Performance on Compressor as Turbine (CAT) Piko Hydro Scale

Asep Neris Bachtiar*, Ahmad Fauzi Pohan*‡, Santosa**, Isril Berd**, Uyung Gatot S. Dinata***

*Department of Mining Engineering, Industrial Technology High School of Padang, Jl. Prof. Dr. Hamka no 121, Padang, 25171, Indonesia.

** Department of Agriculture Engineering, Faculty of Agricultural Technology, Andalas University, Jl. Universitas Andalas Limau Manis Pauh, Padang, 25163, Indonesia.

*** Department of Mechanical Engineering, Faculty of Engineering, Andalas University, Jl. Universitas Andalas Limau Manis Pauh, Padang, 25163, Indonesia.

(asepnerisb@sttind.ac.id, fauzipohan@sttind.ac.id, santosa@fateta.unand.ac.id, isberd@yahoo.com, uyunggsd@ft.unand.ac.id)

‡ Corresponding Author; Ahmad Fauzi Pohan, Jl. Prof. Dr. Hamka no 121, Padang, 25171, Indonesia, Tel: +62 823 1444 9898, Fax: +62751-443000, fauzipohan@sttind.ac.id

Received: 28.03.2019 Accepted:15.05.2019

Abstract- The potential for water energy in Indonesia is around 76170 MW, only 210 MW has been utilized through micro-hydro and piko hydro-scale hydropower plants, one of the challenges because water turbines are not sold on the market, to get them must be ordered first so the price of turbines becomes expensive The purpose of this experimental study centrifugal compressor as a water turbine. Tests were carried out on a 4.7 m constant head and four variations was to determine the characteristics and achievements of a turbo charger of valve openings, namely open 100%, 75%, 50% and 25%. It is known that the greater the valve openings the greater the rotation speed, torque, power and efficiency. At 100% valve openings produce maximum torque of 10.7 Nm, maximum power of 342.11 W and maximum efficiency of 52.7%. The efficiency curve due to the influence of the discharge ratio produces a polynomial curve with mathematical equations $y = 113.5x^3 - 304.5x^2 + 290.6x - 46.92$, that is the finding that can be used as a measure of achievement and characteristics of a centrifugal compressor turbo charger when it functions as a water turbine.

Keywords Compressor as turbine, Pump as turbine, CAT, PAT, Piko hydro, Turbo charger.

1. Introduction

Energy is a very important issue that requires proper handling because 1.6 billion people currently do not have access to the electricity network while another billion depend on unreliable electricity networks [1]. The effort to get energy is a fundamental problem for human life. The development of energy systems through the exploitation of various natural resources such as coal and petroleum has been carried out in recent years, this phenomenon brings an increase in harmful pollutants in the atmosphere [2]. For this reason, renewable energy sources are being investigated, especially the potential of small-scale water energy (micro and micro hydro) which is widely available in the village. hydroelectric power plants have several advantages so that hydroelectric power plants are attractive in terms of sustainable development [3] and hydroelectric power plants only produce 35-70 times less greenhouse gas emissions compared to thermal power plants [4]. The People's Agriculture Service of West Sumatra Province, Indonesia reported, in 1974 in West Sumatra there were 4082 paddy pound waterwheel units [5]. This data shows that the energy potential of the piko hydro scale water in rural West Sumatra is quite abundant. While the potential for water energy at the national (Indonesia) level is around 76170 MW, but until 2010 it utilized around 4410 MW or around 5.8%. Its utilization is 4200 MW through large-scale hydroelectric power plants, and 210 MW through small-scale hydropower or micro hydro and piko hydro [6]. One of the obstacles that hinder the development of small-scale hydropower plants, especially piko Hydro, is the procurement of non-easy prime mover (turbine) components. The public must order first so that the price per unit of the turbine becomes expensive because there are costs of surveys and planning that must be borne by the community, consequently the investment of piko hydro is quite expensive around 5000 US $ / kW [7]. The results of the literature search turned out to be the problem of the challenges and development of the piko hydro power plant that were of concern to world researchers, including explaining the development of piko hydro in Malaysia, Rwanda, Laos and Kenya [8-11]. Other researchers have succeeded in formulating a practical, inexpensive piko hydro generator system that has competitive efficiency achievements. Cost-effective turgo turbines can be used for piko hydro plants at a speed ratio of 0.425, number of 25 blades, optimum jet diameter of 15.4 mm, and ratio of nozzle diameter to distance between blades (d/s : 0.94). The best turbine performance can be achieved when the ratio (d / s) is greater than 0.45 and when the jet is directed to the center of the blade at an angle of 300 [12]. Another challenge that attracts researchers is the alternative to several types of piko hydro turbines. Their idea is how to create a different turbine model with other conventional turbines and make modifications to the turbine runner to increase efficiency [13-15].

