-Low-speed-Water-Pump-Using-River-Flows-As-The-Driving-Force.pdf

by

Submission date: 06-Mar-2023 09:37PM (UTC+0700)
Submission ID: 2030270481
File name: -Low-speed-Water-Pump-Using-River-Flows-As-The-Driving-Force.pdf (359.28K)
Word count: 3700
Character count: 18931

The Development and Test of a Low-Speed Water Pump using River Flows as the Driving Force

Sunardi, Jamrud Aminuddin, Kartika Sari, Wuryatmo Akhmad Sidik

Abstract: Based on previous studies, a low-speed water pump was developed, and assessed through a river flow test. The designed water pump consists of 5 wheels, 2 pistons, and 1 valve. The 5 wheels are arranged in the same axis and chain. The first axis consists of the 1st and 2nd wheels, namely, θ_1. The 2nd wheel is connected in the same chain, with the 3rd in parallel zone as the 4th, θ_2. The 4th is connected to the same chain as the 5th wheel, namely θ_3. Furthermore, the 4th wheel is arranged in the same axis with the piston activator. In the pump system, there are 2 pistons for triggering the lifter, from the lower to the higher position. The size and dimension of the whole component used in the pump system, are developed from the previous computational studies. The testing of the converter and pump system performance, has been carried out based on the water flow condition (v), radial speed of wheels (θ_1, θ_2, θ_3), water lift height (h), and discharge of pumped water (q). The result showed that the selected size and dimension have significant effect in some water flow conditions. However, the flow force is very influential in decreasing the pump system performance, and in lifting water from the lower to the higher position

Index Terms: Euler-Lagrange, Piston, Pump, Runge-Kutta, Valve, Water, Wheel.

1 Introduction

Awater pump is an important piece of equipment, used in moving fluid from a lower to higher position, through mechanical and electrical actions, with definite change in energy. Several types of pumps for lifting dynamic water, such as river flow, have been developed for hydropower optimization [1], [2], [3], [4]. A water flow pump is an energy source, generally known as a hydraulic machine, which works well in high-pressure water flow, while the low form does not perform optimally [5], [6]. Therefore, the development of a new type of pump is needed, using low speed water flow [7], [8]. Also, it is developed from hydraulic machine, with low cost and clean energy [9]. The design and realization of an energy-efficient water pump, with a low-speed turbine as the driving force, is developed after studying and analyzing some physics principles. The valve system is manipulated from the Bernoulli principle, to activate the water, as it flows [10],[11]. The water as an internal fluid flow, is developed in several studies and by improving the Bernoulli model [12],[13]. The other principle related to the driving force, is the turbine rotation. Therefore, the method for analyzing the angular speed of energy converter, includes numerical approximation [14], [15], [16], [17]. A water pump with a low-speed turbine is developed, using these principles with the river flow as a driving force. In previous studies, a turbine water pump used a static buffer [7], [8]. Consequently, when the river surface changes to a different level, an adjustment of the pump position is required. Therefore, in this study, optimization is carried out, by replacing the static buffer with the float. This is known to improve the performance of water pump, with the use of buoys, being adaptive to the change of the river flow conditions. This study is developed from theoretical calculations, and is improved by experimental methods.

- *Sunardi is currently permanent lecturer in the Department of Physics, Faculty of Mathematic and Natural Sciences, Universitas Jenderal Soedirman, Purwokerto-Indonesia, E-mail: sunardi@unsoed.ac.id*
- *Jamrud Aminuddin is currently permanent lecturer in the Department of Physics, Faculty of Mathematic and Natural Sciences, Universitas Jenderal Soedirman, Purwokerto-Indonesia, E-mail: jamrud.aminuddin@unsoed.ac.id*
- *Kartika Sari is currently permanent lecturer in the Department of Physics, Faculty of Mathematic and Natural Sciences, Universitas Jenderal Soedirman, Purwokerto-Indonesia, E-mail: tikasari57@gmail.com*
- *Wuryatmo Akhmad Sidik is currently permanent lecturer in the Department of Mathematic, Faculty of Mathematic and Natural Sciences, Universitas Jenderal Soedirman, Purwokerto-Indonesia, E-mail: wuryatmo.sidik@gmail.com*

