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Indonesian Traditional Two Blades Windmill of Demak for Water Pumping in Traditional Salt Production

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Abstract. Salt farmers in the northern Java coastal Indonesia has a simple technology to support the traditional salt production process. Their technology called the wind-pump. The wind-pumps was used by salt farmers of Demak region to transport and recirculate seawater into the salt ponds. The wind-pump system used two or four blades windmill and a reciprocating pump. The windmill converts wind energy became potential energy through a linear translation of the reciprocating pump. In this experiment, the wind-pump system has two variations of crankshaft, there are 5 cm and 7.5 cm. The reciprocating pump has a constant head of 45 cm height. Wind speed and volume flow rate was gathered every 10 minutes in 10 seconds for six hours. The windpump with arms-length of 5 cm and 7.5 cm has a maximum volume flow rate of 1.65 l/s in 4 m/s of wind speed and 2.02 ml/s in 3.6 m/s of wind speed, capacity production 25.6 m^3 and 18.3 m^3 per day and an average efficiency of 5.03% and 5.93%, respectively.

Keywords: salt production, traditional wind-pump, windmills, salt farmers of Demak, crankshaft

INTRODUCTION

By the year of 2020, about 25% of global electricity was generated by modern renewable energy [1], [2]. As a archipelago and ring of fire country, Indonesia has a high level of renewable energy potential. The coastlines across the islands have land and sea breeze [3]. The development of wind energy for commercial purposes in 2020 is 600.00 MW in Indonesia [4]. The renewable energy source is an environmentally friendly source of energy [5], which does not contribute to climate change and global warming [6]. There is a potential, that Indonesia could contribute to increase renewable energy mix and reduce carbon emissions up to 30%.

Due to COVID-19 pandemic, many countries was not on pathway to achieve their renewable energy mix in 2020, including Indonesia [2]. The small scale of renewable energy especially in remote area, participates on reduce carbon emissions even during COVID-19 pandemic. The community of salt farmers in Demak did not realize that they promote low carbon technology by applying windmills for water pumping [7]. The salt farmers use his traditional method for assisting salt production. They used windmill and reciprocating pump to transport from sea to salt ponds and as transmission from one pond to other ponds. The seawater inside the ponds heated by sunlight and evaporated, then leaving the salt minerals inside the pond. By the year of 2020-2021 during the COVID-19 pandemic, the salt farmers has no difficulties to produce salt.

The study concerning salt farmers windmill from Demak has been done by Deo et al. in 2019 [8]. Purposes in this study have investigated the performance of salt farmer’s two blades windmill from Demak for water pumping. This salt farmers windmill normally uses four blades. In this study, the windmill uses two blades for water pumping. The two blades windmill applies to reduce economic cost in windpump assembly. The result is volume flow rate, capacity production, average efficiency and its relations.

EXPERIMENT METHODS

Salt farmer’s windmill from Demak frequently operates between 09.00 – 15.00 (GMT +07.00). For salt farm is located in coastal area, the wind blows from the sea to the land during the day. In this study, the experiment is carried out in a place that is similar to the original state at Kuwaru beach, Bantul, Yogyakarta. The experimental data was obtained from observations between 09.00 – 15.00 (GMT +07.00). The selection of the place and time was aimed to make the observations as identical as possible to the real situation.

The windmill blades as a part of wind pump was made by the salt farmer’s from Demak. Typically, salt farmers in Demak used four blades and directly coupled by the main-single shaft to crack-shaft of reciprocating pump. The wind pump was main equipment for water circulation as part of the salt production processes. In this study, the

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performance of two blades for water pumping was observed. Figure 1. (a) were schematic of the windpump system with reciprocating pump. The main parts of the wind pump was blades to convert wind power, shaft to transmit power and couple to crank shaft that change rotating to reciprocating motion and reciprocating pump to convert to hydrolic power. The reciprocating pump was equipped with a one-way valves made of flexible rubber. The second one-way valve were became a unit with the piston and called piston valve. Both valves directed fluid moves upward direction and opened based on difference pressures.