One of the most widely used technologies in piko hydro scale hydropower is Pump as Turbine (PAT) technology because many pumps are sold in the market with various brands, types and sizes. The use of PAT is a solution for people to get water turbines more easily [16-17]. PAT technology is suitable for small-scale power plants but the obstacle to using PAT technology is when the pump is used as a turbine does not have a specific speed range. The specific speed (ns) of PAT is generally smaller than 60 and to produce competing PAT efficiency it is recommended that the value of ns ranges from 60 - 150 [18]. A simple piko hydro generator can be built by using PAT as a prime mover because of its low cost. The results of the analysis show that piko hydro investment is considered feasible if the electric power capacity is greater than 380 kWH / month [19]. Through his experimental research concluded the maximum efficiency of PAT is 76% which can be achieved at a specific speed of 0.57 [20]. The centrifugal pump is feasible to function as a turbine, the efficiency of the pump as a turbine reaches 65% on the effective head of 8.4 m and turbine inlet water discharge 18 L / s [21]. Pump optimization as a turbine has been observed by several researchers including optimization testing designed to predict the characteristics of the pump as a turbine and choose the most appropriate pump to be a turbine. Routine optimization is predicted to answer previous uncertainties, especially in low specific speed intervals. Optimization was evaluated experimentally for three pumps with specific speeds of 18.2 rpm, 19.7 rpm and 44.7 rpm [22]. The experimental and numerical results of the effect of PAT impeller diameter reduction on efficiency are known that PAT flow discharge at the best efficiency point (BEP) position shifts from 95.23 m^3 / h to 86.14 m^3 / h and then moves back to 93.63 m^3 / h. The efficiency in the BEP position drops 4.11% for impellers with diameters reduced from 255 mm to 215 mm [23].

The piko hydro generator and the characteristics of a centrifugal pump as a turbine are the objects of observation of researchers and practitioners, it is necessary to observe the characteristics of other alternative fluid engines that can be used as water turbines including centrifugal compressors and centrifugal blowers. This study was successful in testing the performance of the compressor as a turbine (CAT), which is a centrifugal compressor that comes from a turbo diesel motorbike charger component. The community is expected to be inspired to use old engine components that are no longer used to function as turbines at the piko hydropower plant. By using CAT, the community will find it easier to build a piko hydropower plant according to their financial capabilities, water potential and potential alternative fluid engines in their environment.

2. Material and Methods

This research was carried out around the irrigation channel of Limau Manis Village, Kuranji Subdistrict, Padang City, West Sumatra, Indonesia about 500 meters to the east from Andalas University campus precisely at the position of 101.06° East and 1.509° South coordinates and the layout around the test location as shown in Figure 1.

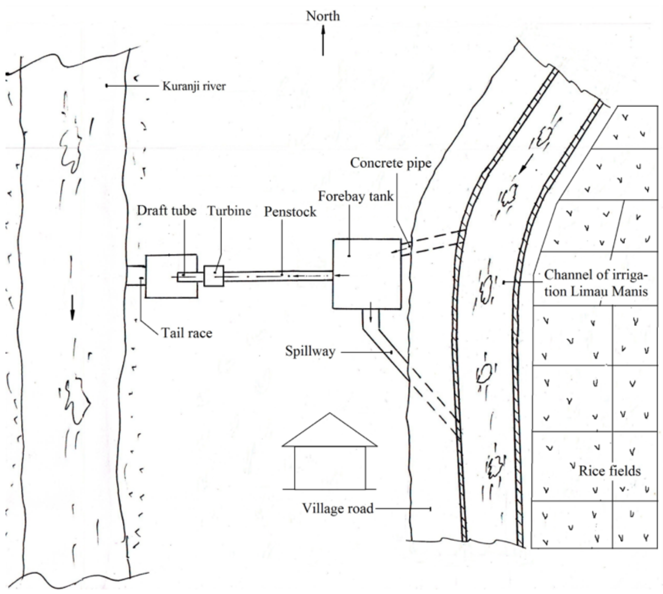

Fig. 1. Layout around the CAT testing location.

2.1. Procurement of Tools and Materials

The initial step of the research is the procurement of tools and materials. The equipment and materials used include centrifugal turbo charger compressors as solution fluid machines, pipe installation equipment, measuring instruments, and building materials such as stone, cement, sand, wood and zinc roofs. The centrifugal compressor tested comes from a turbo charger component, which is a component of a diesel motor which functions to convert heat energy and exhaust gas pressure from combustion results to be used as mechanical energy to spin the impeller to be able to compress the return air into the combustion chamber. Before modified turbo charger construction is shown in Figure 2.

Fig. 2. Photo of a Turbo charger before modification.

2.2. Modification Phase

The Turbo charger in the field cannot be directly used as a water turbine but needs adjustments and modifications. The initial step of modification is to separate the centrifugal compressor with the gas turbine. This separation effort needs to be done because the compressor and gas turbine have the same shaft as shown in Figure 3.

Fig. 3. Photo of turbo charger shaft with two impellers.

The next modification step is to release the volute and compressor impeller from the main body of the turbo charger, then make the compressor shaft with dimensions that match the planning results. Other components that need to be prepared are a ball valve, two 1 inch bearings, a 4 inch diameter pulley one port, type C belt, nut bolt, 3 mm thick steel plate, turbine holder and generator. After all available components are then carried out the generator system assembly process involves the process of cutting, welding, grinding, drilling and painting the results as shown in Figure 4.

