by reduction of axial

velocity pass through Hydro Coil turbine converted to rotational energy.
Specific speed for Hydro Coil turbine can be generated with head constant 4.2 m; flow rate 0.019 m3/s; Output power 0.196 kW; net head 1.31 m by computerize above formula, thereby:

$$N_s = \frac{N.P^{1/2}}{H^{5/4}}$$

where: $N_s$ = Specific speed of turbine (unit less)
N = Turbine rotation speed (rpm)
P = Power (kW)
H = Net Head (meter)

$$N_s = \frac{965\,.\,0.193^{1/2}}{2.86^{5/4}}$$

$N_s$ = 113.58 (rpm, kW, m)

## 4. Conclusions & Recomendations

1. The results of the hydro coil turbine model design, works well on proof tests in the laboratory of piping system – vocational school of Civil Engineering, Gadjah Mada University. Proof test has been functioned properly at all stages of testing at head constant 4.2 m , 4 m, 3.8 m, with a variants discharge.
2. On the proof test without load, Hydro Coil turbine can produce higher speed rotation on 965 rpm on head constant 4.2 m.
3. On the proof test with load, in each head constant, this turbine can produce greater power on 500 – 600 rpm. The highest efficiency is obtained about 92.93% by constant speed 500 Rrpm; head constant 4.2 m.

Based on experience in construction process and testing process oh hydro coil turbine, it is recommended:

1. Need to review of range placement between valves opening to turbine position, because it affects to the level of flow turbulence passing through to the turbine that obviously relevance to the performance of hydro coil turbine.
2. Review to design of ribbon drive coil thickness that affects to spin the turbine due to uncontrolled dimension of current ribbon drive’s thickness during manufacturing process.
3. Locking design is still not perfect, it is necessary to redesign on acrylic tube with two side tubes due to leakage occurs while initiated proof test.
4. Need to develop in further research on the design of draft tube plugged into exit part of hydro coil turbine due to increase the output power of the hydro coil turbine.
5. Need for further research in applied of this turbine to the field spread all over in Indonesia, especially in water resource, small dam, municipal water treatment plants, irrigation canals.

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