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PIPES OUTLET DIRECTIONS AND DIAMETER OF DOUBLE U PIPES CONFIGURATION ON CENTRIFUGAL REACTION PUMP

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ABSTRACT

Centrifugal reaction pump is simple centrifugal pump, easy to built, highly local components and operate at very low shaft speed. Experiment study of double U configurations pipes with three outlet directions and pipes diameter of outer arms effects were carried out for centrifugal reaction pump at very low shaft speed. The outlet directions of double U configurations were 90 deg., 0 deg. and -90 deg. from horizontally straight arm pipes. T-junction fitting, a vertical inlet pipe and two horizontally straight arm pipes as main components of the pump were 18.5 mm diameter. The horizontally straight arm pipes are similar with pump impeller function. The arm pipes are replaceable with 22.5 and 28.0 mm. The pump was rotated with vertical pipes as an axis by adjustable speed electric motor at the top of T-junction. The shaft speeds were 70 rpm up to 150 rpm. Total head and diameter of the pump were 665 mm and 1000 mm. The experiment showed that double U configurations with various outlet directions could be used to replace orifices and springs as moving components of centrifugal reaction pump. The experiment resulted performance of the three configurations and backward-inclined-blades-like as the best configuration and is followed by forward-inclined-blades-like and straight-blades-like configurations respectively. Increasing pipes diameter of the arm increase the pump capacity and does not tend to increase the efficiency.

Keywords: centrifugal reaction pump, low shaft speed, double U pipes configuration, outlet direction, arm pipes diameters

1. INTRODUCTION

Wind power and solar photo voltaic power are dependable and renewable energy resources for the electric generation and water pumping for remote area. The hybrid of them ensures the continuity of energy suitable for the area (Dillon, et al, 2014). Wind energy water pumping system (WEWPS) is used for salt pans, drainage, irrigation, cattle watering, and domestic and community water supply with very low head (up to 3m) up to deep head (more than 10 m). Mechanical WEWPS with 1 up to 7 m rotor diameter pumps water 20 m3 up to 2500 m3 per day. Electric WEWPS having higher flexible placement can pump water continuously and larger capacity than the mechanical (Smulders, 1996).

WEWPS must be reliable to run unattended for most of the time, need minimum maintenance and attention. A WEWPS should run for over 20 years with maintenance only once every year without any major replacements. WEWPS used for irrigation seasonally tend to be indigenous designs that are improvized or built by the farmer to reduce the cost (Wind Power, 2013). Therefore, WEWPS for irrigation has low cost and this requirement tends to override other considerations. WEWPS can supply water at competitive cost especially if manufactured locally (Smulders, 1996). The key actor is the manufacturer who is responsible for choosing and designing, production, marketing and also after sales service.

The main advantages of electric WEWPS are flexibility over other mechanical systems and have more components (Gopal, et al, 2013). The efficiency of electric WEWPS depends on performance of the electric components. It is reported that wind mill could convert 35% wind power to shaft power. For 51% can be lost by all of the electrical components, as a maximum only 17% of the wind energy can be available for water pumping operations. Since a large amount of energy dissipation in converting process, new configuration should be analyzed to avoid such losses (Lara, et al, 2011).

Among of pumps for WEWPS is centrifugal reaction pump. The pump consists of a vertical pipe with a T-joint at the top, from which extend two pipes whose length is dependent upon the rate of rotation of the assembly in operation. An orifice at the end of each pipe arm points, 90° away from the arm. The pump is well adapted to variable low shaft speed and construction is simple. One of these pumps connected to a 3 m diameter wind mill and pumped 30 m^3 per hour at a head of 4.5 m in a 29 km/h wind speed (Rubinski & Rubinsky, 1955). Modification to the pump is done by replacing orifices to reduce moving components. Double U pipe configuration with outlet direction in-line with pipe impeller was successfully replace all of moving parts (Lukiyanto & Wahisbullah, 2014).

This present study aims to experimentally investigate effects of outlet flow directions and pipes diameter of outer arms of centrifugal reaction pump. The centrifugal reaction-pump with double-U pipe channels at each of both arms can be adjusted at three outlet directions. The outlet directions to the inlet are backward-inclined blades-like, straight blades-like and forward-inclined blades-like. The names refer to the three main types of centrifugal pump blades (Cengel & Cimbala, 2006). Each of them effects to the pump performances. The pipes of outer arm are modified and replaceable with various diameters of the pipes. The nominal diameters of pipes are 18.5, 22.5 and 28.0 mm (0.5, 0.75 and 1.0 inches).

