

Achievements of Mechanical Science and Current Technological Innovations for Sustainable Development



Edited by
Prof. Sutardi, Bambang Pramujati, Prof. Rickey Dubay,
Mamoun Abu-Ayyad, Prof. Lai, Jling-Yih



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 CO₂ 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.

Editor in Chief

Bambang Arip Dwiyanoro

Committees

Details affiliation of the organizing committee with emails:

- Bambang Arip Dwiyanoro, PhD (Chairman, email: bambangads@me.its.ac.id)
- Unggul Wasiwitono, PhD (Co Chaiman, email: unggul@me.its.ac.id)
- Vivien Suphandani, PhD (Co Chaiman, email: vivien_s@me.its.ac.id)
- Suwarno, PhD (Co Chaiman, email: warno@me.its.ac.id)

ICOME 2015 Secretariat

Department of Mechanical Engineering

ITS Campus, Sukolilo, Surabaya

INDONESIA, 60111

Telp. +62-31-5946230, 5922941

Fax. +62-31-5922941

Email: icode@its.ac.id

Website: <http://icode.its.ac.id>

Main Sponsors

Ministry of Research, Technology, and Higher Education of Republic of Indonesia

Title of conference:

International Conference on Mechanical Engineering 2015 (ICOME 2015)

Theme: Mechanical Science and Technology for Sustainable Energy

Location, date:

September 3rd - 5th, 2015, Kuta, Bali, Indonesia

Conference website: www.icode.its.ac.id

Book title:

Achievements of Mechanical Science and Current Technological Innovations for Sustainable Development

