Journal of Mechanical Engineering Research and Developments
ISSN: 1024-1752
CODEN: JERDFO
Vol. 45, No. 2, pp. 03-09
Published Year 2022

Undershot Floating Waterwheel a Concept of Small Hydropower Energy Development for Rural Areas of Indonesia

Darmawi*, Irwin Bizzy, Riman Sipahutar, Marwani

Department of Mechanical Engineering of Sriwijaya University

*Corresponding Author Email: darmawi@unsri.ac.id

ABSTRACT

A series of research, testing and measurements are already conducted with regard to the completion of a dream to implemented an effective undershot floating waterwheel operating on rivers with low current speed. It already specify the effective blade working on impulse principles to exstract the energy contained in the water. These testings and measurements including the finding of effective scoopy blade and the effective gamma angle, and the effective pitch of blades at certain wheel diameter. The next work, is testing the stability of waterwheel raft during operation on the river surface. All of the studies on effective undershot waterwheel are aimed at a dream to empowering rivers as a source of microhydro green energy for rural communities. The undershot floating waterwheel becomes interesting because of several following reasons: (1) It could installed in series at the part of the river that does not disturb the river traffic activities. (2) It operating on the river surface with no pollution to water or to air at the site. (3) It gives contribution to grow up the community's economy, through supplying the energy with no cost. (4) It protects the environment and ensuring the sustainability of national economic and physical development.

KEYWORDS

Floating, undershot waterwheel, low current, scoopy blade.

INTRODUCTION

From the previous studies, we realized the importance of effective waterwheel blades in order to get maximum energy from low velocity river currents to be mchanical energy [1]. This is based on the most number of rivers in Indonesia, especially in Sumatra, are having current speed below 1 m/sec. According to Kiho, the economic value of river current speed to be used as energy sources is 1 m/sec [2]. Most of the river in Sumatra has low current speed i.e. below 1 m/sec. How could these rivers be useful for generating power for the people surrounding it. This is the question wanted to be answered by the ideas discussed in this manuscript. A series of experiments were already conducted from the year 2013 to 2020. Starting from doing the experiments for the final work of doctoral dissertation up to doing experiments for the new rotor blade ideas for optimum energy extracted from low river current velocity. Since 2013, we realized that the usage of flat blade to the floating waterwheel created minimum energy regarding energy losses at blades.

For the purpose of maximum energy absorbed by the blades, we need a new form of blade working under the principles of impulse turbine. By finding the form of blades working on the base of impulses, the effective absorbtion of water current energy is possibly [3]. Starting from the year of 2013, the dream to find out an effective blade working on the principles of impulse was chased to come true. From this point, it can be developed the idea to modify the impulse Pelton blade, being a form of blade like a scoop. Work on the principles of impulse turbine, designed for low river current velocity. Finally, it can be called Scoopy Blade as showed in figure 2 [3]. The research of bladed is started in 2018 by testing the effectiveness of turbine blades with variable of gamma angles from 0 degree to 45 degrees. The material of blades was the polymer matrix composite which is predicted as resistant to aqueous corrosion [3]. The research is continued to the year 2019 to complete the previous year research and we get the effective force at gamma angle of 10 degrees [4].

The series research is conducted in 2020 to determine the right pitch of blades at the wheel diameter of 0.8 meters to obtained the maximum power [5]. The year 2021, is testing the Stability of Undershot Waterwheel Raft with Guidance Walls for to be operating on Rivers with low current speed. This research is in preparation at the moment. Energy Sector Management Assistance Program (ESMAP) in Small Hydropower Resource Mapping in Indonesia through Small Hydropower Potential Report, March 2017, does not include rivers in Indonesia as a potential source of green energy (ESMAP, 2017). The main attention is the potential islands related to the national electricity plan handled by PLN such as Maluku, Papua, NTT, NTB, North Sulawesi and South Sulawesi. In the view of the author, rivers are interesting as hydro energy sources mainly for the micro hydropower to fulfill the energy needs of the community at both sides. This paper gives contribution to the framework of World Water Day 2021, in order to utilize water resources, and to ensure the sustainability of future national development. This concept is started by making a pilot project of the floating waterwheels downstream for rural communities. It is believed that the application of floating waterwheels in rural areas will help empower the community's economy through the fulfillment of micro-scale energy at no cost. The energy obtained from floating waterwheels in rural areas can be used to meet small-scale electricity needs, such as: Environmental Security Posts, Mosques / Mushollas, Public facilities. It can also be used to irrigate rice fields and supply water to people's homes [3].