2. METHODOLOGY/ EXPERIMENTAL

The pump consisted of a vertical pipe with a T-junction (5) at the top, from which extend two horizontally pipes (2) as straight impeller blades (Fig.1). At the end of horizontally pipes were attached double U pipe configurations (3). The upper U pipes were designed movable to adjust outlet direction of fluids. The pipes were arranged from pipes and elbow fittings with nominal diameter of 18.5 mm (0.5 inch). A foot valve (8) was attached at the bottom of the vertical pipe. The T-junction was attached to the shaft motor (1) as drivers. The motor shaft was in line with vertical pipe and foot valve. The assembly was attached to the rigid structure by two bearings (4).

A housing (6) was attached to receive, collect and measure the fluid flow rate that comes from the pumps outlets. Fluid from main pond (10) was delivered to feeder (9) excessively by a submersible pump (11). Excessive fluid at feeder was a mechanism to maintain water level input, thus the head always constant.

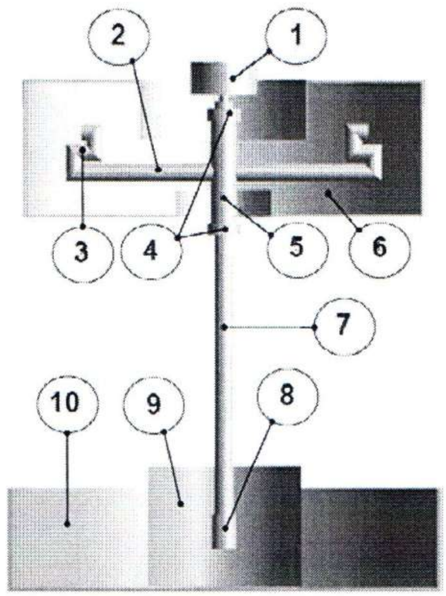


Figure 1. Schematic of centrifugal reaction pump.

The pump outlet directions were adjusted in three positions (Fig.2). The upper U pipes were adjusted 90 degrees (Fig.2a), -90 degrees (Fig.2b) and 0 degree (Fig.2c) away from the straight pipe impeller and were symbolized BB, DD and SS respectively. Based on inlet and outlet impellers geometry, Fig.2a–2c were called backward-inclined blades-like (backward-like blades, BB), forward-inclined blades like (forward-like blades, DD) and straight-like blades (SS) respectively.

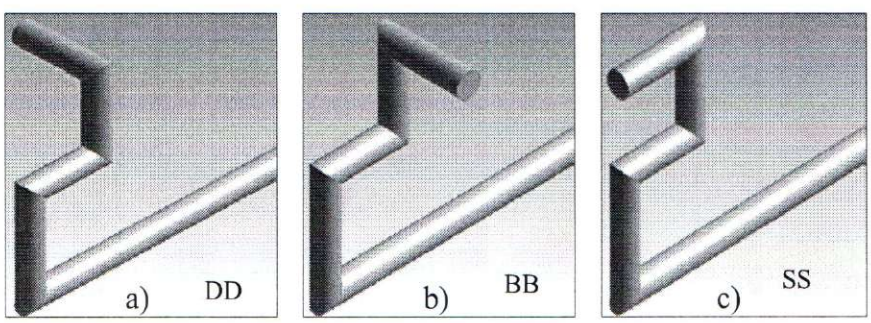
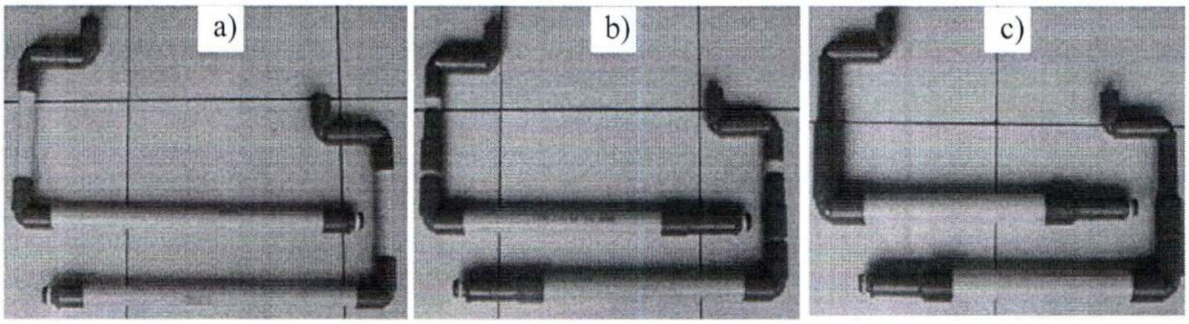


Figure 2. Outlet directions of impeller and symbols, a) backward-inclined blades-like (backward-like blades, BB), b) forward-inclined blades like (forward-like blades, DD) and c) straight-like blades (SS)