2. Methods

The design of the water pump, inspired by the low-speed turbine, was initialled from the configuration energy converter (wheels configuration). The first wheel (turbine) was connected to an axle with the second (θ_1). The second wheel was connected by a chain to the third, which was axially arranged with the fourth (θ_2). The rotation effect of the fourth wheel was converted to mechanics, in a bid to trigger the piston at the fifth wheel (θ_3). Pump testing was carried out, by determining an ideal configuration of wheels, as an energy converter. The dimension of the energy converter was represented in the wheel radius scale comparison. Furthermore, experiments were carried out using several wheels, with varying radii. At this stage, the configuration and dimension of the wheels, is observed to trigger a piston of the pump system. Figure 1 shows the configuration of the energy converter, which had been developed from previous studies [7], [8].

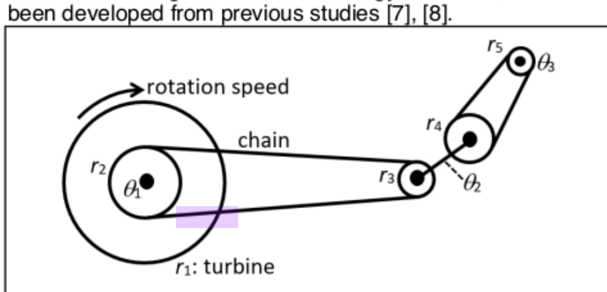

***Fig. 1**. Scheme of the energy converter for driving the pump*

(1)

(1)

where, I-parameter is the moment of wheels inertia, involved in the formulation, namely:

(2)

The numerical solution of equation (1), is determined by the 4th of the Runge-Kutta method. The general form of the numerical solution is,

(3)

In equation (3), the constant k, which consists of four orders, is determined by the following formula,

(4)

(5)

(6)

(7)

The parameter h, is the result of a long division of time interval number (N) in the form,

(8)

The length of the time interval, is the difference between the initial period ($t^{(i)}$), and that of the end ($t^{(n)}$). The method was developed from some numerical analysis, related to the energy converter [15], [16], [17]. Therefore, through the numerical approximation, the size with dimension of the pump, are determined and realized. Furthermore, the whole pump performance was tested, by operating in the real river, to lift water from the lower to the higher position. This pump was placed on the float, which consisted four small drums, adaptive to river flow conditions. However, this measurement had been carried out on various river flows, and heights. Furthermore, the parameters to be measured, are shown in Table 1. The testing of the converter and pump system performance had also been carried out, based on the water flow speed (v), radial pace of wheels (θ_1, θ_2, θ_3), fluid lift height (h), and discharge of pumped water (q). Therefore, the experimental principle is being developed, from several studies about fluid flow [3], [8], [13].

3 RESULTS AND DISCUSSIONS

3.1 Design and dimension of the water pump

Figure 2 is the numerical analysis result, using the 4th order Runge-Kutta method. The angular speed of the first (r_1) and second (r_2) wheels in the same axis, are marked by θ_1. The next wheel connected by a chain to the second, is the third (r_3), and is adjusted in the same axis as the fourth (r_4). Both the third and fourth wheels are expressed as θ_2. The wheel (r_5), arranged in the same axis with the piston handle of the valve system, is represented as, θ_3. The numerical approximation was then carried out, by assuming that the driving force was at approximately, 50 N. Also, the force was assumed, by considering the river flow at around 0.5m/s to 1.5 m/s [7], [16], [17]. The kinetic friction of the whole wheel was adjusted around 0.5, as a consequence for the power loss of about 50% [16], [17]. The other parameter also indispensable in the numerical analysis, was the inertial values of the 5 wheels, as shown in Table 2, which are well determined based on mass and radius [18]. The parameter values that have been tested, are based on the high angular wheel rate, to thrust the handle of the piston. The piston is the trigger of the pump's valve system, to lift water from lower to the higher position.