MATERIAL AND METHODS

The blade materials used in the series of experiments are resist to corrosion attack i.e. polymer matrix composite and wood. The main wheel and the blades holders are made of steel. The area of blade surface are constant, but the difference is the gamma angle. The difference of gamma angle produce different forces acting on the blades and produce different power of waterwheel.

Blades finishing and Balancing

Blade finishing was done by grinding. All finished blades are weighted and identified by numbered. This numbering system is used to create wheel balancing. Balancing is very important in order to find the accurate forces acting on the blades of every different gamma angles.

Moments and Wheel circumferential Speed record

The forces acting on blades are measured by a dynamometer connected to the waterwheel shaft . The moments created by forces on blades times the radius of dynamometer shaft. Finally we get the power of waterwheel on every gamma angle of blades, on every speed of water flow and on every sum of blades mounted on circumference of the waterwheel.

Roadmap

As previously mentioned above, the dream to create the floating undershot waterwheel is conducted by a series of research in years. The main goal is to find the effective undershot waterwheel operating on the river of low current speed. To reach these goals, we arrange the research in series such as explained above. At present, it is prepared to test the stability of undershot waterwheel raft regarding the forces acting on it as internal part of the syatem and external forces acting on it by other river activities.

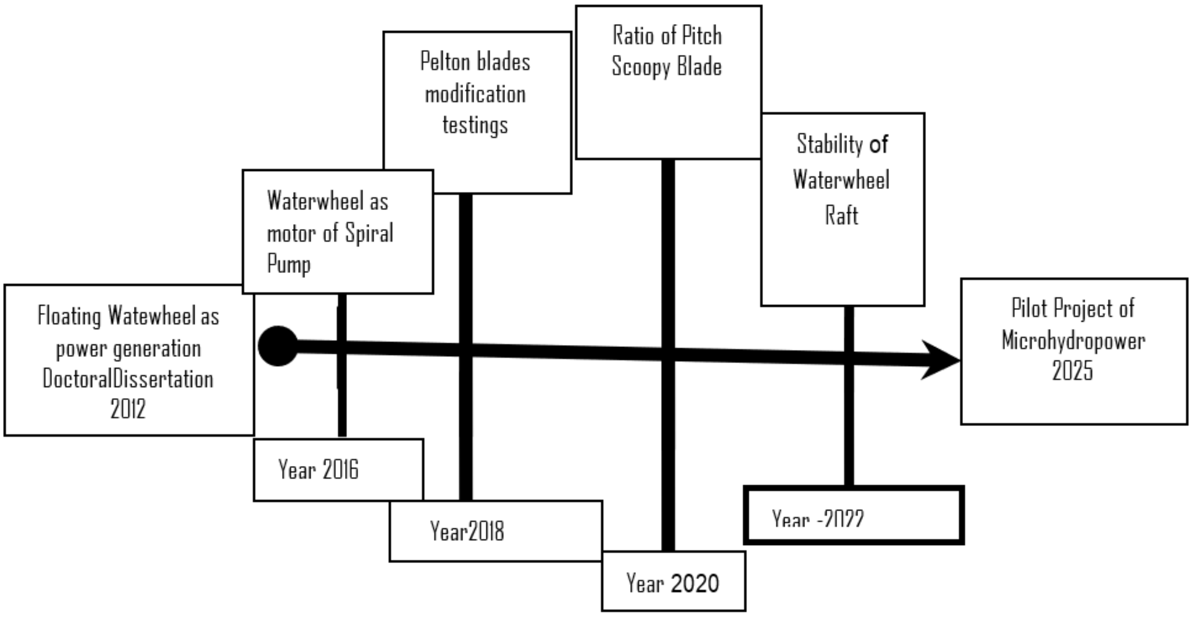

Figure 1. A roadmap to implementing the floating waterwheel on rivers with low current velocity

