RESEARCH ARTICLE | DECEMBER 07 2023

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AIP Conf. Proc. 2680, 020047 (2023)
https://doi.org/10.1063/5.0126474

Waste Water Pipe Flow Water Turbine as a New Renewable Energy Power Plant

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Abstract. According to data from the Ministry of Energy and Mineral Resources, Indonesia has a water energy potential of 75 GW. However, only 8.1% of this potential has been utilized. Therefore, it is necessary to develop potential energy sources to increase energy for Indonesia. one of the potential energies comes from water resources known as hydro energy. This paper aims to design an innovative concept of a water turbine that flows from inside a pipe that utilizes wastewater. Pipe Flow Turbine or TULIPA is an innovative concept of water turbine with exhaust pipe as a new renewable energy power plant. TULIPA is a hydroelectric power plant that has advantages, among others; sustainable, low emission, can be used in any season. This turbine will produce an estimate power around 2395,379 kW, whereas this number is expected to be enough to supply for the daily needs of electricity for devices like television, lights, and any room cooler. With this turbine available in the market, we expect that the cost of electricity for every household may be decreased severely, and to change people mind from using limited energy source, such as fossil energy and try to make use of better technology.

INTRODUCTION

Energy will never run out because energy is conserved (law of conservation of energy). Along with the development of energy, there are many activities that require energy. Currently, energy sourced from fossils are decreasing due to excessive use of fossil energy in almost all fields, one of which is in the field of power generation. The data of fossil fuel usage in Indonesia are shown below.

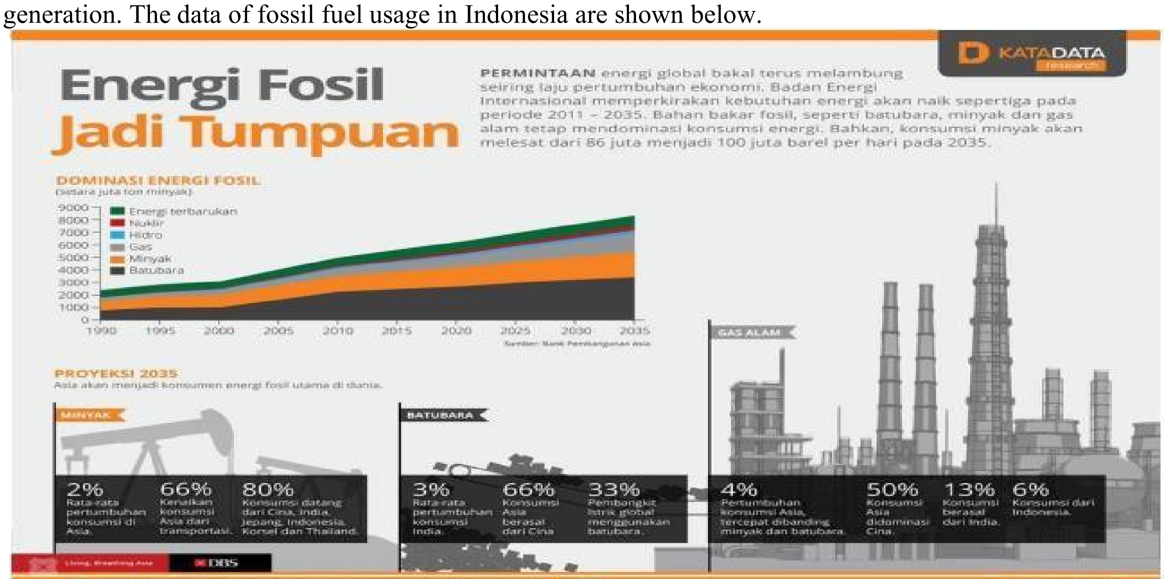


FIGURE 1. Global Energy Fossil Data (Arifin, 2015)

Proceedings of the 4th Tarumanagara International Conference of the Applications of Technology and Engineering (TICATE) 2021
AIP Conf. Proc. 2680, 020047-1–020047-9; https://doi.org/10.1063/5.0126474
Published by AIP Publishing. 978-0-7354-4698-4/$30.00