Proceedings editor's name

- Prof. Sutardi

Mechanical Eng. Dept., Institut Teknologi Sepuluh Nopember - ITS, INDONESIA

Website: www.me.its.ac.id

Email: sutardi@me.its.ac.id

- Bambang Pramujati, PhD

Mechanical Eng. Dept., Institut Teknologi Sepuluh Nopember - ITS, INDONESIA

Website: www.me.its.ac.id

Email: pramujati@me.its.ac.id

- Prof. Rickey Dubay

Mechanical Eng. Dept., University of New Brunswick, CANADA

Website: www.unb.ca

Ema: dubayr@unb.ca

- Mamoun Abu-Ayyad, PhD

Mechanical Eng. Dept., Pennsylvania State Univ., USA

Website: www.psu.edu

Email: maa21@psu.edu

- Prof. Lai, Jiing-Yih

Mechanical Engineering, National Central University, TAIWAN

Website : <http://www.me.ncu.edu.tw/eng/>

Email: jylai@ncu.edu.tw

Table of Contents

Characteristics of Decompression Tank Internally Pressurized with Water Using OpenFOAM Syamsuri	3
Experimental Study on the Dynamic Characteristics of Hydro-Magneto-Electric-Regenerative Shock Absorber H.L. Guntur and W. Hendrowati	9
Flexible and Ergonomically Three Wheel Bike for Post Stroke Patient I.M.L. Batan, Syifa and D. Prasetyo	14
Thrust Force of Three Circular Windings of Conductor in Magnetic Field S. Iswahyudi and W. Arnandi	20
Anti-Plane Interaction of a Coated Circular Inclusion with a Crack Located in Matrix A. Wikarta	26
Influence of Spring Ratio on Variable Stiffness and Damping Suspension System Performance U. Wasiwitono, A.S. Pramono, I.N. Sutantra and Y. Triwinarno	31
Inverse Kinematics Modelling and Simulation for Upper Case Writing Robot Control Using ANFIS A.T. Syamlan, B. Pramujati and H. Nurhadi	37
Dimensionally Homogeneous Jacobian and Condition Number L. Nurahmi and S. Caro	42
Type Synthesis of Two DOF Hybrid Translational Parallel Manipulators L. Nurahmi and S. Caro	48
Effect of Impeller Condition on Blower Performance, Case Study: Impeller of K-2201 in Pt. Pertamina RU III H. Budiman	54
Base Aspect Ratio Effects on Resonant Fluid Sloshing in a Rectangular Tank N. Vaziri and M.J. Chern	60
Morphology of Crown Tube Austenitic Stainless Steel TP316 HTF Failure H.C. Kis Agustin, I.D. Wijayanti and R.S. Wibowo	67
Metallography Investigation of Dry Corrosion Boiler Tube A. Hariyadi, H.C. Kis Agustin and I.D. Wijayanti	72
Effect of Adhesive Layer Thickness on the Shear Strength of Adhesively Bonded Steel Joints in Wet Environment Sugiman, I. Akbar, E.D. Sulistyowati and P.D. Setyawan	78
Numerical Study of Mixed Convection around a Heated Circular Cylinder V.S. Djanali, A.N. Syah and S. Rizal	85
Cooling Load Estimation to Determine the Proper Capacity of Air Conditioners in the Engineering Building at Engineering Academy of Soroako M.A. Hamarung, Harman and Jasman	90
Convective Regimes on Porous Media within Sudden Changed Channel due to Tangential Gas Flow E. Siswanto, A. Veriyawan Rahana, M.A. Choiron, N. Ryuichi, H. Katsurayama and K. Yasuo	96
Effect of Mass Flow Rate on Dryer Room Radiator Pressure Drop and Heat Transfer Mirmanto, E.D. Sulistyowati and I.K. Okariawan	102
CFD Studies of the Dynamic Stall Characteristics on a Rotating Airfoil G.P.C.T. Hutomo, G.S.T.A. Bangga and H. Sasongko	109
Analysis of Turbulence Characteristics in the Laminar Sub-Layer Region of a Perturbed Turbulent Boundary Layer S. Sutardi and W.A. Widodo	115
CFD Analysis on Thermal Comfort and Indoor Air Quality Affected by Partitions in Air-Conditioned Building P. Aryal and T. Leephakpreeda	121
CFD Based Investigations into Optimization of Diffuser Angle on Rear Bus Body W.A. Widodo and M.N. Karohmah	127