RESULTS AND DISCUSSION

Pelton blade is an impulse blade working on high velocity water jet. The Pelton blade speed triangle is as follows:

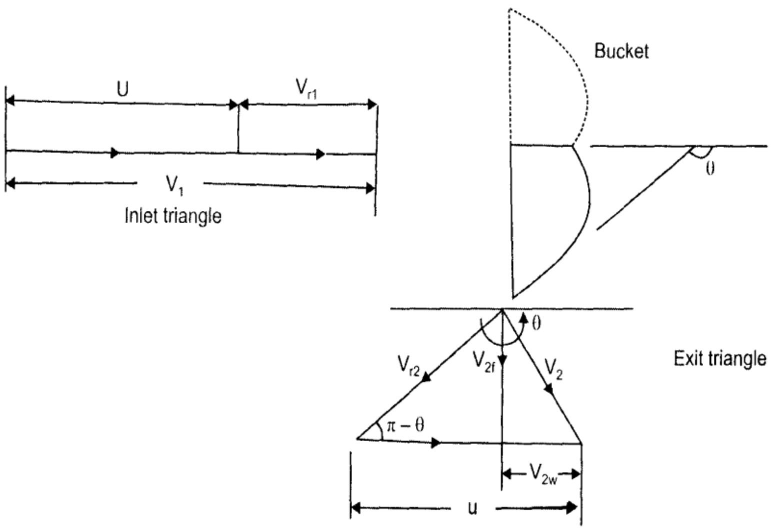

Figure 2. Pelton blade speed triangle diagram [5]

These work principles are need to be modified for a low current river. We conclude the form of blades are as shown in figure 2 [2, 6].

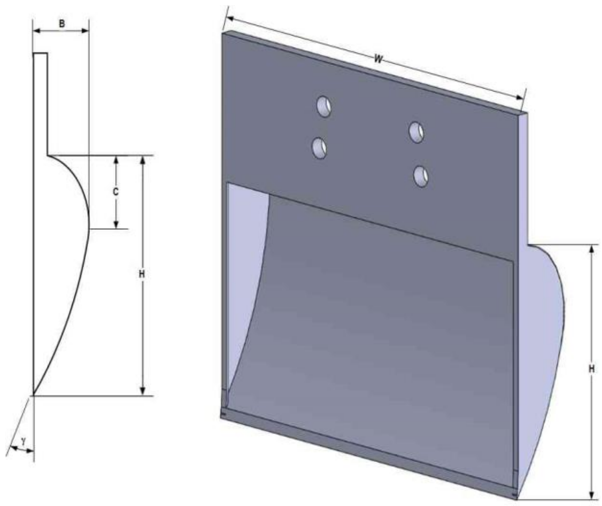

Figure 3. The form of scoopy blade which is a modification of the Pelton Blade. This blade is designed for rivers with low current speed.

Where, B = depth of blade

H = height of the blade

C = curvature of the upper blade, approximately 0.33 H

ɣ = Angle of inclination of blade.

W = blade width.

The speed triangle diagram of scoopy blade are as follows:

