Achievements of Mechanical Science and Current Technological Innovations for Sustainable Development

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TRANS TECH PUBLICATIONS

Preface

The world population is growing very rapidly over the past decades, which in turn, increasing the number of people aspire to higher standard of living. As prosperity continues to grow, we all need more and more energy and effective engineering solutions and technological innovations to have a better life, which eventually can only be produced in a sustainable way, i.e. creating less waste and lowering CO_2 emission. Renewable energy sources allows the reduction of the dependency on fossil fuel resources, and hence, increases the world energy security. Therefore, opportunities for technologies improvement have become significant issues to be challenged by researchers, scientists and engineers around the globe.

Department of Mechanical Engineering, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia, has been an important player in developing and promoting sustainable technologies in mechanical engineering and energetics. One way of promoting these issues by actively provide means to share and disseminate research findings and knowledge in this particular area. Therefore, the Department is organized **the 2nd International Conference on Mechanical Engineering**, ICOME 2015, with its theme "*Mechanical Science and Technology for Sustainable Energy*". ICOME 2015 that was held in Bali on 3rd-5th September 2015, offers a great opportunity to bring together researchers, scientists, and industrial professionals around the globe to foster an environment conducive in exchanging new ideas and information. It also provides a forum to discuss the most recent development and trends in mechanical science and engineering related fields.

The conference and publication can only be conducted and made available due to the hard work and supports of many contributors. In this opportunity, we would like to thanks the authors and reviewers who have spent their time to contribute and made suggestions such that the published papers met the international journal standard. Our sincere gratitude also goes to Ir. Lukman Mahfoedz, Prof. Jyh-Chen Chen, Prof. Katsuhiko Sasaki and Prof. Volodymyr Yartys for their willingness to be the keynote speakers at this conference. We would also like to thank ITS, Ministry of Research Technology and Higher Education and sponsorship companies for their support and contribution in ICOME 2015. Special thank goes to all committee members who have dedicated their time and effort to ensure everything runs as planned. We believe that this book can serve as a high quality archive of research findings and establish future directions of research in the related topics.

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A Couple of Savonius Wind Mill and Centrifugal Reaction Pump as a Wind Energy Water Pump System

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Abstract. Wind energy is one of renewable energy which became the center of attention and grew rapidly. Especially for remote area, wind energy is one of alternative dependable energy sources which can be used for water lifting. Savonius wind mill can be a solution for decentralized power generation, with low cost and reduced environmental impacts. This study observed a couple of Savonius wind mill and a centrifugal reaction pump which used as a wind energy water pump system (WEWPS). The Savonius wind mill has 0.8 m diameter, 1.0 m height, 2 stages, 2 buckets in every stage and 0.1 m width of the buckets spacing. The centrifugal reaction pump with a T-junction has 0.9 m diameter, 18.5 mm (0.5 inch) nominal inner diameter for both vertical and horizontal pipes. Both arms of T-junction have similar dimension and functioned as impeller. The pump, which is suitable for low shaft speed, is modified by replacing the couple of fixed orifices and sliding orifice with double U pipe configuration to restrict the air entering the pipe channel, either while stopped or rotated. The transmission used to connect the shafts of both devices is the couple of belt and pulleys with transmission ratio 7:4. WEWPS started pumping the water at 4.5 m/s wind speed and total head 1.5 m. The wind speed produced low shaft speed 120 rpm, shaft power 13 Watt and through the transmission driving the pump into cut-on mode.

Introduction

The utilization of renewable energy is popular, as the issue of global warming comes up and people are trying to anticipate the extinction of fossil energy. One of the energy sources which is now getting attention and popularized is wind energy. Other than electric generating and milling utilizations, wind energy could also be used as energy sources for desalinating process, water purification [1] and water pumping [2,3]. The social and economic health of the modern world depends on sustainable supply of both energy and water. On the other side, with the increasing population, industrial and agricultural activities, available water resources has been excessively exploited and severely polluted.

Wind energy water pumping systems (WEWPS) is one of the solutions to overcome the scarcity of water accessibility and availability and not connect with national power grid in rural area [4]. WEWPS can stand alone or hybrid with other renewable energy resources which are available in the area as solar photovoltaic water pumping systems (SPWPS) [2]. WEWPS had already been used, especially for irrigation [5,6] and supporting agricultural activities, even before wind generator which convert wind energy into electricity. The main advantages of WEWPS are economical, environmentally friendly and possible to built, install and properly maintain them himself for small or medium sized windmills [7].