TABLE 1
THE PARAMETERS HAVE BEEN TESTED TO KNOW THE PUMP PERFORMANCE

Parameters	Unit	Equipment
Speed of river flow (v)	m/s	meter block, stopwatch, dan light ball
Angular speed of wheels (θ_1, θ_2, θ_3)	rad/s	tachometer
Heigh at which water is raised by the pump	m	meter block
The volume of water lifted at each time unit	L/s	vessel

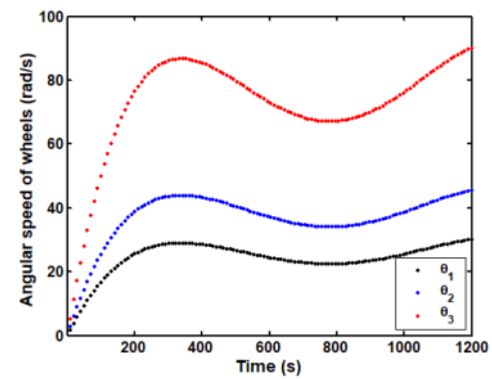

Fig. 2*. The numerical analysis of the angular speed of the wheels*

Furthermore, the real form of the pump system was realized based on numerical approximation. Table 2, showed the physics parameter related to the pump design. It is possible for both diameter and inertial of wheels to improve in higher dimension, by using scale comparison form. The inertial is the parameter, which depends on the mass and radius of the wheels [18], [19]. Although the mass is not specified explicitly, the inertial of the whole wheel is assumed, by considering approximations, based on the wheel's material [20]. The scale of comparison is the multiplier used for the change in pump size. The values in Table 2, as the converter energy design, are confirmed to possess the ability of triggering the piston, even though the system was driven with a small force. Figure 3 shows the scheme and real form of the pump, developed from previous experimental and computational studies [7], [16]. The design of the water pump consists of, 5 wheels, 2 pistons, and 1 valve. The 5 wheels are arranged along the same axis and chain. The first axis is observed to consist of the first and second wheels (θ_1). The second wheel is connected on the same chain, with the third axially parallel as the fourth (θ_2). The fourth is connected to the same chain as the fifth wheel (θ_3), which is arranged in parallel axis with the activator of the piston, for the pump system. In this pump system, there are 2 pistons for triggering the lifter from the lower to the higher position.

***Fig. 3**. Scheme and real form of the water pump with the river flow as a driving force*

TABLE 2

THE PHYSICS PARAMETERS OF WHEELS RELATED TO THE PUMP DESIGN

Wheels diameter (m)	Inertial (kg/m)	Scale comparison
$r_1 = 0.35$	0.050	1.0
$r_2 = 0.16$	0.005	0.5
$r_3 = 0.12$	0.002	0.3
$r_4 = 0.14$	0.003	0.4
$r_5 = 0.10$	0.001	0.2

3.2 The texting of the pump performance

Figure 4 shows the testing process in the river, with various flow conditions. Testing of all pump components, had been carried out in several river flow conditions. In this study, they are grouped into three categories, namely, high, medium, and low river flows. The average values of the river flow velocity are, 1.05, 0.86, and 0.62 m/s, classified as high, medium, and low categories, respectively. Furthermore, among the three river flow conditions (v), the pump performance was verified for various height, at which water is raised (h). The heights in this experiment are, 1, 2, 3, and 4 meters, respectively. Also, the volume of water lifted at each time unit, is measured with the radius speed of the whole wheels (θ_1, θ_2, θ_3), simultaneously. The result in Table 3, shows the average values of the measurement process, for the fastest condition of the river flow. The time in the second unit illustrates the periodic length to attain 1 L (Litre) of water. Therefore, the measurement result is converted to the volume of water, in the unit of Litre per second (L/s). The same measurement method, had also been applied for various hydraulic ram pumps (Hussin et al. 2017).