Figure 1. shows that the need for fossil energy continues to increase every year. According to Arifin Tasrif, fossil energy will run out within nine years. One source of energy that is still not used properly is the energy from water currents, although many uses from there have been found in Indonesia like the water turbines, but those water turbines are still unable to become a pedestal as a substitute for fossil energy. Indonesia is an agricultural country with the 5th largest potential for water resources in the world. According to Djoko Kimrmanto, the potential for water resources are very abundant with the total amount of around 3,200 billion m^3/year (Limbrata, 2013).

This hydroelectric power plant is one of the options in utilizing renewable energy sources. In this paper, the team will design a water flow turbine in a drain pipe as a new renewable energy power plant which we call Waste Water Pipe Flow Water Turbine. Waste Water Pipe Flow Water Turbine is a turbine designed to utilize the fluid flow contained in a pipe. This turbine works by using water currents which will rotate the blade in the pipe that will be rotated due to kinetic energy, potential energy, and also the pressure of the water which will be converted into mechanical energy in the form of shaft rotation (Uiker, 2003; Kim, 2007; Cubberly, 2007). 1989). The rotation of the shaft will be converted into electric power by a generator. The turbine pipe will be used in the sewage pipe, which will always flow rapidly and without stopping. According the description above, the development of a water flow turbine in the wastewater disposal pipe will be carried out as a hydroelectric power plant.

FIGURE 2. Example of Wastewater Pipeline Water Flow (Prawiro, 2018)

WASTE WATER PIPE FLOW WATER TURBINE

The need for electrical energy increases as the economy and Indonesia's population grows rapidly. On the other hand, people are still using coal and petroleum energy that will create waste and pollutes the environment. Therefore, an effective and efficient alternative energy is needed. This case underlies the idea of creating new renewable energy, the Waste Water Pipe Flow Water Turbine that will maximize liquid waste that can be turned into emission-free electrical energy.

The mechanical concept applied to Waste Water Pipe Flow Water Turbine is in the form of the principle of using micro-hydro. The utilization of micro-hydro does not require large media and abundant water sources, just water from the waste final disposal system. Some of the water is channeled into reservoirs and irrigation. The water that flows into the reservoir will be filtered to make it cleaner so that the turbine performance will be more efficient. After that, the water will be flowed through a pipe called a penstock to the power house. Inside the power house, there are generators and turbines that convert the flow of water into electrical energy and use a transformer to get a higher or higher voltage (Truman, 1997; Zaretsky, 1998).

METHODOLOGY

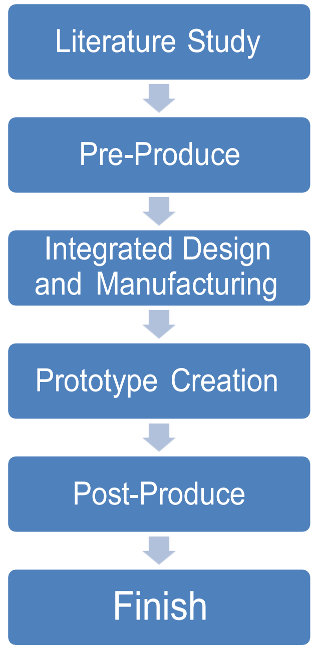


FIGURE 3. Flow Chart

These are the following implementation steps for the research Wastewater Pipe Flow Water Turbine as a New Renewable Energy Power Plant:

1. Problems related with the energy required and how to make use of the flow of water inside of waste pipe with a certain amount of debit and flowing speed.
2. Literature study, which first to be done is to implement a study about concept and idea that will be executed.
3. Create a creative concept for plan from a turbine that will be moved under the flow of waste water to operate a electric generator.
4. Next step is to pre-produce, whereas in this step, the material to be used and specification of the turbine will be decided with job desk for every member.
5. After decision for material and job desk, a scheme of CAD-CAE-CAM is used for the next step, whereas the design calculation is conducted so to avoid a defective product or to minimalize defection.
6. If the integrated results meeting expectation, the process to produce prototype are ready to be realize. If not meeting expectation, then turn back to pre-producing step to review and make changes on the specifications and designs.
7. After the prototype produced, next step is post-produce, where evaluation is made to see the performance of the product. The indicator of success is rated from the suitability of the calculated date with the performance of the prototype.
8. Last step is the program is complete, and the data obtained is corresponded with the expected surface.