WEWPS in rural areas is used to pump water by means of mechanical systems and electric-wind systems. The electric-wind systems show better efficiency at high wind speed. The electrical systems also have the additional advantage that the turbine can be located on a site with a better wind profile and not necessarily on the site where the water is pumped. The disadvantage is the expensive price, because they require more electric components to convert the wind energy into electrical energy [8]. The mechanical systems show better efficiency at low wind speed. The most popular mechanical system is WEWPS by using piston pump because it could be used in low (3-10 m), medium (10-30 m) and deep (more than 30 m) head [4,9]. There are a lot of other mechanical systems which can be used on WEWPS with very low head (up to 3 m). This mechanical system is usually used for irrigation, livestock, drainage and salt pans. WEWPS used for irrigation tends to be indigenous designs that are often improvised or built by the farmer as a method of low-cost mechanization. One of the type of those mechanical systems is centrifugal reaction pump [5,10,11]. The centrifugal pump is a good load for a wind turbine because the power input will be proportional to the cube of the wind speed of the air passing through the wind turbine, which is proportional to the pump rotational speed [12].

Centrifugal reaction pumps are continuous rotary-motion pumps and well coupled to a wind mill because they operate at a relatively constant torque and generally operate for a variable low speed. The impeller is composed of two horizontal pipes joined on the top of and perpendicular with a vertical pipe. The vertical pipe is designed as inlet and pump rotary axis. This simple 'T'-join construction is equipped with two automatic on-off devices. The devices work mechanically and each of them installed on the outer edge of horizontal pipe. The automatic on-off devices which are usually used is a pair, fixed and sliding, of centered holes orifices, 90° away from the horizontal pipes [11,13]. Each of sliding orifice is equipped with a pair of spring and moved according to the centrifugal force existed. When the 'T'-join construction is filled and over flooded with water and rotated in the direction opposite to the orifices, the water is forced out through the orifices by centrifugal force and replenished by water coming up through a stop valve in the bottom of the vertical pipe.

This paper investigated a centrifugal reaction pump, a Savonius wind mill and a transmission which coupled both devices as WEWPS. Centrifugal reaction pump had been modified by replacing the fixed and sliding orifices with double U pipe configuration as automatic on-off devices. The Savonius wind mill is chosen because it has advantages in the form of high starting torque, reasonable peak power output [15] and wind acceptance from any direction. Transmission is needed to transmit shaft power from wind mill shaft to pump shaft. The suitable transmission ratio (i) is needed for WEWPS could start to operate in low wind speed.

Methods

Evaluation of the WEWPS was based on the performance characteristics of a Savonius wind mill and a centrifugal reaction pump. Both performance characteristics was carried out from the experiment studies. The Savonius wind mill has 2 stages, two buckets in every stage and sweeping area 0.8 x 1.0 m^2 [17]. The centrifugal reaction pump has 0.9 m diameter with double U pipe configuration at the end of both impeller [14]. A simple transmission was investigated to get transmission ratio that match for shaft speed of both devices.

Centrifugal reaction pump. Double U pipe configuration which was installed in both outer edges of centrifugal reaction pump successfully replaced the fixed and sliding orifices [14]. The configuration successfully restricted the air from entering into the pipe channel which functioned as impeller, when stopped or rotated. Fig. 1 was characteristic of the centrifugal reaction pump. The other data about the pump were 0.9 m diameter, the maximum efficiency 31.58 %, 185 rpm cut-on speed, 174 rpm cut-off speed, 1.5 m head and 18.5 mm (0.5 inch) nominal inner diameter of both vertically and horizontally pipes.

Savonius Wind Mill. The wind mill can be a solution for decentralized power generation with low cost impacts. The wind device has advantages as simple construction, wind acceptance from any direction for the operation, low noise and angular velocity in operation, reduced wear on moving parts, various rotor configuration options and high static and dynamic moment [16]. The wind mill observed has 2 stages, two buckets in every stage, the spacing of each bucket 0.1 m. The diameter and height are 0.8 m and 1.0 m with 2.5 m/s cut-on speed [17]. This configuration gave the best peak power output and starting torque [15]. Fig. 2 was characteristic of the Savonius wind mill. The wind speed used for observation were 4.5, 5.5 and 6.5 m/s.