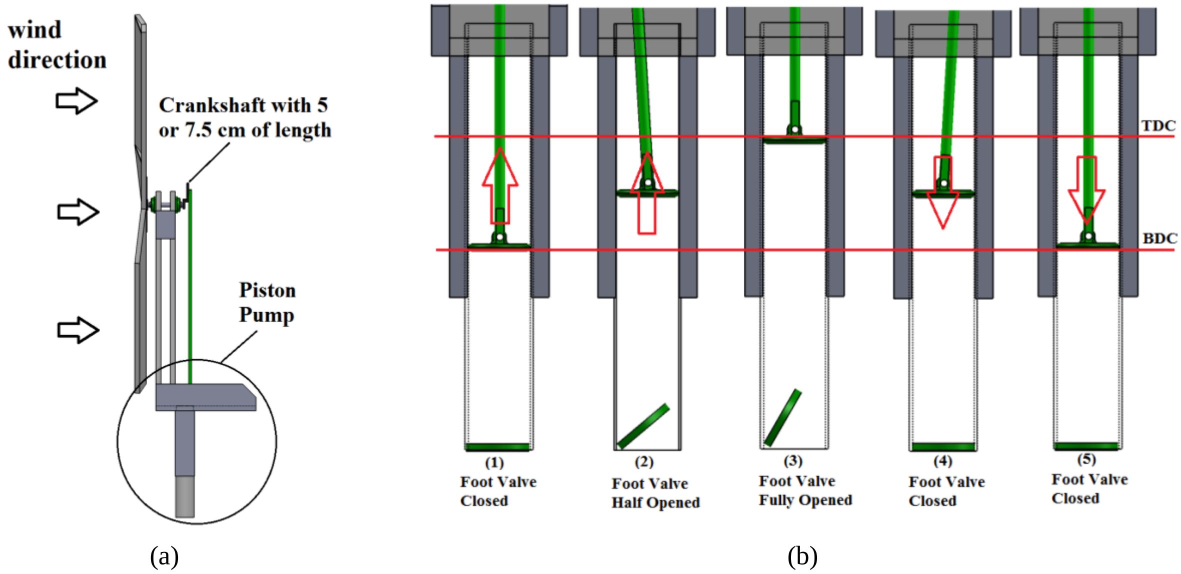

FIGURE 1. Windpump system (a), Reciprocating pump of salt farmer windmill (b)

Figure 1. (b) was schematics working of reciprocating pump for a cycle. Steps (1)-(3) shows the pump started lifting the water. The piston moves from the bottom dead centre (BDC) to the top dead centre (TDC). The foot valve were closed as initial position. The foot valve opens following the piston moves upward. The valve were opened for the space below the piston were became vacuum. The foot valve were opened as final position. Steps (3)-(5) shows the piston moves from TDC to BDC. Following the piston moves downward, the foot valve was closed. The water under the piston moves upward through the piston valve and fill upper side space of the piston. The pump will continue to operate by restarting the new cycle.

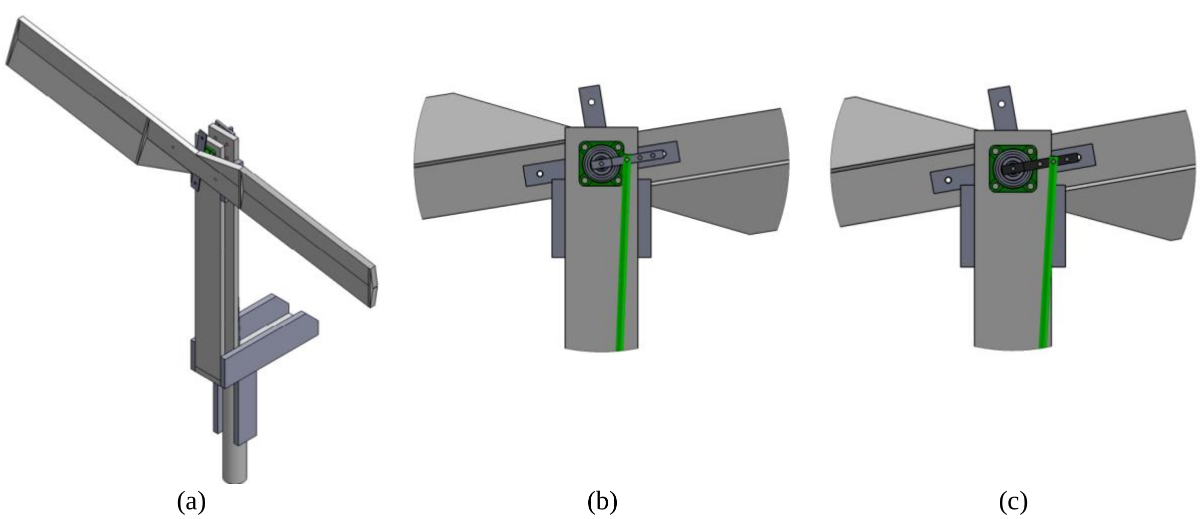

FIGURE 2. Salt farmer's windmill from Demak with two blades (a), 5 cm of crank shaft (b), 7.5 cm of crank shaft (c)