***Fig. 4**. The texting process of the pump component in the river with various flow condition*

The data in Figure 5, shows the summary of the three-river flow, which is marked as, 1.05, 0.86, and 0.62 m/s, classified as fast, medium, and low speeds, respectively, with the amount of water discharge represented in litre per second (L/s). The height with the unit of a metre (m), illustrates the output pipe position in measuring pump performance, to lift water from the river. The highest water discharge at around 0.09 L/s, is observed at the fast river flow (1.05 m/s), with the output pipe height approximately 1 m. Furthermore, in the case of the height at which water is raised at about 2, 3, and 4 m with the same river flow velocity (1.05 m/s), the pump system's ability to lift fluid, should be around, 0.07, 0.06, and 0.05 L/s. Also, it is observed that, the pump performance for raising water decreases by approximately 0.01 L/s, for changing every 1 m of output pipe height. In the condition of different river flow speeds, the pump performance decreases at about 0.02 L/s. The result from this study, has been compared with that of the hydraulic ram pump [21], [22]. Therefore, from this performance testing, the design and dimension of the pump system ability to lift river water has been observed, though it operates with low driving force.

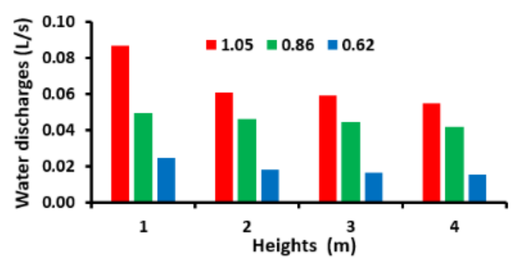

***Fig. 5**. Summary of the water discharge for every height condition depends on the river flow speed*

3.3 Discussions

Designing and realizing the simple pump with the low and green energy, have been carried out, using a turbine and valve system. The machine was designated and developed from the commercial pump, which used an energy converter to rotate the trigger of the valve, for lifting water from lower to higher position. In this study, the energy converter was manipulated, using the turbine and the connection of several wheels, to trigger the simple valve. The wheels' configuration was analyzed, using numerical methods to obtain an ideal design, for the water pump system. From the theoretical approximation, the design and dimension of the whole pump were realized, and tested in real water. The experiment for testing the water pump performance was conducted, by measuring the real angular speed of the energy converter in the form of wheel configuration. However, in the experiment, the volume of water pumped, was also verified in several conditions of the river flow speed, with the height at which water is possibly lifted. Comparing the numerical analysis in Figure 2 and real measurement from Table 3, there was a deviation of angular speed. When the angular speed was connected directly to the pisto`n (θ_3), at around 80 rad/s from the theoretical calculation, the real measurement was shown at approximately 20 rad/s. Furthermore, since the numerical analysis was assumed to be frictionless with the loss of angular speed of about 50%, the velocity of the fifth wheel according to the theoretical calculation, was around 40 rad/s [15]. The condition indicated that, there was a deviation of about 50%, between numerical analysis and experiment. Therefore, the development of the real water pump with a different dimension, was referred to the experiment result, using the scale comparison. For instance, when the pump is to be realized twice as higher than the dimension of that from this study, the developer needs to multiply/divide the domain, with the scale of comparison. Therefore, the whole physics parameters shown in Table 2 were indispensable to consider, as regards realizing the other dimension [8], [23].