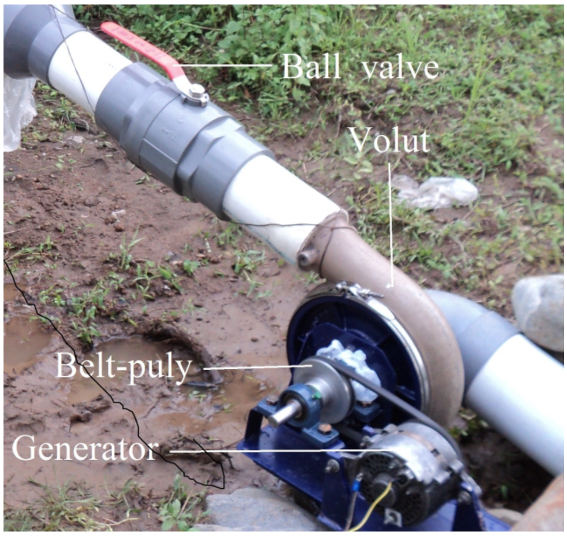

Fig. 4. Photo of a turbo charger compressor as a water turbin.

2.3. Construction of a Testing Installation

The next step is to build a CAT testing installation as shown in Figure 5. Rapid pipelines are selected from lightweight and easy materials in the connecting process, namely 8 inch diameter PVC pipes. At the end of the pipe, a 6-inch valve is installed which is directly connected to the CAT inside the generator house as shown in Figure 6. The difference in height between the water surface in the sediment tank and the surface of the drainage is about H : 5.30 m.

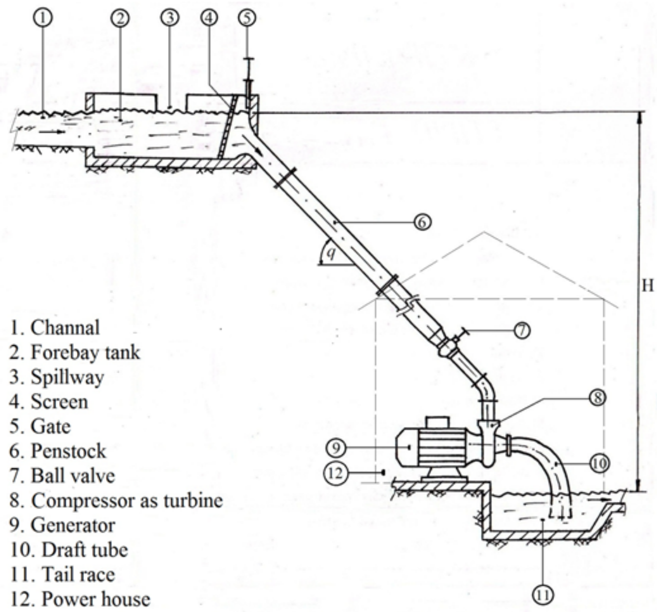

Fig. 5. Scheme of compressor testing as a turbine.

Fig. 6. Photo of power house for securing test equipment.

2.4. Head Turbine Analysis

The turbine head (H_t) is the effective head of the generating system which can be known from the actual (H) head difference with head losses (H_l), the head losses consist of major head losses and minor head losses. Major head losses (H_{lma}) occur due to friction losses between water and walls in the pipe which can be calculated by Eq. (1) [24].

$$H_{lma} = f \times l/d \times V^2/2 \times g, \quad (1)$$

where f is the friction factor, l is the length of the pipe (m), d is the diameter of the pipe (m), V is the speed of water flowing in the pipe (m/s) and g is the gravitational acceleration (9.81 m/s^2). Minor head losses (H_{lmi}) occur due to obstacles from pipe installation equipment that can be calculated by Eq. 2 [24].

$$H_{lmi} = \sum k \times V^2/2 \times g, \quad (2)$$

where $\sum k$ is the number of drag coefficients of the pipe installation equipment

2.5. Testing Phase

Turbine torque testing is carried out with the braking mechanism as described in Fig. 7. In the braking process, there will be a tensile force (F_t) and a compressive force (F_c), the difference between F_t and F_c is the braking force (F_b). After the value of braking force is known, the torque that occurs can be calculated by Eq. (3) [25].

$$T = F_b \times r, \quad (3)$$

where r is the radius of the pulley (m).

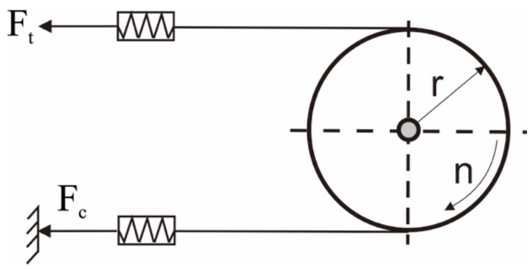

Fig. 7. Measuring torque with the braking mechanism.

The next stage is the measurement of CAT performance, testing is divided into two treatments, namely constant valve opening and constant rotation. Valve opening variations are fully open (100%), open 75%, open 50% and open 25%. At each valve opening ten rotation variations are carried out and each rotation is measured by torque (T), turbine inlet discharge (Q), turbine rotation speed (N), potential power (P_p) and turbine (P_t) power which can be known with Eq. (4) and (5) [25].

$$P_t = 2 \times \pi \times N \times T / 60, \quad (4)$$

$$P_p = \rho \times g \times Q \times H_t, \quad (5)$$

where ρ is the dencity of water (1000 kg/m^3).