The windmill blades has diameter and width of 200 cm and 22 cm for each blade. The blades and main shaft was installed on simple windmill tower and was built by salt farmer itself (Fig. 2(a)). The two blades windmill in this study has a coefficient of power (Cp) of 0.08 and an optimum tip speed ratio (TSR) of 2.97 [9]. Both of the windmill blades and the tower made of wood. The tower has 150 cm high and installed on a rigid wood construction. The reciprocating pump in this study has a piston, cylinder, connecting rod, and crankshaft. The piston has diameter of 8.9 cm. The cylinder has inside diameter of 8.9 cm. The piston were made of cylindrical rubber and the cylinder were made of PVC pipes with 60 cm height. In the botom of the cylinder was installed a foot valve made of cylindrical rubber. The foot valve were used for the water inlet gate. The connecting rod has length of 128 cm, connected to the piston and crankshaft. The crankshaft in this study were made of steel with three variations of length (5 cm, 7.5 cm and 10 cm). The crankshaft length applied this windpump system was 5 cm and 7.5 cm lenght (Fig. 2 (b) and (c)). The 10 cm of the crankshaft was not evaluated in this experiment.

The following equations was used to determine the salt farmer's windpump performance with two blades. These equations was essential to create charts to illustrate the windpump performance.

The energy conversion were begun with wind power [3], [10] as input energy in this windpump system:

$$E_{wind} = \frac{1}{2}\rho_{air} A v^3 \qquad (1)$$

ρ is the air density (constant at 1.225 kg/m^3). A is the sweep area of the windmill. The sweep area were a circle (constant at 3.14 m^2) [10]. v is the average wind speed in 10 seconds of measurement. Interval of measurements was ten minutes.

Wind power were converted to hydraulic power due to the linear translation of the reciprocating pump. Hydraulic power as the output of the windpump system could be written as [11]–[13]:

$$P_{hydraulic} = \rho_{water}\ g\ h\ Q \qquad (2)$$

ρ is the sea water density (constant at 1030 kg/m^3). g is the acceleration of gravity (constant at 9.807 m/s^2). h is the height from sea level to the top of the cylinder (in this study constant at 45 cm). Q is the volume flow rate in 10 seconds with interval of measurement ten minutes.

The efficiency of the windpump was calculated based on the ratio of water power as output power with wind power as a power source. The equation could be written as:

$$\eta = \frac{P_{hydraulic}}{E_{wind}} \times 100\% \qquad (3)$$

E_{wind} as input power and $P_{hydraulic}$ as output power [12], [13].

RESULT AND DISCUSSION

Fig. 3 shows distribution of wind speed obtained during observation of 09.00 – 15.00 (GMT +07.00). This study collects wind speed data in natural conditions of Kuwaru beach as input power for the windpump system. The wind speed has various range between 1,5 - 4,5 m/s as maximum and minimum value. Average wind speed of 5.0 cm and 7.5 cm of arm's length was 3.7 and 3.2 m/s.