4 CONCLUSION

The size and dimension of the water pump were successfully analyzed, using computational and experimental methods. From the theoretical approximation, the design and dimension of the whole pump were realized and tested in the real water. The converter testing and pump system performance, were carried out, based on water flow condition (v), radial wheels' speed (θ_1, θ_2, θ_3), fluid lift height (h), and pumped water discharge (q). The result showed that the selected size and dimension have significant effect in some water flow conditions. However, the flow force was very influential in decreasing the pump system performance, and in lifting water from lower to higher position. To develop this pump into a different dimension, the scale comparison is needed to be considered, as a multiplier and divider for new size. An indispensable verification process was performed by comparing the system, developed in this study, and that of the conventional pump, which is driven by a machine. Therefore, the verification process is very important, in order to understand the economic aspect of the pump, driven by the river flow, with low and green energy. It is then possible to conduct precise comparisons, within the same physics parameter, and river conditions.

ACKNOWLEDGMENT

The authors are grateful to the Research and Public Service Institute of Universitas Jenderal Soedirman (LPPM-Unsoed), for the financial support, namely Institutional Research Competitive Grant (RISIN-DT), based on Contract Number, T/326/UN23.18/PT.01.03/2020

REFERENCES

[1] K.V. Alexander, and E.P. Giddens, "Optimum Penstocks for Low Head Micro Hydro Schemes", Renewable Energi, vol. 33, no. 3, pp. 507-519. 2018.
[2] J.C. Blanco Y., Secretan, and A.L.A. Mesquita, "Decision Support System for Micro-hydro Power Plants in the Amazon Region under a Sustainable Development Perspective", Energy for Sustainable Development, vol. 12, no. 3, pp. 25-33. 2008.
[3] G. A. Caxaria, D. M. Sousa, and H. M. Ramos, "Small Scale Hydropower: generator analysis and optimization for water supply systems", World Renewable Energy Congress 2011, Sweden, 8-13 May Lingköping-Sweden, pp. 1386-1393, 2011.
[4] A. Santoni, G. Cavazzini, G. Pavesi, G. Ardizzon, and A. Rossetti, "Techno-Economical Method for the Capacity Sizing of a Small Hydropower Plant", Energy Conversion and Management, vol. 52, no. 7, pp. 2533-2541, 2011.
[5] A. Suryawan, A. Adhi, and I.M. Suarda, "An Experimental Study of the Flow Acceleration to the Performance of the Hydraulic Ram Pump" Scientific Journal of Mechanical Engineering: Cakram, vol. 3, no. 2, pp. 10-15, 2009.
[6] I. M. Suarda, "Designing and Texting of the Hydraulic Ram Model for Torak Pump with Two Flow Sources: Clear and Dirty Water". Proc. of Seminar Nasional Tahunan Teknik Mesin (SNTTM) Ke-9, Palembang, 13-15 Oktober 2010.
[7] J. Aminuddin, M. Effendi, Nurhayati, A. Widiyani, and Sunardi, "Application of Euler-Lagrange Formalism and Solution of its Equation of Motion in Designing of Hydraulic Pump with Turbine as Driving Force", Journal of Teras Physics, vol. 2, no. 2, pp. 18-20, 2019.
[8] J. Aminuddin, Nurhayati, and A. Widiyani, "Modification of the Water Pump with the Low-Speed Turbine as a Driving Force", Elkawnie: Journal of Islamic Sci. and Tech, vol. 1, no. 2, pp. 38-46, 2019.
[9] Y.A. Cahyanta, and A.W. Mandagi, "The Effect of Waste Valve Stroke Length on The Hydraulic Ram Pump Performance". Int. J. of Eng. and Sci., vol. 2, no. 4, pp. 56-60, 2011.
[10] M.M. Alnakhlani, Mukhtar, D. A. Himawanto, A. Alkurtehi, and D. Danardono, "Effect of the Bucket and Nozzle Dimension on the Performance of a Pelton Water Turbine", Modern App. Sci., vol. 9, no. 1, pp. 25-33, 2015.
[11] J.P. Thavamani, "Bernoulli Equation in Fluid Flow", Int. J. of Current Research, vol. 8, no. 10, pp. 459-461, 2016.
[12] D. Azevedo and M.C. Valentino, "Generalization of the Bernoulli ODE, Int. J. of Math. Education in Sci. and Tech., vol. 48, pp. 256-260, 2016.
[13] K. Nirmaladevi, M. Mythilee, M. Navein, and K. Manikandaprabhu, "A Study on Bernoulli's Equation and Its Application in Fluid Mechanics", Int. J. for Sci. Research and Development, vol. 6, no. 12, 2019.
[14] A. Battezzato, G. Bracco, E. Giorcelli, and G. Mattiazzo, "Performance Assessment of a 2D of Gyroscopic Wave Energy Converter", J. of Theory. And Appl. Mechanics, vol. 53, no. 1, pp. 195-207, 2015.
[15] W. Beabpimai, and T. Chitsomboon, "Numerical Study of Effect of Blade Twist Modifications on the Aerodynamic Performance of Wind Turbine", Int. Journal of Renewable Energy Development, vol. 8, no. 3, pp. 285-292, 2019.
[16] J. Aminuddin, M. Effendi, Nurhayati, A. Widiyani, P. Razi, Wihantoro, A.N. Aziz, R.F. Abdullatif, Sunardi, Bilalodin,