RESULT AND DISCUSSION

In this section, to make sure the product has been planned well for its components, performance, and maximum efficiency, a counting for the result is needed. These are the following necessary limitations and assumptions that is needed to obtain the result, such as:

A. Steady state flow of water.
B. The fluids are assumed to be incompressible (ρ).
C. No changes happen in internal energy.

D. Constant capacity of flow.
E. Diameter pipe, D = 0.2 m, and head pipe, H = 5 m
F. Number of rotations per minute obtain from turbine, n = 300 rpm
G. Efficiency, η = 70%
H. Density of the water, ρ = 988 kg/m^3
I. μ = 1.002 kg/m.s

TABLE 1. Calculations for the flow of waste water of water turbine in waste water pipe**.**

No.	V_o (m/s)	Re $\frac{\rho.v.D}{\mu}$	f $\frac{0.3164}{Re^{0.25}}$	$\Sigma H\ (m)$ $(f\frac{\tau}{p} x \sum kl)\frac{v^2}{2g}$	V (m/s) $v = \sqrt{2g(H-H_l)}$	ΔV $V - V_o$
1	1	199243,51	0,0149	0,493	9,404	8,404
2	2	398487,03	0,0126	0,796	9,081	7,081
3	3	597730,54	0,0114	1,368	8,442	5,442
4	4	796974,05	0,01059	2,189	7,426	3,426
5	5	996217,56	0,0100	3,257	5,849	0,849

TABLE 2. Calculation for the turbine power

No.	Q V x A	P_{water} WHP = ρgQH	$P_{turbine}$ P_{water} x η
1	0.0314	1371.65	960.155
2	0.0628	2558.87	1791.209
3	0.0942	3316.06	2321.242
4	0.1256	3421.97	2395.379
5	0.1570	2652.30	1856.611

Results Example

V_o = 1 m/s

Re = $\frac{\rho.v.D}{\mu} = \frac{998\ kg/m^3 \times 1\ m/s \times 0.2\ m}{1.002 \times 10^{-3}\ m/s}$ = 199243.51

f = $\frac{0.3164}{Re^{0.25}} = \frac{0.3164}{199243.51^{0.25}}$ = 0.0149

ΣKL = $KL_{in} + 2KL_{elbow} + KL_{valve} + KL_{exit}$ = 0.5 + 2(0.3) + 0.2 + 1.06 = 2.36

H_{total} = $(f\frac{l}{D} + \sum KL)\frac{V^2}{2g}$ = $(0{,}0149\frac{5m}{0.2\ m} + 2{,}36)(\frac{1\ m/s}{2 \times .9{,}81\ m/s^2})$ = 0.493

V = $\sqrt{2g(H - HL_{total})}$ = $\sqrt{2 \times 9.81\ m/s^2\ (5 - 0.493)m}$ = 9.404 m/s

ΔV = V – V_o = 9.404 m/s – 1 m/s = 8.404 m/s

1. Flow Rate

$$Q = V\ x\ A$$
$$Q = 5.25\ m/s \times \pi \times (0.1\ m)^2 = 0.1649\ m^3/s$$

2. **Water Power**

$$WHP = \rho g Q H = (988\ kg/m^3) \times (9.81\ m/s^2) \times (0.1649\ m^3/s) \times (5\ m) = 7991.284\ W \approx 7.99\ kW$$