The efficiency of the turbine (η_t) can be known with Eq. (6) [24].

$$H_t = (P_t / P_p) \times 100\%. \quad (6)$$

3. Result and Discussion

Table 1 shows the specifications of the CAT testing installation components starting from the sediment tank, rapid pipeline to the generator house. The achievement test and characteristics of CAT are carried out in seven variations of the influence relationship, the constants are turbine head (H_t : 4.7 m). Tests are carried out in four variations of valve openings, which are full valve openings (100%), 75% valve openings, 50% valve openings and 25% valve openings, 10 variations of the rotation speed and discharge of each valve at each valve opening.

Table 1. Specifications of compressor components as turbines

Components	Dimension
Forebay tank	2 m × 1.2 m × 0.8 m
Diameter, penstock length	6 inch, 15 m
Penstock track angle (α)	35^o
Aktual head (H)	5.33 m
Losses head (H_l)	0.63 m
Turbin head (H_t)	4.7 m
Discharge (Q_{mak})	19 L/s
Diameter of the ball valve	4 inch
Diameter of impeller	4 inch
Power house	1.25 m × 1.25 m × 2 m

3.1. Variation of Torque (T) due to Effect of Rotational Speed Variation (N)

Figure 8 shows the variation in torque due to the effect of rotation speed variations, this test aims to determine the trend of the maximum torque and torque curves that occur at the optimum turbine rotation. The results of the analysis that the four curves have relatively the same slope or slope, there is no crossing with each other, this indicates that the generating system can continue to operate stably despite variations in valve openings. The curve trend that occurs produces a linear curve with a coefficient of determination (R^2) that is convincing, close to a value of 1. This implies that the diversity of the value of torque can be explained easily by the diversity of the value of rotation. There is a direct relation between valve openings and torque. The biggest torque is 10.7 Nm occurs at the open valve position of 100% followed by torque of 8.9 Nm, torque of 7.4 Nm and torque of 6.3 Nm occur at valve openings of 75%, 50% and 25% respectively.

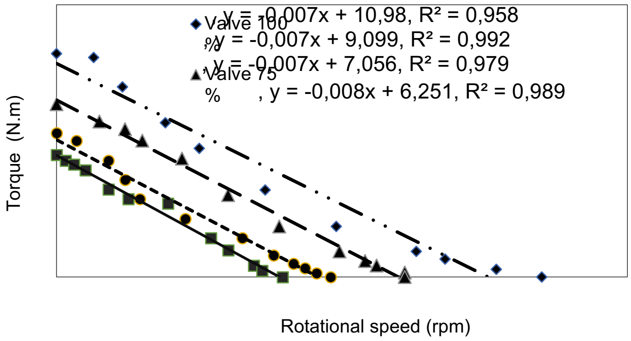

Fig. 8. Variation in torque versus rotational speed.

3.2. Variation of Power (N_t) due to Effect of Rotational Speed Variation (N)

After the torque data for 10 round variations is obtained, then the CAT power can be identified directly from the formula Nt = 2 × π × N × T / 60, the power trend is shown by the curve in Figure 9. The coefficient of determination (R^2) is convincing, close to the value 1. Between curves one with the other curves close together so that the four curves have relatively the same shape only the scale is different. This indicates the power trend due to the effect of the rotation variation is strongly influenced by variations in valve openings. Initially in line with the turbine rotation increase, there was an increase in power but after going through half the rotation interval there was a decrease in power to reach the lowest power. In the picture seen in the 100% valve openings the highest power reaches 342.11 W at an optimum rotation of 750 rpm. At 75% valve opening the maximum power is 264 W, rotational speed of 600 rpm, at valve opening 50% maximum power 204 W rotation 470 rpm and at valve opening 25% maximum power 154 W rotation speed 390 rpm.

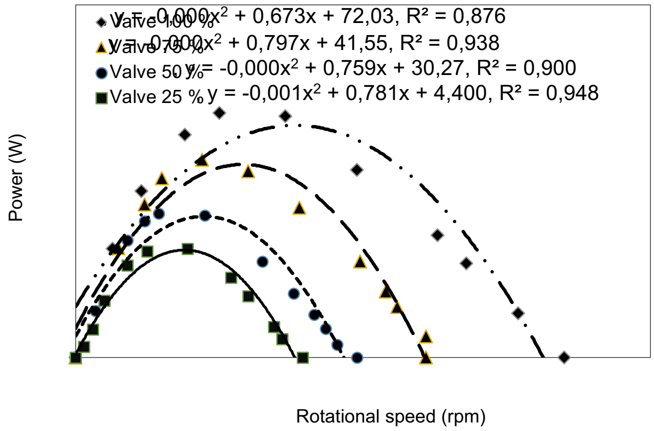

Fig. 9. Variation in power versus rotational speed.

3.3. Variation of efficiency (ηt) due to Effect of Rotational Speed Variation (N)

Figure 10. Shows there are four efficiency curves have the same pattern which is up to half the efficiency rotation interval tends to increase and after passing half the round interval the efficiency value continues to decrease until it reaches the lowest efficiency. Curve trends that occur produce parabolic curves with simpler equations that are sufficiently solved by quadratic equations but still produce a coefficient of determination (R^2) that is convincing, close to value 1, this implies that the portion of the diversity of efficiency values can be explained easily by a variety of values - turbine rotation value. High rotation does not indicate the optimum rotation, the maximum CAT efficiency of 52.7% is obtained at an optimum rotational speed of 750 rpm when the valve position is open 100%. The next maximum efficiency occurs at the open valve position 75%, 50% and 25% is 50.2%, 48.5% and 46% in the turbine rotation of 600 rpm, 450 rpm and 400 rpm. From these findings, it is recommended that the community-built piko hydro generator must be operated in a rotation between 700 rpm to 750 rpm with valves in full open position (100%).