A CFD Analysis of the Viscous Fluid Behavior of Glycerin in Various of Stirring Patterns R. Wulandari, I.N.G. Wardana, S. Wahyudi and N. Hamidi	132
Rheology Margarine on Non-Newtonian Fluid Proving through Small Gap A. Harijono, I.N.G. Wardana, N. Hamidi and D. Widhiyanuriyawan	139
A Review Paper on Product Surface Defect Detection of Ironing Process A. Faizin, A. Wahjudi, I.M.L. Batan and A.S. Pramono	147
Tempering Process Gradually to Improve Quality Tool R.E. Purwanto, M. Hartono and A. Sujatmiko	153
Optimization of Cable Ties Injection Molding Process Using Back Propagation Neural Network and Genetic Algorithm (BPNN-GA) A. Wahjudi, B.O.P. Soepangkat and Y.F. Arriyani	159
Influence of Argon-Nitrogen Gas to Balance the Microstructure in the Welding of Super Duplex Stainless Steel Suheni	165
The Effects of Pulse on Time and Arc on Time on Surface Quality in Wire-EDM of ASSAB XW-42 and ASSAB 8407 2M Tool Steels Hasriadi, B.O.P. Soepangkat and H. Subiyanto	173
Multi Response Optimization Using Taguchi-Grey-Fuzzy Method in Drilling of Kevlar Fiber Reinforced Polymer (KFRP) Stacked A. Mufarrih, B.O.P. Soepangkat and I. Krisnanto	179
Optimization of Multiple Response Characteristics in the WEDM Process of Buderus 2379 ISO-B Tool Steel Using Taguchi-Grey-Fuzzy Logic Method M. Diantoro and B.O.P. Soepangkat	185
Groove Overhang Impact on the Result of Surface Roughness on Vertical CNC Milling Process A. Sujatmiko, M. Hartono and R.E. Purwanto	191
Simulation of Ironing Process for Bullet Case to Get Minimum Forming Force with Variation of Die Angle and Reduction Wall Thickness M.N. Ali Mukhtar, I.M.L. Batan, B. Pramujati and A.S. Pramono	197
Numerical Simulation of Cutting Stress Deformation in Tungsten Carbide Turning Tools P.H. Huang, J.R. Chen and H.Z. Lu	203
Friction Stir Welding on Corner Joint with New Surface Preparation Design W. Setiawan, D.B. Darmadi, W. Suprpto and R. Sunoko	208
Effect of Hydrogen Addition on the Characteristics of Nitrided Martensitic Stainless Steel AISI 420 Istiroyah, I.N.G. Wardana and D.J. Santjojo	214
Effect of Low Temperature Sintering on the Porosity and Microstructure of Porous Zeolite Ceramic S.M.B. Respati, R. Soenoko, Y.S. Irawan and W. Suprpto	219
Design and Modeling Pile Breakwater for LNG Jetty at Senoro Field, Central Sulawesi K. Sambodho, M. Zikra, M.R.F. Aldhiansyah and Y. Mulyadi	227
Investigation of Risk Based Decision Making for Mobile Mooring System Silvianita, M.F. Khamidi, K. Sambodho, N. Syahroni, Y. Mulyadi and M. Zikra	233
Model of Ground Water Elevation around Mud Reservoir in Coastal Area of Porong Sidoarjo M. Mustain	239
Anchor Strength Analysis for Mooring of a Floating Breakwater in Senoro Field, Central Sulawesi Y. Mulyadi, K. Sambodho, M. Arif Wicaksono and M. Zikra	245
Response Reduction of Two DOF Shear Structure Using TMD and TLCD by Considering Absorber Space Limit and Fluid Motion L. Son, M. Bur and M. Rusli	251
Optimization of Water Scrubbing Method for Enhancement of Biogas Quality through Base Solutions Addition H. Sakke Tira, Y.A. Padang, T. Rachmanto and A.A. Syahida	259
The Effect of Nitrogen on Flame Characteristics in Biogas External Premixed Combustion W. Anggono, F.D. Suprianto, K. Purnomo, T.I. Hartanto and T.P. Wijaya	265
Flame Stability Measurement on Rectangular Slot Meso-Scale Combustor S. Adiwidodo, I.N.G. Wardana, L. Yuliati and M.N. Sasongko	271

Experimental Study and Analysis of the Generated Electric Power of Salter Duck-Ocean Wave Energy Harvester (OWEH) due to Additional Weight Change and Wave Amplitude W. Hendrowati and H.L. Guntur	277
Simplicity Design of Hybrid Energy of Marine Current and Offshore Wind Energy Plant in Indonesia M. Mustain and A. Suroso	283
Simulation Savonius Wind Turbine with Multi-Deflector B. Sugiharto, S. Soeparman, D. Widhiyanuriyawan and S. Wahyudi	289
Performance of Distilled Water Electrolysis with Adding of Sodium Bicarbonate as Catalytic D. Widhiyanuriyawan	294
A Couple of Savonius Wind Mill and Centrifugal Reaction Pump as a Wind Energy Water Pump System Y.B. Lukiyanto	299
Experimental Study of the Cross Flow Turbine D. Sutikno, R. Soenoko, S. Soeparman and S. Wahyudi	304
Modeling of Well Service and Workover to Optimize Scheduling of Oil Well Maintenance S. Kromodihardjo and E.S. Kromodihardjo	311
Evaluation of Delay Factors in Jacket Structure Project Silvianita, A.T. Putra, D.M. Rosyid, D.M. Chamelia and I. Rochani	317
Strategy in Reducing the Pace of the Greenhouse Gas Emission from the Electricity Sector in Southeast Sulawesi M. Musaruddin, A. Rachman, M. Hasbi and A. Kurdin	323

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

Y.B. Lukiyanto

Mechanical Engineering Department, Sanata Dharma University
Paingan, Maguwoharjo, Depok, Sleman, 55282, Yogyakarta, Indonesia
lukiyanto@usd.ac.id

Keywords: wind energy, Savonius wind mill, centrifugal reaction pump, WEWPS, low shaft speed

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 $0.8 \times 1.0 \text{ m}^2$ [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.