3. **Turbine Power**

$$NT = WHP \times \eta = 7.99\ kW \times \frac{70}{100} = 5.593\ kW$$

4. **Turbine Wheel Tangential Velocity**

$$U = \frac{V}{2} = \frac{5.25\ m/s}{2} = 2.625\ m/s$$

5. **Outer Turbine Diameter**

$$U = W.\frac{D_1}{2}$$

$$D_1 = \frac{2U}{W} = \frac{2 \times 2.625\ m/s}{2\pi \times 5} = 0.167\ m \approx 16.7\ cm$$

6. **Inner Turbine Diameter**

$$D_2 = \frac{D_1}{1.4} = \frac{16.7\ cm}{1.4} = 11.93\ cm$$

7. **Turbine Outer Blade Velocity**

i) **Relative Velocity**

$$C_1 = V = 5.25\ m/s$$
$$U_1 = 2.625\ m/s$$

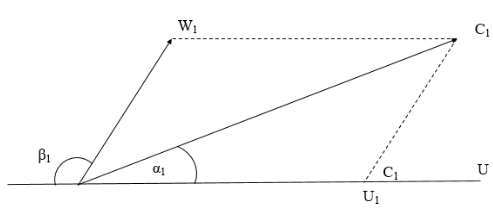
ii) **Alpha Angle (α_1)**

$$C_1 \cos \alpha_1 = U_1 + W \cos(180 - \beta_1)$$
$$5.25\ m/s \times \cos \alpha_1 = 2.625\ m/s + 1.9\ m/s \cos(180 - 80^o)$$
$$\cos \alpha_1 = \frac{2.3\ m/s}{5.25\ m/s}$$
$$\alpha_1 = cos^{-1}(0.44) = 63.9^o$$

8. **Absolute Velocity Towards Tangential**

$$C_1 U = C_1 \cos \alpha_1 = 5.25\ m/s \times \cos 53.5^o = 4.352\ m/s$$

9. **Resultant Velocity**



$$C_1{}^2 = V_1{}^2 + W^2 + 2U_1 W_1 \cos(180 -$$

$$\beta_1)0 = W_1{}^2 = 0.91 \times W_1 -$$

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$$W_1 = 1.9\ m/s$$

10. Turbine Inner Blade Velocity

i) Tangential Velocity (U_2)

$$U_2 = \frac{\pi . D_2 . n}{60} = \frac{\pi \times 0.12\ m \times 300\ rpm}{60} = 1.885\ m/s$$

ii) Relative Velocity (W_2)

$$W_2 = W_1 \times \frac{\pi r_1^2}{\pi r_2^2} = 1.9\ m/s \times \frac{\pi \times 8.35^2}{\pi \times 6^2} = 3.37\ m/s$$

iii) Absolute Velocity

$$C_2 = \sqrt{U_2^2 + W_2^2} = \sqrt{(1.885)^2 + (3.37)^2} = 3.76\ m/s$$

11. Alpha Angle (α_2)

$$\cos \alpha_2 = \frac{1.885\ m/s}{3.76\ m/s}$$

$$\alpha_2 = cos^{-1}(0.501) = 57^o$$

12. Number of Blade

$$Z_{min} = 2\pi \times \tan \alpha_2$$

$$Z_{min} = 2\pi \times \tan 57^o = 9\ blades$$

13. Pivot Diameter

$$T = 9.74 \times 10^5 \times \frac{WHR}{RPM}$$

$$T = 9.74 \times 10^5 \times \frac{5{,}59}{300} = 18158.6\ kgmm$$

14. Pivot Diameter

$$dp = [\frac{5.1}{4.8} \times 2 \times 1 \times 18158.6\ kgmm]^{\frac{1}{3}}$$

$$dp = 33.72\ mm \approx 3.4\ cm$$

From this diameter result, we are able to obtain the required size for the pivot, which is for minimum of 30 mm, b = 10 mm and t = 8 mm (Source: Agustinus, 2009)

15. Bolt

$$L = \frac{\pi d^2}{tb} = \frac{\pi \times (3.4\ mm)^2}{8.1} = 4.5cm$$

16. Bearing

The bearing that will be used for this turbine is the Bearing Number 6007 (Ball-Singlerow – Deep Grove), which specifications are made of:

d	=	35 mm (Inner diameter)	C	=	4489.79 kg
D	=	62 mm (Outer Diameter)	P	=	806.85 kg
B	=	14 mm (Bearing Thickness)	Limit Speed	=	1500 r/min