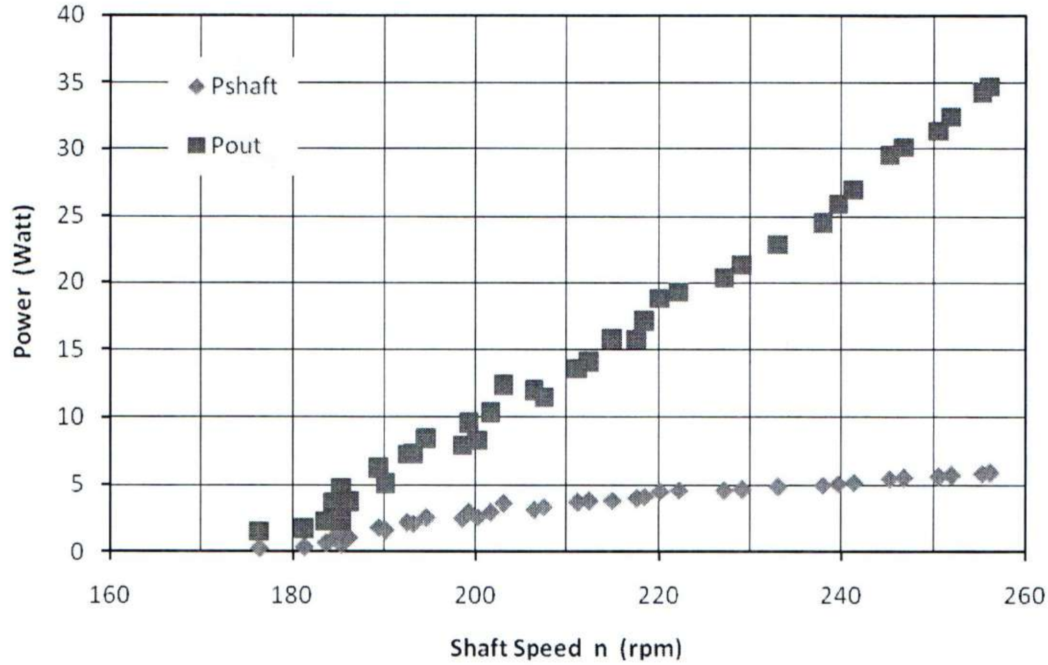

Fig.1 Characteristic of the centrifugal reaction pump [14]

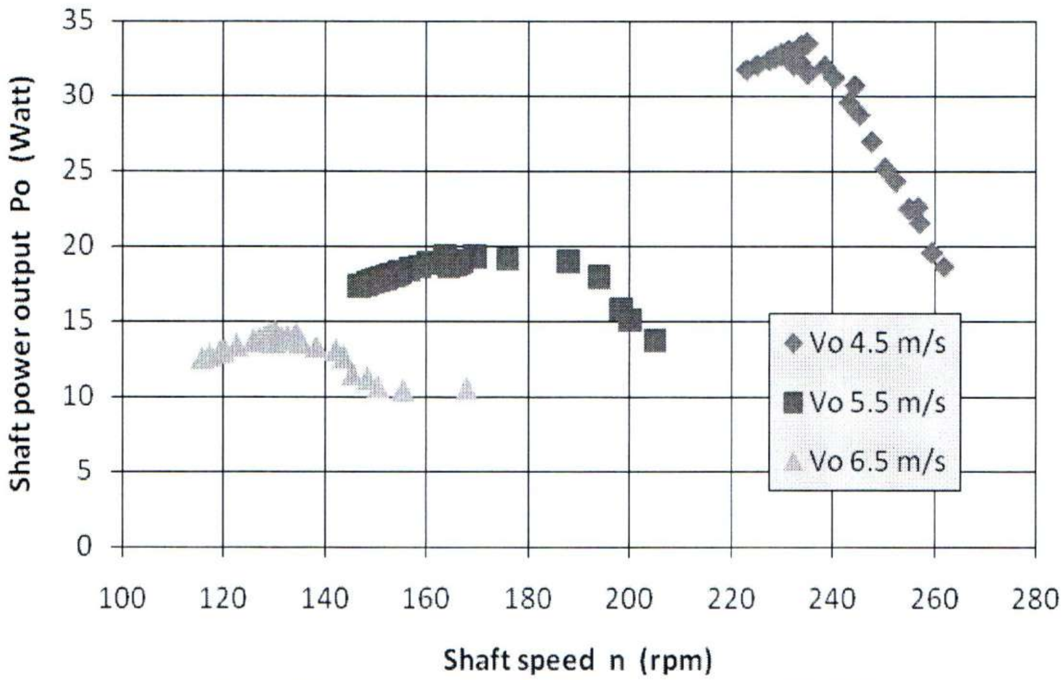

Fig.2 Characteristic of the Savonius wind mill [17]