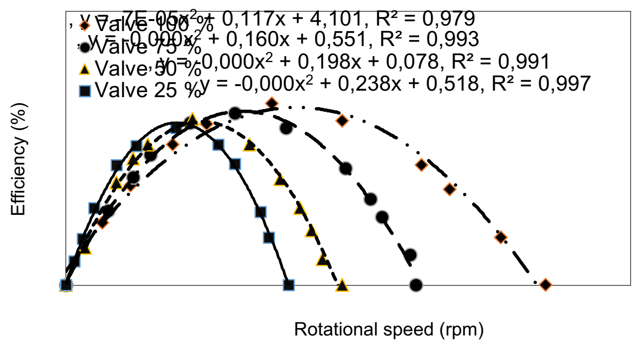

Fig. 10. Variation in efficiency versus rotational speed.

3.4. Debit Variation (Q) due to Effect of Rotational Speed Variation (N)

The CAT intake water discharge is known from the water level data on the weirmeter tub installed at the end of the exhaust line. Data on rotation and discharge variations, then plotted into curves and the results as explained in the curve in Figure 11. The curve in Figure 11 describes a relationship inversely proportional to the rotation with turbine intake water discharge. This phenomenon explains that the slower the turbine turns, the flow of water out of the turbine gets smoother, with the discharge increasing, the energy potential of the water pushes the turbine runner bigger so that at slow turns it will produce greater torque as evidenced in the discussion in section 3.1 . Figure 11 also explains that each curve has a slightly different slope, the smaller the percentage of valve openings the slope or a decrease in water flow is getting steeper, besides that the rotation interval that produces the discharge is also getting shorter. This finding shows that variations in valve openings reduce the ability of the turbine to produce rotation as a result of the instability of the driver which is initially related to mechanical construction of the CAT especially the character of the impeller. The maximum discharge of the turbine intake occurs at the lowest turbine rotation approaching 0 rpm which is 19 L/s, 16 L/s, 13.5 L/s and 11.5 L/s, each of which occurs at valve openings 100%, 75% , 50% and 25%.

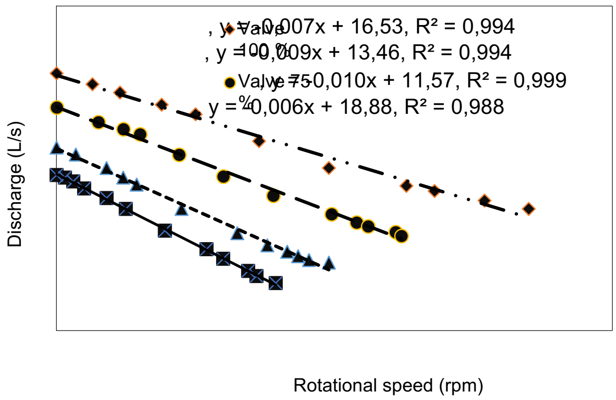

Fig. 11. Variation in discharge versus rotational speed.

3.5. Variation of Efficiency (ηt) due to Effect of Discharge Variation (Q)

This test aims to determine the shape of the efficiency pattern of the four variations of the discharge and to find out the optimum discharge that can produce maximum efficiency as well as the starting discharge of each variation of valve openings. Figure 12 shows that, the efficiency trend produces a parabolic curve with quadratic equations but still produces a convincing coefficient of determination (R^2), close to the value of 1. In the first half of the debit interval the trend of efficiency increases significantly and the next half of the water discharge interval continues the lowest efficiency is 0%. The smaller the percentage of valve openings, the narrower the water discharge interval that occurs, at the 100% valve opening the discharge interval is 10 L/s as the difference between 19 L/s and 9 valve opening is 25% the discharge interval is 8 L/s difference between 11.5 L/s to 3.5 L/s. There is a relationship that is directly proportional to the percentage of valve openings with maximum efficiency, the greater the percentage of valve openings the greater the efficiency of CAT is greater. At valve openings 100%, 75%, 50% and 25% obtained maximum efficiency of 52.7%, 50.2%, 48.5% and 46% at optimum discharge of 14 L/s, 11.8 L/s. 9.2 L/s and 7.3 L/s.

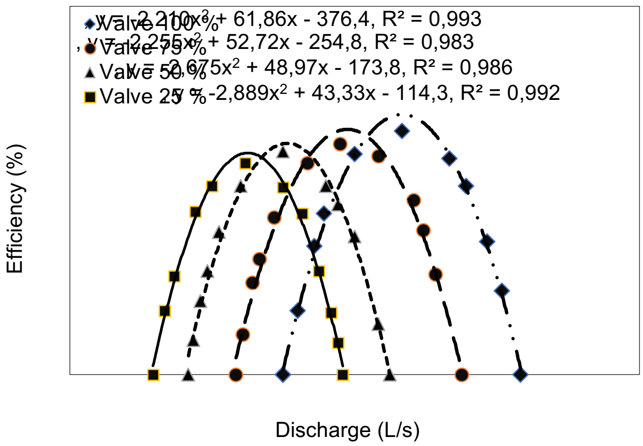

Fig. 12. Variation in efficiency versus discharge.