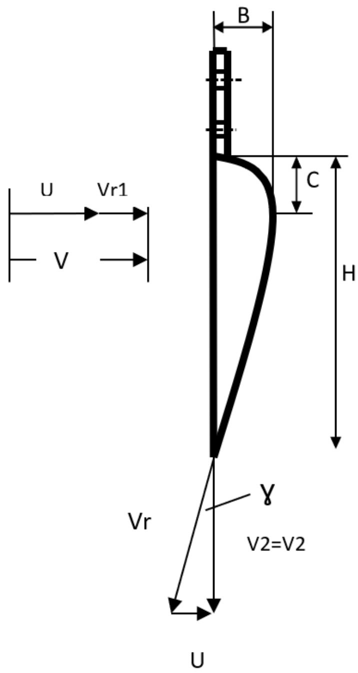

Figure 4. Speed triangle at inlet and outlet of scoopy blade

Where, V1 = Speed of water entering the blade (m/sec). U = velocity around the blade (m/sec) Vr1 = relative velocity of water to the blade in the direction X. Vr2 = relative velocity of water to the blade in the direction of the Y axis. In the state that water energy is completely absorbed by the blade, V_{2w} =0, then V2 = velocity of water out of the blade = flow velocity at outlet V2f. From the results of the 2018-2019 research, it was found that the most effective gamma angle for weak currents between 0.8 m / sec to 2.5 m / sec was 10 degrees [7]. Results in 2020 identifying the effective pitch of blades related to the diamater of 800 mm wheel diameter is (0.1962 – 0.261) wheel diameter [7].

The next research

Through these results, the next research is to test an important part of a floating waterwheel, namely testing the stability of the raft where the wheel is working. Akimoto (2013) have been warned that floating hydropwer axis would be suffering deflection by water current [8]. The axis deflection will significantly change the output power regarding the change of attack angle of water to the blade [8]. Studies are being carried out for a wheel installed on a raft. Testing should includes the forces acting on the wheel and the real forces acting on the raft in the field. The research was conducted in two stages, namely the analysis of the forces obtained analytically. This analysis is supported by laboratory scale testing as well as field scale testing with the dimension analysis and similitudes in the form of the model [9-11].

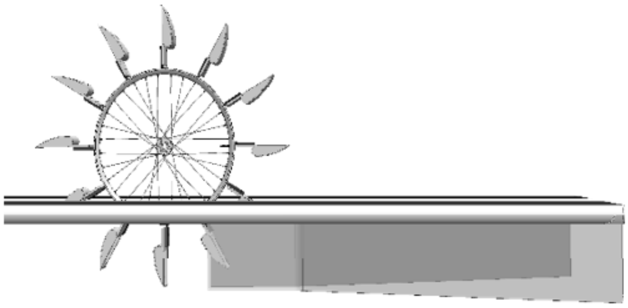

Figure 5. Testing Model to support the analysis of the forces on the Floating Wheel.

The forces acting on the floating wheel raft refer to the forces acting on floating objects in the broad sea, for example, boats or ships. Schematically the forces are as follows:

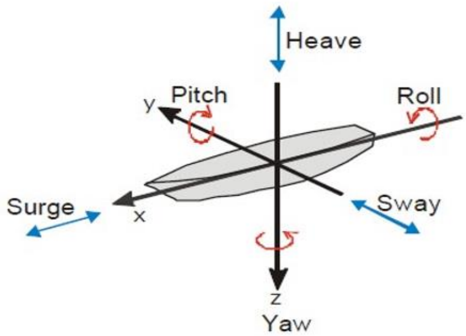

Figure 6. Motions and Types of forces acting on floating wheel raft [9].

1. Rolling: angular movement according to the X-axis in the form of a roll towards the starboard-portside
2. Pitching: angular movement according to the Y axis in the form of a nod by thebow-by the stern
3. Yawing: angular movement according to the Z axis
4. Surging, linear movement according to the x axis
5. Swaying, lenear movement according to the Y axis
6. Heaving, linear movement according to the z axis

The above movement is accounted as being caused by the forces existed in the river. The forces are covering the external forces acting on waterwheel raft and the internal forces acting on the waterwheel raft. The internal and external forces acting on waterwheel raft is including:

Internal raft forces

1. Own weight of hollow pipes.
2. The construction weight of the floating pipe fastening system.
3. The weight of the wheel support system construction
4. Wheel Weight with Blades5. Flow guidance wall weight
5. Forces of anchor rope in x,y,z axis direction.
6. Raft buoyancy.

External raft forces

1. The force of water flow on the whole raft.
2. Wind force in the X direction
3. Wave force in x,y,z axis directions.

CONCLUSIONS

From the previous years research, i can be concluded that:

1. Scoopy blade allows Floating Waterwheel implemented as a source of microhydropower in rivers with low current speed.

2. The effective pitch of blade regarding its relationship to the diameter is:

   Pitch = (0.1962 – 0.261) Diameter

3. The advantage of Floating Waterwheel could be installed in series along the river side as long as it does not disturb the river traffic activities.