and A. Arifin, “Numerical Analysis of Energy Converter for Wave Energy Power Generation-Pendulum System”, Int. J. of Renewable Energy Development, vol. 9, no. 2, pp. 255-261, 2020. http://dx.doi.org/10.14710/ijred.

[17] J. Aminuddin, Nurhayati, A. Widiyani, P. Razi, Wihantoro, A.N. Aziz, R.F. Abdullatif, and A. Arifin, “Estimation of Ideal Configuration and Dimension of Pico Hydropower using Euler-Lagrange Equation and Runge-Kutta Method”, J. of Phys.: Conf. Series, vol. 1494, no. 012039, 2020. doi:10.1088/1742-6596/1494/1 /012039.

[18] L. Feng, G. Lin, W. Zhang, and P.I Rogedo, “The inertial effect of acceleration fields on a self-decoupled wheel force transducer”, Latin American Journal of Solids and Structures, vol. 12, no. 8, pp. 1448-1461, 2015. https://doi.org/10.1590/1679-78251540

[19] Y. Eray, and H. Kuşçu, “Effect of Weight and Diameter Variables on Balance Process for Inertia Wheel Pendulum by Using Swing Up and PID Controller”, Int. Sci. J. Machines Technologies Materials, vol. 16, no. 5, pp. 191-193, 2020.

[20] E. A. Hogan, and H. Schaub, “Three-axis Attitude Control Using Redundant Reaction Wheels with Continuous Momentum Dumping”, J. of Guidance, Control, and Dynamics, vol. 38, no. 10, pp. 1865–1871, 2015.

[21] N.S.M. Hussin, S.A. Gamil, N.A.M Amin, M.J.A. Safar, M.S.A Majid, M.N.F.M Kazim, and N.F.M. Nasir, “Design and Analysis of Hydraulic Ram Water Pumping System”. J of Phys: Conference Series, vol. 908, no. 012052, 2017. doi:10.1088/1742-6596/908/ 1/012052.

[22] D. Ariwibowo, “Failure Analysis ff Water Pump Shaft”, J. of Vocational Studies on App. Research, vol. 1, no. 2, 2019.

[23] F. Alkarrami, T. Iqbal, K. Pope, and G. Rideout, “Dynamic Modelling of Submersible Pump Based Solar Water-Pumping System with Three-Phase Induction Motor Using MATLAB”. J. of Power and Energy Engineering, vol. 8, pp.20-64, 2020. https://doi.org/10.4236/jpee.2020.82002.

-Low-speed-Water-Pump-Using-River-Flows-As-The-Driving-Force.pdf

ORIGINALITY REPORT

6%	3%	2%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Federal University of Technology Student Paper	2%
2	Submitted to Universitas Jenderal Soedirman Student Paper	2%
3	www.atlantis-press.com Internet Source	1%
4	oamjms.eu Internet Source	1%

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		