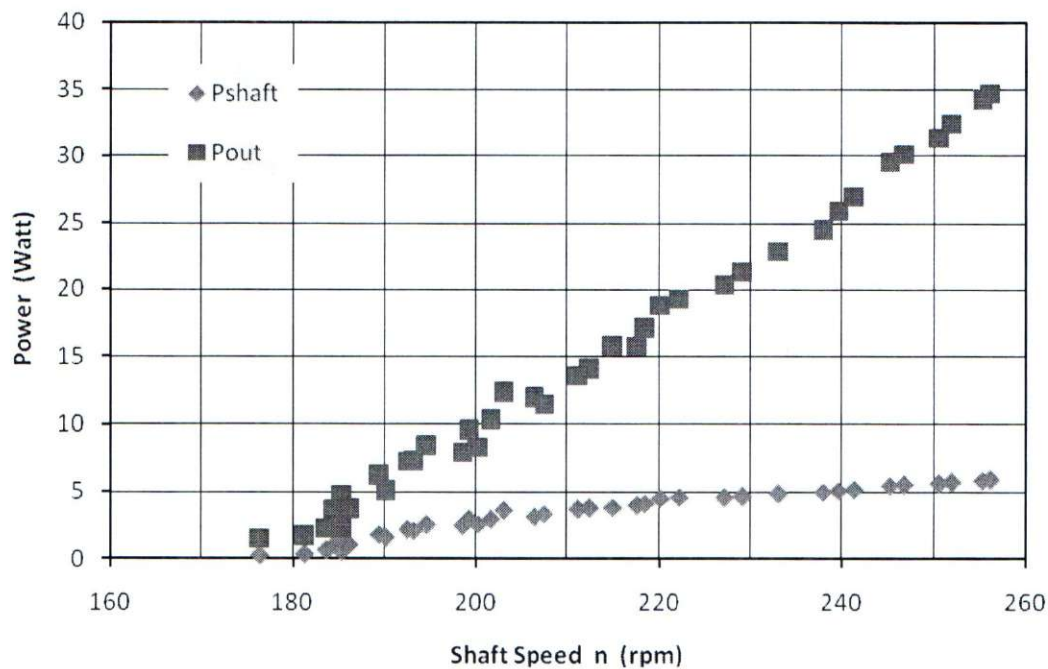


Fig.1 Characteristic of the centrifugal reaction pump [14]