ACKNOWLEDGEMENTS

Thank you very much to Universitas Sriwijaya, especially the Faculty of Engineering who has financed the series of research, testing and the measurements. Thanks also extended to Program Pascasarjana Unsri and the late Robiyanto H Susanto, who has been directing the usage of Telang Area as a place of tidal micro hydropower research in 2013.

REFERENCES

[1] Darmawi. “Presentasi Ujian Terbuka Doktor a.n. Darmawi, Pascasarjana Universitas Sriwijaya tahun”, 2013. https://docs.google.com/presentation/d/1v9fOO9wJtaiV8xUVwHp6KShkE-dJ-7PB/edit?usp=sharing&ouid=107861301171947750799&rtpof=true&sd=true

[2] S. Kiho, M. Shiono, and K. Suzuki, “The power generation from tidal currents by darrieus turbine”, Renewable Energy, 9 (1–4), Pp. 1242–1245, 1996. https://doi.org/10.1016/0960-1481(96)88501-6

[3] Darmawi, R. Sipahutar, and Q. Hadi, “Pengembangan sudu Turbin pelton untuk diaplikasikan pada Kincir air undershot arus lemah 0,8 – 2,5 m/detik dengan bahan dasar Polymer matrik Komposit”, 2018. https://repository.unsri.ac.id/42229/1/UNGKOMP 2018 Sdh Digabung%29-merged.pdf

[4] Darmawi, R. Sipahutar, and I. Bizzy, “Scoopy Blade for Low Current River Waterwheel Supporting the Energy Needs in the Rural Areas of Indonesia”, Journal of Physics: Conference Series, Vol. 1500, No. 1, Pp. 0–9, 2020b. https://doi.org/10.1088/1742-6596/1500/1/012024

[5] Z. Hussian, Z. Abdullah, and Z. Alimuddin, Basic Fluid Mechanics and Hydraulic Machines, 2008. https://books.google.com/books?id=FABEAQAAIAAJ&pgis=1

[6] Darmawi, R. Sipahutar, and Q. Hadi, “A New Rotor Blade for low Current River Waterwheel Supporting the Energy Procuremenin the Countryside of Indonesia”, International Journal of Science and Research

(IJSR), Vol. 8, No. 3, Pp. 239–242, 2019. https://www.ijsr.net/archive/v8i3/ART20193256.pdf

[7] Darmawi, R. Sipahutar, and I. Bizzy, “Pitch” yang tepat untuk sudu jenis “Scoopy Blade” dengan sudut gamma 10 derajat pada diameter roda kincir 0,8 meter dan kecepatan arus 0,8 m/detik hingga 2 m/detik, 2020a. https://drive.google.com/file/d/1FNRBmr0OJPQlyMppEYUHMhsXz5wQUxad/view?usp=sharing

[8] H. Akimoto, K. Tanaka, and K. Uzawa, “A conceptual study of floating axis water current turbine for low-cost energy capturing from river, tide and ocean currents”, Renewable Energy, Vol. 57, Pp. 283–288, 2013. https://doi.org/10.1016/j.renene.2013.02.002

[9] D. Kurniawan, F. Teknik, and U. Diponegoro, “Analisa Pengaruh Variasi Bentuk Hullform Karena Perubahan Ukuran Utama Kapal Kri Teluk Kupang”, Jurnal Teknik Perkapalan, Vol. 3, No. 4, Pp. 568–579, 2015.

[10] Darmawi, R. Sipahutar, J.D. Nasution, A. Taqwiym, Nurussama, “The efficiency decrement of the spiral pump regarding the pipe coil diameter”, Forum in Research, Science and Technology (FIRST) 2016. https://repository.unsri.ac.id/42190/, 2018.

[11] ESMAP. 2017. Small hydro resource mapping in Indonesia : Small hydropower potential report. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/315901506072186354/small-hydropower-potential-report%0A%0A