(Source: Deustchman, 1975)

From the data above, it can be used to deduce the Life Hour of the bearing:

$$f_n = \left(\frac{33{,}3}{300}\right)^{\frac{3}{10}} = 0.52$$

17. Age Factor

$$f_h = f_n \frac{C}{P} = 0.52 \times \frac{4489.79}{806.85} = 2.89$$

18. LH Nominal Age

$$LH = 500\, f_h^{\frac{10}{3}}$$

$$LH = 500 \times 2.89^{10/3} = 17190.802\ Hour \approx 2\ year$$

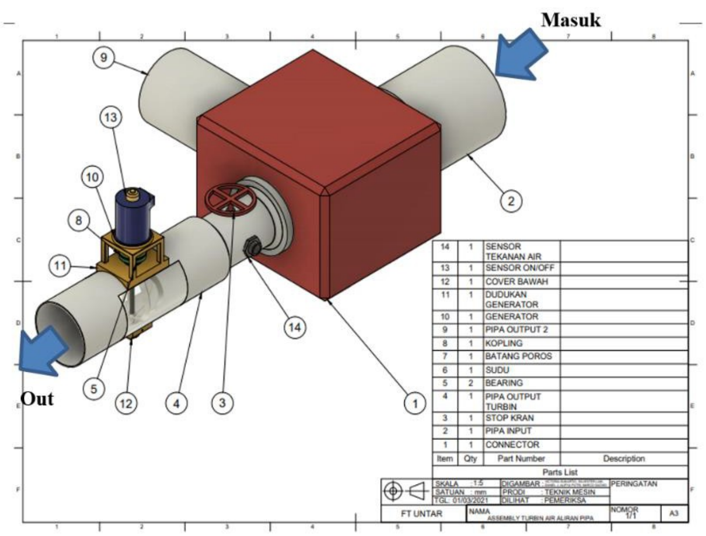

FIGURE 4. Drawing of Waste Water Pipe Flow Water Turbine

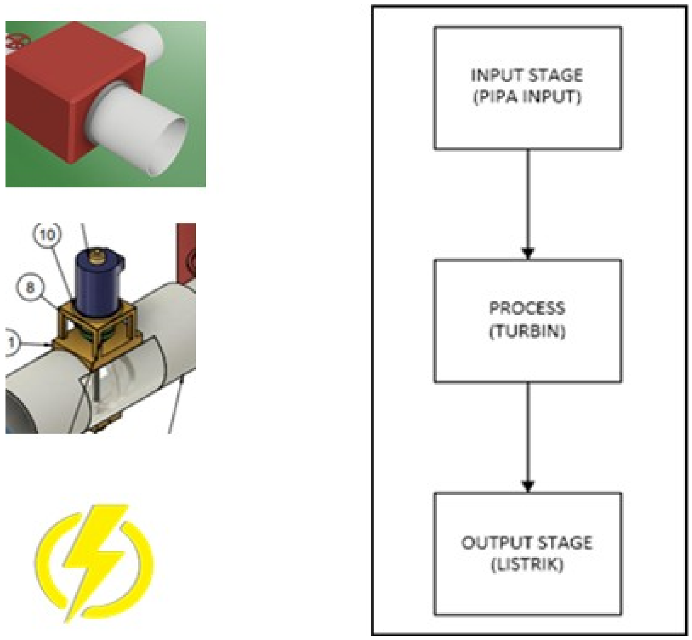

FIGURE 5. Stages of Wastewater Pipe Flow Water Turbine

The stages of Wastewater Pipe Flow Water Turbine as such:

a. Input Stage: in this stage, the residue of waste water will enter into input pipe, whereas those water will then be directed to the connector and continued towards the pipe that contains the water turbine.
b. Process Stage: in the second stage, the waste water that had already entered the pipe with water turbine will rotate the turbine blade, which also rotates the turbine pivot. The pivot rotations will then be subjected to the generator, where those rotations become an electricity source.
c. Output Stage: at the last stage, the waste water that had already been used to rotate the turbine blade will be led toward output pipe. The waste water flow that turns the turbine blade will become the electricity for the usage of daily activities.