Transmission. Both of Savonius wind mill and centrifugal reaction pump functioned as WEWPS when both shafts of them were coupled with a transmission. The transmission used in this observation are the couple of belt and pulley and ignoring the mechanical losses. The transmission ratio (i) is determined by the shaft power characteristic of both devices.

Results and Discussions

The interesting discussion object was the balance of shaft power, between pump shaft and wind mill shaft. The priority target was WEWPS could start operating in the minimum wind speed design (4.5 m/s), marked with cut-on mode of centrifugal pump. The fluid used was water with 1.5 m head.

In the observation, cut-on rotating speed design was 210 rpm or 13.5% higher than minimum requirement of the pump. In cut-on speed, pump's shaft power requirement was around 13 watt. When the transmission with i=1:1 and the wind mill rotated on the minimum design wind speed of 4.5m/s, shaft speed had not reached cut-on speed even with enough shaft power. In the wind speed between 5.5 and 6.5 m/s, the wind mill had matched shaft speed to cut-on speed, so both devices functioned as WEWPS, but windmill's shaft power exceeded the needs of pump's shaft power (Fig.3). Because the shaft speed and shaft power could not match, transmission with i=1:1 was not suitable for the WEWPS.

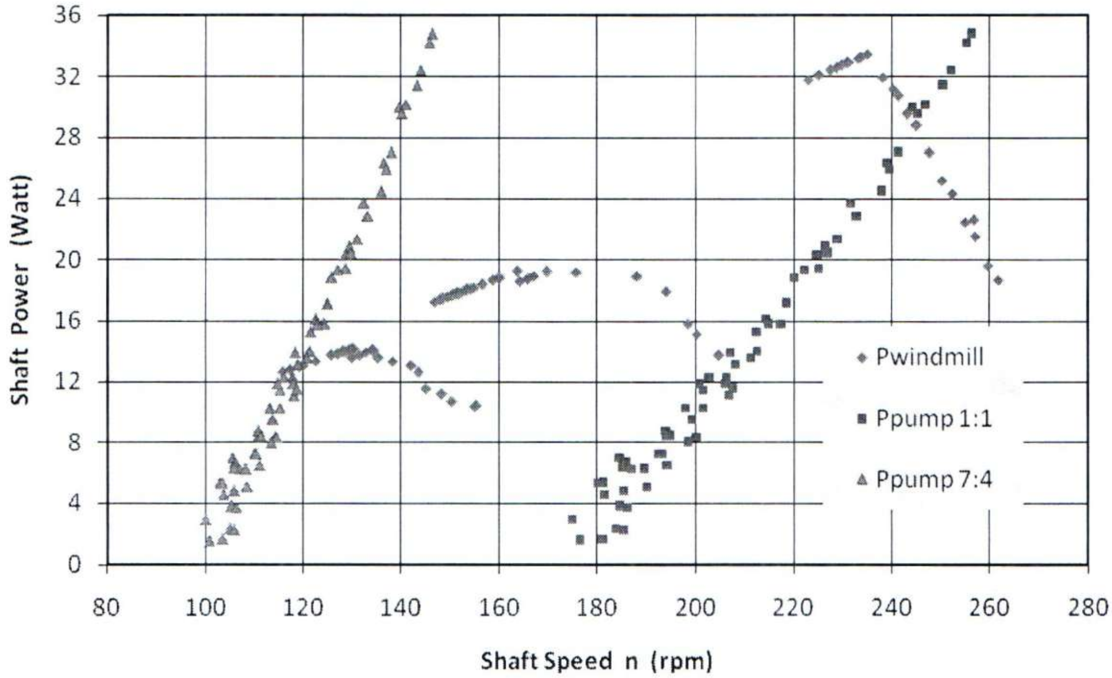

Fig.3 Trasnmission ratio of WEWPS.