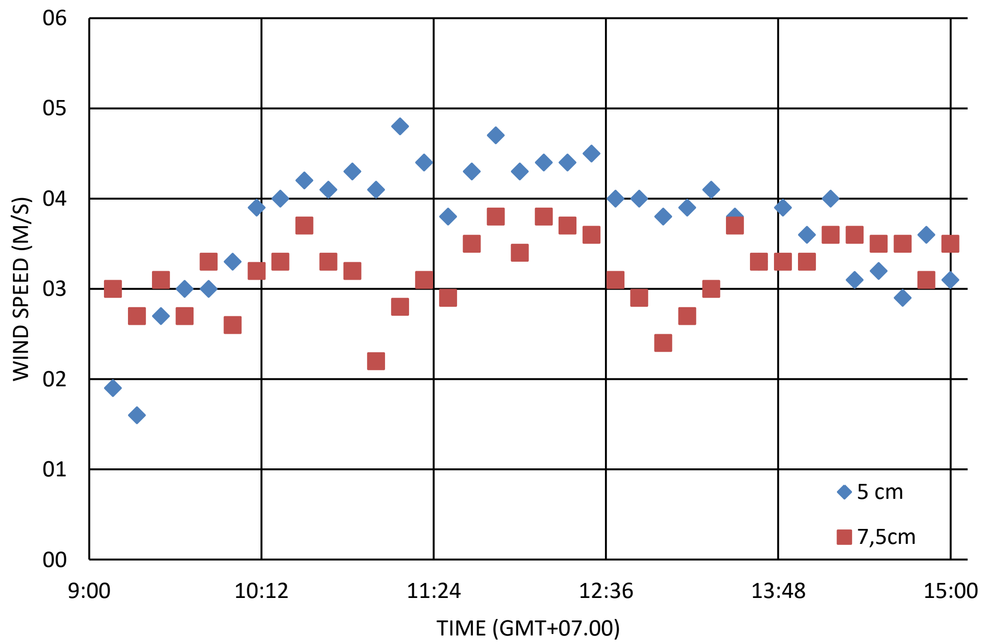

FIGURE 3. The wind speed recorded during experiment

Fig. 4 shows a relation of wind speed and volume flow rate. The data showed distribution of volume flow rate to fluctuate due to uncontrolled wind speed. The windpump with 5 cm of arm's length starts pumping water at 2.7 m/s of wind speed meanwhile windpump with 7.5 cm of arm's length starts pumping water at 3.0 m/s of wind speed. Due to the different amount of load was received by the reciprocating pump, then, the different starting points was different. The salt farmer’s windmill from Demak in this study with two blades has a maximum torque of 1.55 Nm [9].

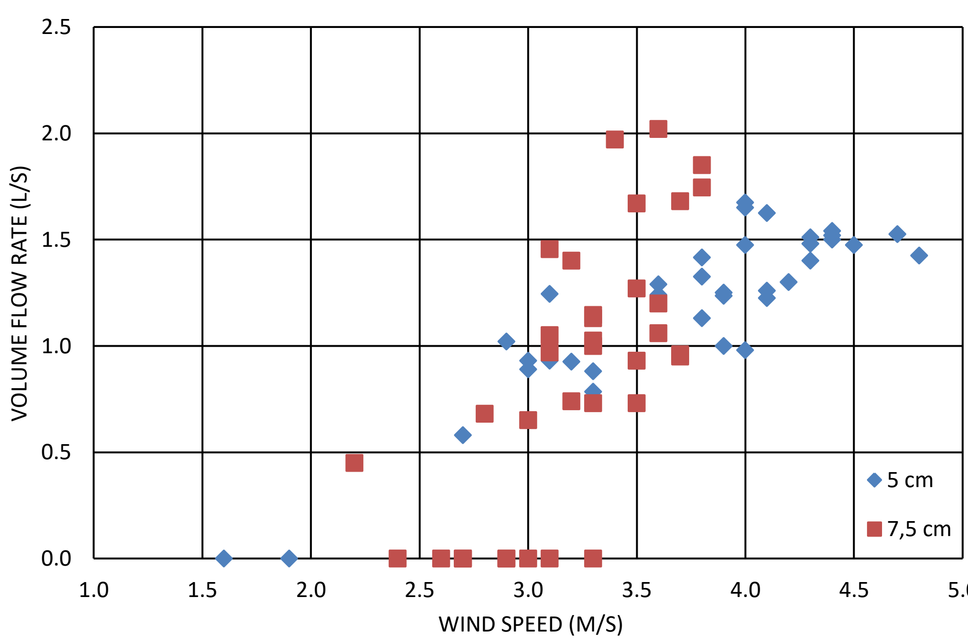

FIGURE 4. Wind speed and volume flow rate

Fig. 5 shows the increase of the volume of water pumped by the windpump in a day. Total volume of wind pump system with 5.0 cm and 7.5 cm of arm’s length was 25.581 m3 and 18.276 m3. The wind pump system with 5 cm of arm's length has more volume produce than windpump system with 7.5 cm of arms-length for the 5 cm of arms-length windpump received higher windspeed than 7.5 cm of arms-length windpump and also has lower starting wind speed.