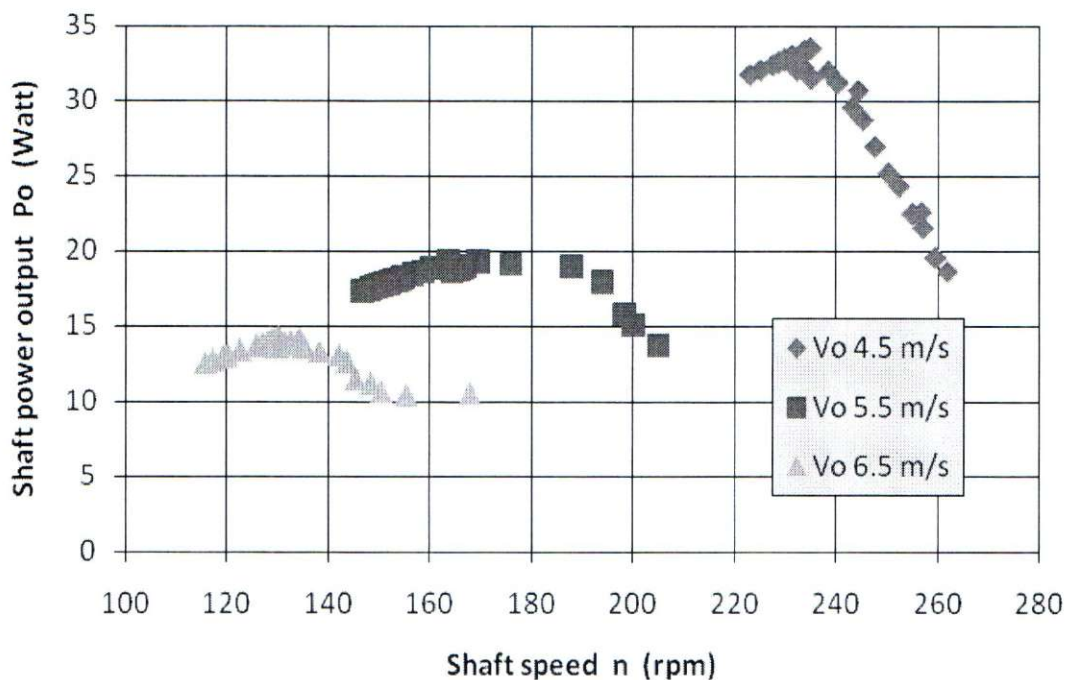


Fig.2 Characteristic of the Savonius wind mill [17]

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.

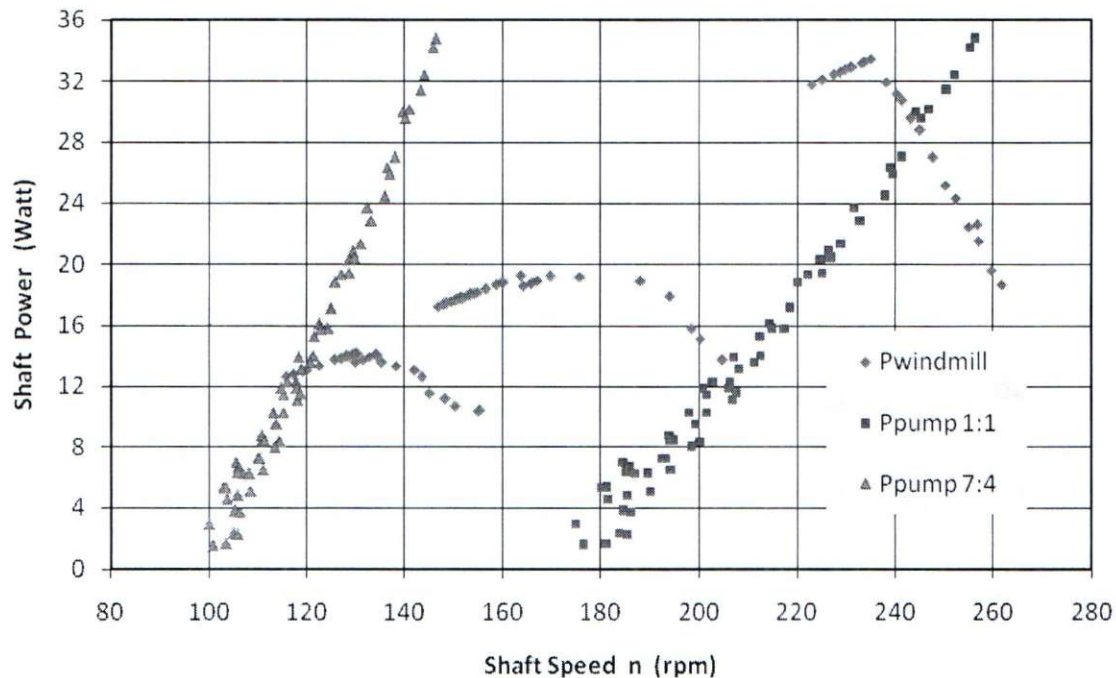


Fig.3 Transmission ratio of WEWPS.

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 for Wind–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