Transmission with i=7:4 gave the suitable effect to both devices for a WEWPS. In the cut-on pump's speed, windmill shaft speed needed was around 120 rpm. The pump's shaft speed was increased 7/4 times windmill's shaft speed by the transmission with constant power. In the minimum wind speed design and 120 rpm shaft rotating speed, 13 watt of windmill's shaft power could give enough supply to the pump's shaft power. In higher wind speed, both devices and the transmission still functioned as WEWPS because it had exceeded the cut-on speed and pump's power. When the wind speed was smaller than minimum wind speed design, WEWPS still functioned, as long as the pump shaft speed was above the pump cut-off speed.

Conclusion

The couple of a Savonius wind mill and a centrifugal reaction pump had been observed as a WEWPS. Both devices coupled with a V-belt and pulleys with transmission ratio of 7:4. The transmission ratio matched the shaft speed and shaft power both devices so WEWPS could operate with 4.5 m/s wind speed and up.

References

[1] Q. Ma, H. Lu, Wind energy technologies integrated with desalination systems: Review and state-of-the-art, Desalination. 277 (2011) 274–280

[2] C. Gopal, M. Mohanraj, P. Chandramohan, P. Chandrasekar, Renewable energy source water pumping systems—A literature review, Renewable and Sustainable Energy Reviews. 25 (2013) 351–370.

[3] J. Dhillon, A. Kumar, S.K. Singal, Optimization methods applied forWind–PSP operation and scheduling under deregulated market: A review, Renewable and Sustainable Energy Reviews. 30 (2014) 682–700.

[4] S. Rehman, A.Z. Sahin, Wind power utilization for water pumping using small wind turbines in Saudi Arabia: A techno-economical review, Renewable and Sustainable Energy Reviews. 16 (2012) 4470–4478

[5] Information on http://www.fao.org/docrep/010/ah810e/ah810e10.htm 27/08/2013 13:54

[6] T.Y Lin, W.F. Lin, Structure and motion analyses of the sails of Chinese Great Windmill, Mechanism and Machine Theory. 48 (2012) 29–40

[7] Information on http://www.wikiwater.fr/e42-wind-powered-pumps.html 25/02/2014

[8] D.D. Lara, G.G. Merino, B.J. Pavez, J.A. Tapia, Efficiency assessment of a wind pumping system, Energy Conversion and Management. 52 (2011) 795–803.

[9] G.Y. Pam, I.B. Mansir, M.I. Borok, Y.B. Kolo, Efficiency And Hydraulic Power Of Poldaw Windpump Systems At Some Locations In Northern Nigeria, The International Journal Of Engineering And Science (IJES). 2 (2013), Issue 8, 80-85,

[10] P.T. Smulders, Wind water pumping: the forgotten option, Energy for Sustainable Development. Vol. II, No. 5, (1996) 8-13

[11] Information on http://www.nzdl.org 27/08/2013

[12] Johnson G.L, Wind Energy System, Electronic Edition, Information on www.eece.ksu.edu/~gjohnson/ Windbook.pdf, (2006) pp.1-17

[13] I.A. Rubinski, A.I. Rubinsky, A low specific speed pump for small discharge; Civil Engineering and Public Works Review. 50 (1955) No. 591, pp.987-990.

[14] Y.B. Lukiyanto, E. Wahisbullah, A Simple Double U Pipe Configuration to Improve Performance of a Large-Diameter Slow-Speed Centrifugal Impeller, Proceedings of the 3rd Applied Science for Technology Application, Yogyakarta, Indonesia. 13-14 August (2014) pp.204-209

[15] P.N. Shankar, Development of Vertical Axis Wind Turbine, Proceeding Indian Acad. Science, Vol. C2, Pt. 1, India. (1979) pp. 49-66

[16] J.V. Akwa, H.A. Vielmo, A.P. Petry, A review on the performance of Savonius wind turbines, Renewable and Sustainable Energy Reviews. 16 (2012) 3054– 3064

[17] Y.B. Lukiyanto, Y.T. Triharyanto, Two Stages Savonius Windmill with Variation of Blade Gap, Proceeding Indonesia National Seminar PPET-LIPI, ISSN 2303-0798, Bandung, Indonesia. (2012) pp.21-26