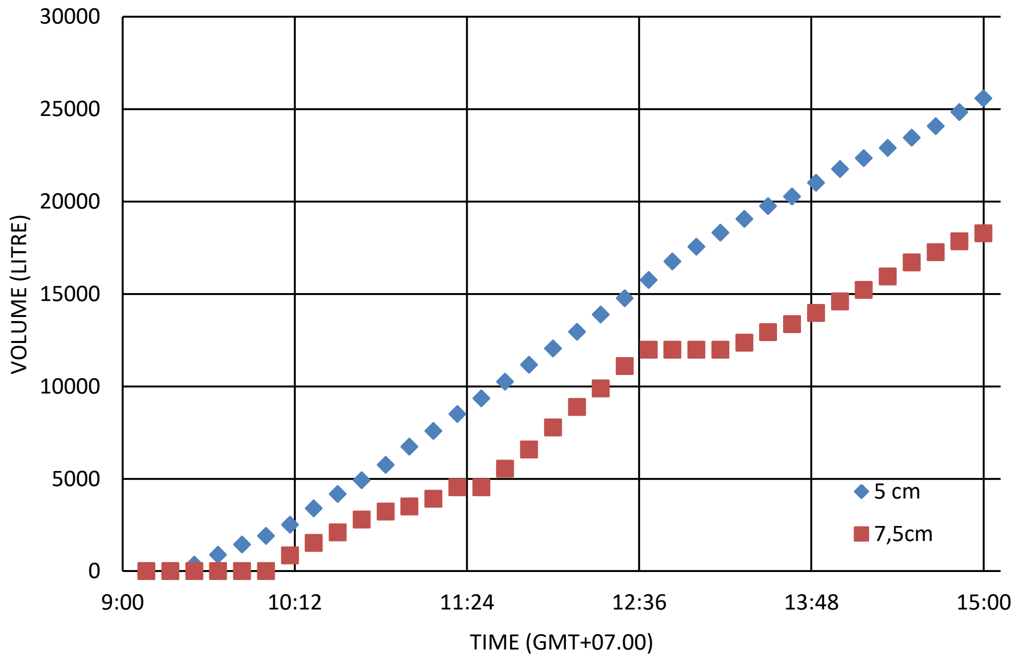

FIGURE 5. Pumping capacity of wind pump system in a day

Fig. 6 shows windpump's efficiency in a day of observation. The chart were made based on wind speed and volume flow rate (Fig. 4.) and equation (3). The unsteady wind speed due to natural condition on Kuwaru Beach contributed a fluctuation result. The 5 cm of arms-length windpump has 10.09% of maximum efficiency on 2.9 m/s and 1.02 litre/s, while 7.5 cm or arms-length windpump has 12.09% on 3.4 m/s and 1.97 litre/s, respectively. The windpump with 7.5 cm of arms-length has some 0% of efficiency for of the windmill could not drive the reciprocating pump. Average efficiency of 5.0 cm and 7.5 cm of arm's length wind pump was 5.03% and 5.93%.

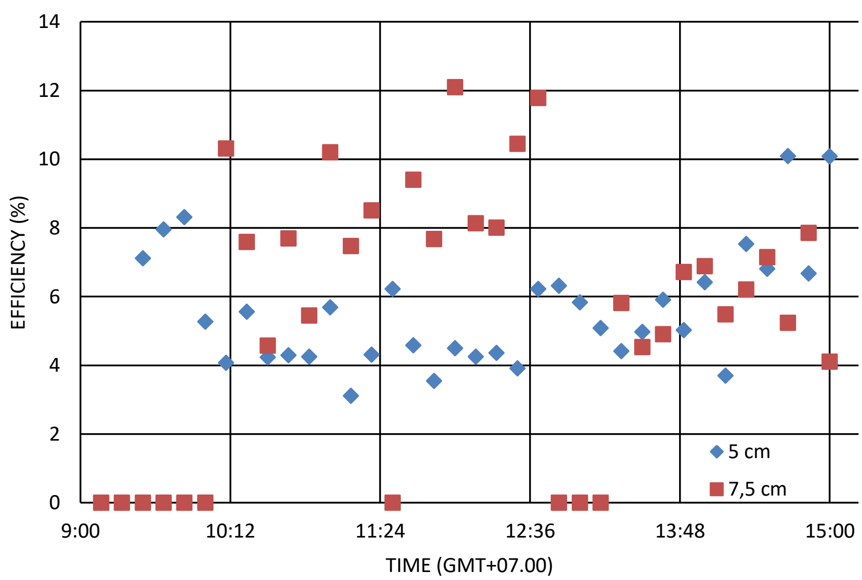

FIGURE 6. Efficiency of wind pump system in a day

CONCLUSION

This study was fullfilled to investigate the salt farmer's windmill from Demak with two blades to pump seawater with a reciprocating pump. The wind mill was observed on Kuwaru Beach, Bantul region, Daerah Istimewa Yogyakarta for the similarity with original condition. The experiment was observed two variation of arm's length of crank shaft of the windmill 5.0 cm and 7.5 cm. The maximum efficiency achieved by this windpump with 5 cm and 7.5 cm of arm's length was 10.09% (2.9 m/s; 1.02 litre/s) and 12.09% (3.4 m/s; 1.97 litre/s), respectively. The average efficiency wind pump system was achieved 5.03% and 5.93% for 5 cm and 7.5 cm of arm's length, respectively.

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