Indonesian traditional windmill of Demak, Central Java for water pumping in traditional salt production

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Abstract. Wind is a renewable energy and has many benefits. This energy is used by the salt farmers in the north coast of Java. Windpump is used to convert the wind energy for pumping water from sea to the salt pond. The purpose of this study is to get the performance of salt farmer’s windmill from Demak Region, Central Java for water lifting with vertically reciprocating pump. Rotation of shaft is directly converted to linear translation by crankshaft and connected to the piston pump. This study uses three variations lenght of the crankshaft arm in a piston pump. In 2 up to 5 m/s of wind speed range, the windmills from Demak with arm length of 5.0 cm, 7.5 cm, and 10.0 cm has an average volume flow rate of 0.89 litre/s, 1.8 litre/s, and 1.3 litre/s, respectively. For a day, these variations has a daily average volume of 19,278 litre, 39,162 litre, dan 27,804 litre.

1. Introduction
Indonesia is a country with high energy consumption in Southeast Asian. Gross Domestic Product is projected in 2017-2050 with an average 6.04% each year [1]. Energy demand increases with increasing population [2]. With this projection, it could be estimated Indonesia’s energy needs will increase. A several solution about this problem already done with Indonesia’s Government. One of the solution is the utilization of renewable energy. The use of renewable energy not only maintains the Indonesia’s energy stability, but it’s a global commitment to reduce greenhouse effect [3].

Indonesia is the world’s largest archipelago country, with 17,000 of islands and coastline almost 81,000 km. These coastline had a high amount of wind energy potential for Indonesia [2]. One example for renewable energy is wind energy, based on data Indonesia has wind energy potential for almost 60,6 GW [3]. Wind energy is clean, reliable, free, inexhaustible, and renewable source of energy and one of the right example is windmill [4]. In the north coast of Java, salt farmers already use windmill technology for water pumping [5]. But, salt farmer’s windmills from north coast of Java, doesn’t has certain sizes or shapes. Size and shape of these windmills are depends on the maker. Because of this reason salt farmer’s windmills at north coast of Java are various from sizes and shapes.

Salt farmer’s windmills are use to pump sea water from sea into the salt ponds in salt production process. Pump use is single piston pump has a one piston and one cylinder. Single piston pump has a simple works, with crankshaft, piston move up and down, then this movement will rise water up. Arm length which is use by salt farmer’s windmills are not well measured, but it estimated by salt farmers itself. These windmills and piston pump is made, instal, and maintain by the salt farmers.

This study discusses the performance of salt farmer’s windmills from Demak, Central Java with single piston pumps. Windmill which is use are four blades with 200 cm diameter. The pump used is a
piston pump with variations in arm length (5 cm; 7.5 cm; and 10 cm). The results are chart of wind speed and single piston pump volume flow rate and daily average volume.

2. Experiment Methods
This research used several tools needed, there are a couple of blades, single piston pump, windmill tower, arms with three variations, and rigid structure. The windmill, single piston pump, and windmill tower were bought from salt farmer at Demak, Central Java. The windmill has four blades and 200 cm in diameter. Single piston pump and a piston were 3.5 inch nominal diameter. Piston in single piston pump has 128 cm maximum length and connected with windmill shaft. Piston pump’s cylinder has a foot valve with 3.5 inch diameter to prevent water from flowing back into the sea, but the water remains in the cylinder. The arm has three length variation there are 5 cm, 7.5 cm, and 10 cm. The arm was made with steel material. The shaft used to connect the blades and arm has 19 cm diameter and 35 cm length.

Fig. 1. (a) windmill, tower, and piston pump; (b) shaft connection to the arm

Fig. 1. (a) shows layout of windmill, tower, and piston pump used, and Fig. 1. (b) shows magnification of windmill’s shaft. When windmill’s blades rotating then arm will rotate also, and then piston pump working. A piston pump was a pump whose piston work up and down in the cylinder. The inner chamber of cylinder which was isolated by the piston automatically filling the empty space with water. The workings of this single piston pump could be seen in Fig. 2(a) and 2(b). When piston begins to move from top dead centre to bottom dead centre, water volume will be remains and foot valve will be closed. When piston pump begins to move form bottom dead centre to top dead centre, water volume above the piston comes out as volume flow rate, while water under the piston rise up to fill the emptiness due to different pressure, and foot valve open [6].
Fig. 2. (a) piston pump moves down; (b) piston pump moves up