3.6. Variation of Power (Nt) and Efficiency (ηt) due to the effect of variation of discharge (Q) on constant rotation speed

The purpose of the test is to determine the variation of power and turbine efficiency due to the influence of the variation of the discharge at constant rotation. The previous analysis results get one round value which results in the highest efficiency of 750 rpm, thus this analysis is focused on the constant rotation of the 750 rpm. Data recapitulation related to this analysis is as described in Table 2. Furthermore, valve opening, discharge, turbine power and efficiency data are plotted into curves and results as shown in the curve in Figure 13.

Table 2. Data analysis of the effect of water discharge on the power and efficiency of CAT on constant rotational speed of 750 rpm

Valve (%)	H_t (m)	N (rpm)	Q (L/s)	N_t (W)	Q/Q_{max}	η_t (%)
25	4.7	750	4.13	30.53	0.29	15.05
50	4.7	750	6.63	106.72	0.47	34.54
75	4.7	750	10.56	232.80	0.75	47.68
100	4.7	750	14.00	342.11	1.00	52.70

The curve in Figure 13 shows that the trend of the influence of discharge variations on power forms a linear curve, which means that the water discharge has a consistent effect on turbine power. From the linear curve it is known that the maximum power of 342.11 W occurs at an optimum discharge of 14 L/s with a maximum efficiency of 52.70%, turbine rotation of 750 rpm and head of 4.7 m. While the efficiency trend due to the influence of the variation of the discharge forms a polynomial line, it means that the water discharge is not the only factor that affects the efficiency value, but there are other influential variables such as the quality of construction from the CAT, especially the impeller components which begin to saturate at certain test positions. At the discharge interval from 2.8 L/s to 14.0 L/s, the CAT efficiency trend continues to rise stably, indicating that at this effective discharge interval CAT is consistently sensitive to changes in debit. At the discharge position of less than 2.8 L/s, CAT has not been able to produce power until the lowest efficiency achievement. The open valve position of 10% is the valve position which will produce a starting discharge of 2.8 L/s as explained in the curve in Figure 14.

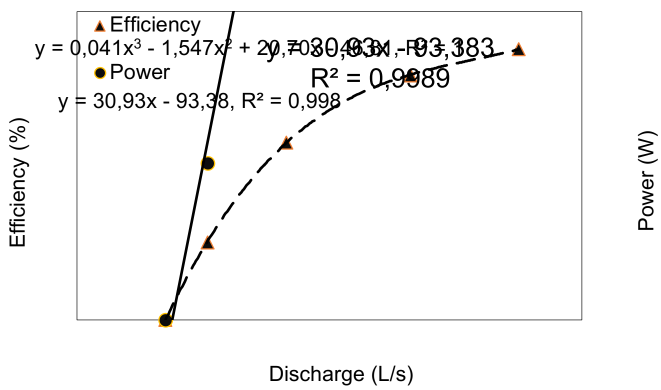

Fig. 13. Variation in the efficiency and power versus discharge.

3.7. CAT Efficiency Variation (ηt) Due to Effect of Discharge Ratio on Constant Rotational Speed

Observing Table 1, the discussion continued to find out the trend of efficiency due to the variation of the discharge ratio at 750 rpm constant rotation and the results as shown in the curve in Figure 14. The analysis results that the efficiency curve due to the influence of the discharge ratio produces polynomial curves with mathematical equations $y = 113.5x^3 - 304.5x^2 + 290.6x - 46{,}92$ with the coefficient of determination $R^2 = 1$ indicating the diversity of efficiency values according to the diversity of the value of the discharge ratio. At the discharge ratio (Q/Q_{max}) below 0.2 turbine efficiency reaches the lowest point, meaning that at that interval CAT has not been able to produce power. Starting from the discharge ratio of 0.2 to 0.754, the increase in turbine efficiency increases significantly, this indicates that CAT is quite sensitive in terms of increasing efficiency due to an increase in the debit ratio. Furthermore, from the discharge ratio of 0.754 to 1.0 resulting in a trend of efficiency that began to increase gradually as seen from the increase in sloping curves, this situation explained that CAT began to be saturated or less sensitive to changes in discharge ratio above 0.754, this is due to construction of impellers or volute houses who cannot compensate or adjust to the addition of water discharge. However the highest efficiency of CAT of 52.7% occurs at the highest discharge ratio of 1.0, that is the finding that can be used as a measure of achievement and characteristics of a centrifugal turbo charger compressor when it is used as a turbine.

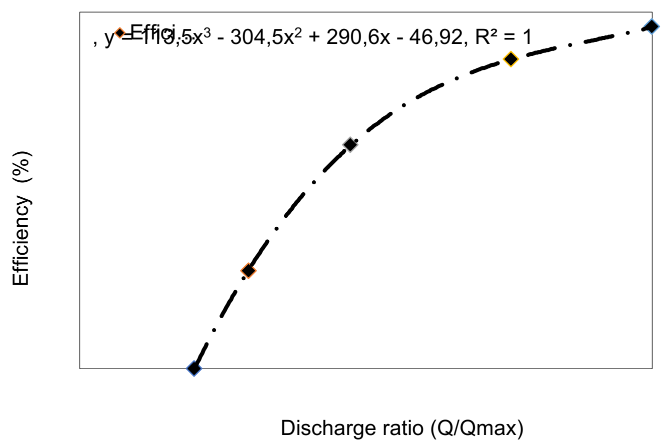

Fig. 14. Variation in efficiency versus discharge ratio.