CONCLUSION

The utilization of micro hydro theory in Indonesia has yet maximized due to its reliance on using fossil as fuels, whereas the development of recycled energy also yet to be optimized. This Flowing Water Turbine Pipe is the solution for the matter above, because it is a very unique innovation and utilization of unused object, which in this case is a waste disposal water, to create and convert those flowing waste water into an additional electricity or as a backup energy source.

Flowing Water Turbine Pipe will make use and optimizes the flow of waste water in pipes of every industry, which then will be converted into electric energy. The wastewater flow will be directed to the powerhouse, which will then be led to the water turbine that rotates when its blade is hit and push by the flowing wastewater, then those rotating energy will be transmitted to the generator, which will then become a renewable energy that can be used.

This turbine will produce an estimate power around 2395,379 kW, whereas this number is expected to be enough to supply for the daily needs of electricity for devices like television, lights, and any room cooler. With this turbine available in the market, we expect that the cost of electricity for every household may be decreased severely, and also to change people mind from using limited energy source, such as fossil energy and try to make use of better technology.

ACKNOWLEDGMENTS

Thanks to ALLAH for his mercy and guidance in giving this team full strength to complete this research. A lot of thanks to our tutor, Mechanical Engineering Department for all of his support and guidance in helping us to finish our research. Special appreciation to the Tarumanagara University authority and community for giving me permission and great co-operations.

REFERENCES

1. Arifin Tasrif, 2015, Fossil Energy So Focused, Said Data, seen December 13, 2020, <https://katadata.co.id/arsip/infografik/5e9a5705e8380/energi-fosil-jaditumpuan>.
2. Arismunandar, Wiranto 1982, Turbine Start Drive, ITB, Bandung.
3. Cubberly, W 1989, Handbook of Tools and Manufacturing Engineers.Society of Manufacturing Engineers.
4. E. Truman, J, J. Coleman, M & R. Pirt, K 1997, 'Influence of nitrogen content on resistance to pitting corrosion of stainless steel', British Corrosion Journal, vol. 12, hh. 236-238.
5. E. V. Zaretsky, 1988, Selection of rolling-element bearing steels for long-life applications, USA.
6. Hydro Power-Waterwheels, Smith engineering. Viewed March 6, 2021, <https://www.smith-eng.co.uk/hydro>.
7. *ISO - Pipe, Tube and Fittings Standards and Specifications Archived* 2010-09-09 at theWayback Machine
8. J. Uicker, J, R. Pennock, G & E. Shigley, J 2003, *Theory of Machines and Mechanisms,*
9. 3rd edn, Oxford University Press, New York. Kim, Y.T., Nam, S.H., Cho, Y.J., Hwang, Y, Choi, Y, Nam, C.D. & Lee, Y.H. 2007,
10. Tubular-Type hydro turbine performance for variable guide vane opening, CFD,China.
11. Libratama.com, 2013, What is a Generator?, Libratama.com, views December 10, 2020, <http://libratama.com/apa-itu-generator/ >
12. M. O'Brien, J, F. Hosford, W 1997, 'Spheroidization of medium-carbonsteels', *Journalof Materials Engineering and Performance*, vol. 6, hh. 69-72.
13. Cink Hydro Energy, 2021, Turbin Cross Flow, CINK, seen March 6, 2021, <https://www.cink-hydro-energy.com/id/turbin-crossflow/>.
14. M.Prawiro, 2018, Definition of Waste: Definition, Type, Characteristics, and Impact.https://www.maxmanroe.com/vid/umum/pengertian-limbah.html
15. Zabadi, F 2020, Mysterious disc hole function, Belipart, seen December 12, 2020, <https://www.belipart.com/blog/fungsi-lubang-cakram-yang-misterius/>.