Datas was collected at Kuwaru Beach, Bantul, Special Region of Yogyakarta. Layout of windmill was directed as wind directions with various wind speed between 2.0 – 5.5 m/s. This research approaches to the actual work condition between windmill and piston pump in Demak, Central Java. Water used for this study was take from the sea and contains salt. During the data collection process, the source of water pumped by piston pump which was placed in a bucket with a constant head of 45 cm. The volume flow rate for data collections was measured by a cup every 9 minutes 50 seconds, the last 10 seconds used to take some data. The data taken are the average wind speed in 10 seconds, windmill rotation speed, and volume flow rate which comes out from piston pump. All these data collected at 09.00 – 15.00 (GMT+7), this time was the effective working hours of salt farmer’s windmill from Demak.

In data processing, there are several formulas for creating charts needed. One of the parameter which determine in wind energy is wind speed \([2]-[3]\). Wind energy is input power with \(v\) as wind speed (m/s), \(A\) as sweep area of the windmill (m\(^2\)) with constant diameter (200 cm), and \(\rho\) as air density (1.225 kg/m\(^3\)). Output power in this study is hydropower in the form as a piston pump. The hydropower in this piston pump is the power generated by the pump which could be transferred to the fluids \([4]-[5]\). There is a formula to use to calculated the hydropower, \(\rho\) as sea water density (1030 kg/m\(^3\)), \(g\) as gravity (9.81 m/s\(^2\)), \(H\) as head (constant = 45 cm), and \(Q\) as volume flow rate which coming out from piston pump (m\(^3\)/s). Based on definition of wind energy and hydropower that have been explained, there are some data which need to take, there are wind speed, volume flow rate, and shaft rotation speed.

The wind speed was measured by digital anemometer (model CR-2032), shaft rotation speed by Photo-Tachometer (model DT-2268), and volume flow rate by simple measuring cup. Those tools were used to take all of the datas in every arm length (5 cm, 7.5 cm, dan 10 cm). Since the wind could not be controlled, then the datas collection were done by loading a piston pump with three variations of arm length. This was needed to determine the performance of Demak salt farmer’s windmill for pumping water.
3. Result and Discussion

Based on the result of data collections and processing that has been done, could be shown by graphic relationship of wind speed and piston pump’s volume flow rate (Fig. 3.), and graphic relationship of effective working hours and volume (Fig. 4.).

Fig. 3. shows salt farmer’s windmill performance from Demak for pumping water in arm length of 5 cm, 7.5 cm, and 10 cm. These trendlines looks fluctuate because of data collections are approach in real conditions. In the real condition, the wind speed could not be set and it depends on nature. Windmills with arm length 5 cm, 7.5 cm, and 10 cm has average volume flow rate of 0.89 litre/s, 1.8 litre/s, and 1.3 litre/s. This windmill starting to rotate and drive the piston pump at 2.5 m/s of wind speed.

![Fig. 3. Relationship of Windspeed and Piston Pump’s Volume flow rate](image)

Fig. 3. Relationship of Windspeed and Piston Pump’s Volume flow rate

Fig. 4. shows daily average volume of salt farmer’s windmill from Demak with piston pump. Effective working hours of this windmill with arm length 5 cm, 7.5 cm, and 10 cm has daily average volume of 19,278 litre, 39,162 litre, dan 27,804 litre in a day. Windmill with 7.5 cm of arm length has the highest daily average volume of 39,162 litre. Windmill with arm length of 5 cm doesn’t release much volume as 7.5 cm because of short distance from BDC to TDC. Windmill with 10 cm of arm length has the highest load of piston pump, because of this windmill at windspeed less than 2.5 m/s didn’t rotating and this windmill require higher torque for starting [5].
4. Conclusion
Performance of salt farmers windmill from Demak was successfully recorded. Based on result shown before, there are conclusion to inform. Salt farmers windmills from Demak with arm length 5 cm, 7.5 cm, and 10 cm has an average volume flow rate of 0.89 litre/s, 1.8 litre/s, and 1.3 litre/s. These variation has a daily average volume of 19,278 litre, 39,162 litre, dan 27,804 litre in 2 – 5 m/s of wind speed.

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