3.8. Efficiency Curves of Centrifugal Compressors as Turbines with Conventional Turbines for Comparison

Until now the standard mapping curve that is commonly used by practitioners and observers of turbines is the efficiency curve of several types of conventional turbines. In the curve, it is known that the Francis turbine has a trend of efficiency that rises regularly according to the addition of the value of the discharge ratio. Unlike the Pelton turbine, Kaplan and Cross Flow, the increase in efficiency has increased dramatically at the beginning or the value of the discharge ratio is below 0.25 and the discharge ratio is above 0.25 to debit 1.00 The trend of relative efficiency remains even tending to decrease slightly. Compared to the other three conventional tubes, the Francis turbine has the best performance, namely at the position of the discharge ratio of 0.9, achieving efficiency of around 92%. Figure 15 shows a comparison of the efficiency curves of four conventional turbines with CAT. The efficiency trend of CAT is relatively similar to the trend of increasing the efficiency of the Francis turbine, there is no surge in efficiency but what happens is a regular upturn that is consistent from starting minimum efficiency to achieving maximum efficiency. This is very possible because of the volute construction and the CAT impeller resembling a volute and a Francis turbine impeller. Next, pay attention to the curve Figure 16 shows that turbine efficiency achievements derived from the centrifugal compressor turbo charger are lower than all conventional turbines, especially with the Francis turbine, this is due to the curvature of the centrifugal compressor backing towards the direction of the impeller. The Francis turbine impeller blade forward the incoming water so that the efficiency of the Francis turbine is better than the CAT. In addition, the Francis turbine impeller is technically different from the CAT impeller, the Francis turbine impeller is designed as a turbine and the turbo charger compressor impeller is designed as a compressor.

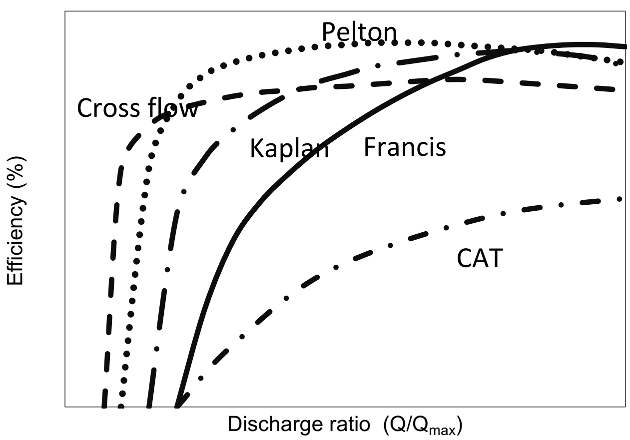

Fig. 14. Variation in efficiency versus discharge ratio of four conventional turbines compared to CAT.

4. Conclusion

The CAT test results with a 4.7 m constant head and four valve opening variations, it is known that the greater the valve opening position can produce better torque, power, efficiency, rotational and discharge speeds. At 100% valve openings with 14 L/s water discharge get maximum torque performance of 10.7 Nm, maximum turbine power is 342.11 W and maximum efficiency is 52.7%. Furthermore, the four variations of valve openings with a constant rotation of 750 rpm produce effective turbine discharge intervals between 2.8 L/s to 14.0 L/s. At the discharge position of less than 2.80 L/s, CAT has not been able to produce power until the lowest efficiency achievement. The discharge of water below 2.80 L/s is called the start discharge which occurs at the open valve position of less than 10%, while the water discharge above 2.80 L/s to 14.00 L/s is referred to as effective turbine discharge. The efficiency curve due to the influence of the discharge ratio produces a polynomial curve with mathematical equations $y = 113.5x^3 - 304.5x^2 + 290.6x - 46.92$ with the coefficient of determination $R^2 = 1$. At the discharge ratio (Q/Q_{max}) below 0.20 efficiency the turbine reaches its lowest point, starting from the discharge ratio of 0.20 to 0.75 the increase in turbine efficiency increases significantly. The discharge ratio of 0.75 to 1.00 results in a trend of efficiency which starts to increase gradually as seen from the increase in the sloping curve. The highest efficiency of CAT of 52.7% occurs at the highest discharge ratio of 1.0, that is the finding that can be used as a measure of achievement and characteristics of a turbo centrifugal compressor when it is used as a turbine. The test results prove that the turbo charger centrifugal compressor has been proven to function as a water turbine with quite reliable efficiency achievements. At present many production machines are old and not used anymore, so careful research can be identified and any compressor from engine components that can be recommended as a water turbine can be recommended. The stage of compressor adjustment into a turbine is an interesting challenge for researchers to be able to formulate it.

Acknowledgements

We express our gratitude to the community of Limau Manis Village, Kuranji District, Padang City, West Sumatra. Indonesia and students of Mechanical Engineering, Andalas University who have facilitated and assisted during the development, assembly and testing process

References

[1] Asian Development Bank (ADB), Energy outlook for Asia and the pacific, Man-daluyong City, Philippines, 2009.

[2] Kumar A and M. P. Sharma, Greenhouse Gas Emissions From Hydropower Reservoirs, Hydro Nepal Journal of Water Energy and Enviroment, DOI: 10.3126/hn.v11i0.7159.

[3] Kumar A, T. Yang and M.P. Sharma, Long-term Prediction of Greenhouse Gas Risk to the Chinese Hydropower Reservoirs, Science of the Total Environment, Vol. 646. pp. 300-308, 2019.

[4] World Health Organization (WHO), *WHO releases country estimates on air pollution exposure and health impact*, Available at: http://www.who.int/mediacentre/news/releases/2016/air-pollution-estimates/en/.

[5] Bappeda Provinsi Sumatera Barat, *Sumatera Barat Dalam Angka*, Padang-Indonesia, 1986.

[6] Dirjen LPE-DESDM, *Undang-undang Republik Indonesia Nomor 30 Tahun 2010 Tentang Energi*. Jakarta, 2010.

[7] Paish, O. "Small hydro power : technology and current status", *Renewable and Sustainable Reviews*, Vol. 6, pp. 537-556, 2002.

[8] Powell, D., A. Ebrahimi, S. Nourbakshsh, M. Meshkahaldini, and A.M. Bilton. "Design of pico-hydro turbine generator systems for self-powered electrochemical water disinfection devices. *Renewable Enerrgy an International Journal*, DOI:10.1016/er.2017.12.079.

[9] Gladstone, S., V.Tersignia, K. Francforta, and J. A. Haldeman, " Implementing pico-hydropower sites in rural Rwanda", *Procedia Engineering,* Vol. 78, pp. 279 – 286, 2014.

[10] Maher, P., N.P.A. Smith and A. A.William. 2009. "Assessment Of Piko hydro As An Option For Off-Grid Electrification In Kenya". *Original Research Article Renewable Energy*, Vol. 28, pp. 1357-1369, 2009.

[11] Arriaga, M., "Pump as Turbine – A Piko Hydro Alternative In Laos People's Democratic Republic", *Renewable Energy an International Journal*, Vol 35, pp. 1109-1115, 2010.

[12] Gaiser K., P. Erickson, P. Stroeve, and J. P. Delplanque, "An Experimental Investigation of Design Parameters for Pico Hydro Turgo Turbines Using a Response SurfaceMethodology", *Renewable Energy an International Journal*, Vol. 85, pp. 406-418, 2016.

[13] Ho-Yan, B.P., "Tesla Turbine For Pico Hydro Applications", *Guelph Engineering Journal*, Vol 2, pp.1 – 8, 2011.

[14] Singh, P. and F. Nestmann, "Experimental Optimization Of A Free Vortex Propeller Runner For Micro Hydro Application", *Renewable Energy an International Journal*, Vol 33, pp. 991-1002, 2009.

[15] Haidar, A.M.A. and Senan, M.F.M., "Utilization Of Pico Hydro Generation In Domestic And Commercial Loads", *Article Renewable and Sustainable Energy*, Vol. 16, pp. 518-524, 2012

[16] Barbarelli, M. Amelio, G. Florio, and N. M. Scornaienchi, "Prosedur selecting Pumps Running as Turbines in Micro Hydro Plants". *Energy Procedia*, Vol. 126, pp.549–556, 2017.

[17] Bozorgi, A., E. Javidpour, and A, Riasi, "Numerical And Experimental Study Of Using Axial Pump As Turbine In Pico Hydropower Plants", *Renewable Energy Journal*, Vol 53, pp. 258-264, 2013.

[18] Novara, D and A. M. Nabola, "Model for the extrapolation of the characteristic curves of Pumps as Turbines from a datum Best Efficiency Point", *Energy Conversion and Management,* Vol. 174, pp. 1–7, 2018.

[19] Carravetta, A. O. Fecarotta, dan H.M. Ramos, "A new low-cost installation scheme of PAT for pico-hydro power to recover energy in residential areas", *Renewable Energy*, DOI: 10.1016/er.2018.02.132.

[20] Rossi, M. and M. Renzi, "Analytical Prediction Models for Evaluating Pump-As-Turbines (PaT) Performance", *2nd International Conference on Advances on Clean Energy Research*, Belin, 7-9 April 2017.

[21] Chuenchoopklin, S., "Development of Piko - hydropower Plant for Farming Village in Upstream Watershed, Thailand", *International Journal Of Environmental Sciences*, Vol 1, 2010.

[22] Singh, P., and F. Nestmann, "An Optimization Routine On A Prediction And Selection Model For The Turbine Operation Of Centrifugal Pumps". *Experimental Thermal and Fluid Science Journal.* Vol 34, pp. 152–164, 2010.

[23] Yang, Sun-Sheng, Kong, Fan-Yu, and J. Wan-Ming, "Effects Of Impeller Trimming Influencing Pump As Turbine". *Computers & Fluids Journal*, Vol.67, pp. 72–78, 2012.

[24] White, F. M, *Mekanika zalir*, Jakarta: *Erlangga.* 1987, pp. 207-218.

[25] Khurmi R. S, *Machine design*, New Delhi: Eurasia Publishing House (Pvt) Ltd, 1980, pp. 332-337.