T-junction is cross fitting with nominal diameter 0.5 inch. At the ends of T-junction channels are for attaching the mountings (Fig.1). The horizontally channels are for impeller pipes mountings and vertical channels are for shaft mounting and input pipe mounting. The pipes of outer arm in various diameters are modified, replaceable and mountable at the horizontally T-junction mountings. The nominal diameters of outer arm pipes are 18.5, 22.5 and 28.0 mm (0.5, 0.75 and 1.0 inches). (Fig.3). The T-junction with various diameters of outer arm pipes is 1000 mm. The ends of double U pipe configuration as outlets are rotatable thus the outlet directions are adjustable.



a) b) c)

Figure 3. Diameters of arm pipes, a) 18.5 mm, b) 22.5 mm and c) 28.0 mm

The shaft driver was a brush DC (BDC) electric motor 48 volt, 250 watt, maximum speed 540 rpm. The motor speed controller was serial of electric transformer and adjustable voltage regulator. The pump was converted shaft power as power input into hydraulic power as power output. The measurement parameters of power input and power output were based on shaft power (Eq.1) and hydraulic power equations (Eq.2)

Shaft power:

$$P_{in} = 2\,\pi\,\dot{n}\,T \tag{1}$$

Hydraulic power :

$$P_{out} = \dot{m}\,g\,h \tag{2}$$

Pump efficiency :

$$\eta_P = P_{out}/P_{in} \tag{3}$$

Where $\dot{n}$ = shaft speed (rpm), T = shaft torque (N m), $\dot{m}$ = mass flow rate (kg/s), g = standard acceleration of gravity (9.80665 m/s^2) and h = total head (665 mm).

Based on the Eq.1 to Eq.3, the measured parameter were shaft speed (rpm), shaft torque (N m), flow rate (m^3/s), and constant suction head (665 mm). The shaft speed was measured by tachometer. The shaft torque was measured by multiplying the length of torque-arm (345 mm) and the force reading on weight-scale. The Portable Electronic weight-scale (maximum 40 kg/5 g) was installed at the end of torque-arm. Mass flow rate was the result of multiplying fluid flow rate with standard of fluid density. The fluid was standard water (ρ = 998.0 kg/m^3). Water flow rate was measured by using measuring glass and stopwatch. Total head parameter in this experiment was adjusted to be constant at 665 mm.

The measurement of the shaft torque was calculated based on the shaft torque of motor. Shaft power input was the difference between shaft motor power and the mechanical losses caused by the bearing friction. The mechanical losses were calculated by measuring torque and shaft speed without pumping load by deactivated foot valve.

3. RESULTS AND DISCUSSION

3.1. Various outlet directions

Mechanical power losses (Ploss) were found by measurement of motor shaft torque and speed without pumping load measurement. On the no-load measurement, foot valve was in off mode. The foot valve channel was blocked with removable sealer. The shaft speed measurement was in the range of 70 up to 150 rpm (Fig.4). Pump shaft power input (Pin) was calculated by reducing motor shaft power (Pmotor) with the Ploss.

On the experiment measurements, shaft speeds were started at 145 rpm and down to 75 rpm. The system was start pumping (cut-on) about 95 rpm and stopped pumping (cut-off) at about 84 rpm. The maximum speed and flow rate were 143.8 rpm and 0.244 dm3/seconds respectively. The total head was maintained constant at 665 mm. The main arm diameter was 1000 mm. Based on equation (2), hydraulic power was dependent on flow rate and total head. The study show that hydraulic power was only depended to single parameter flow rate linearly due to total head maintained constant. Due to flow rate dependency on shaft speed, the hydraulic power was only dependent on shaft speed. The results showed that hydraulic power of the three double-U pipe configurations tends to linear to the shaft speed (Fig.5). Each of the three double-U pipe configurations were also coincide.

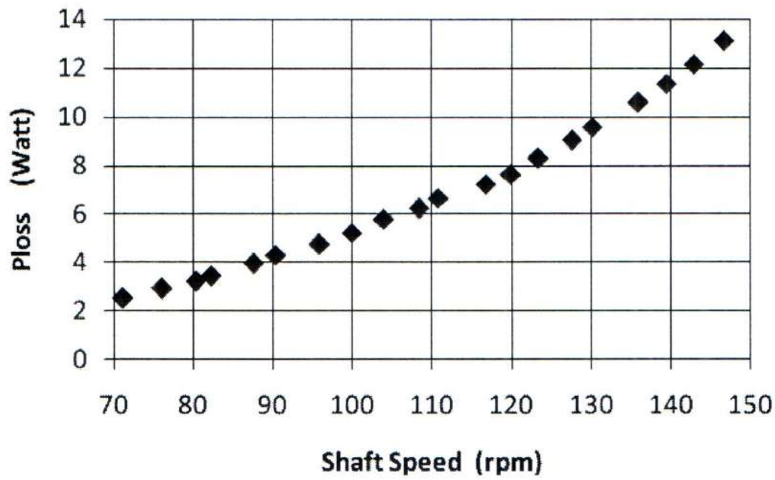


Figure 4. Mechanical power losses and shaft speed

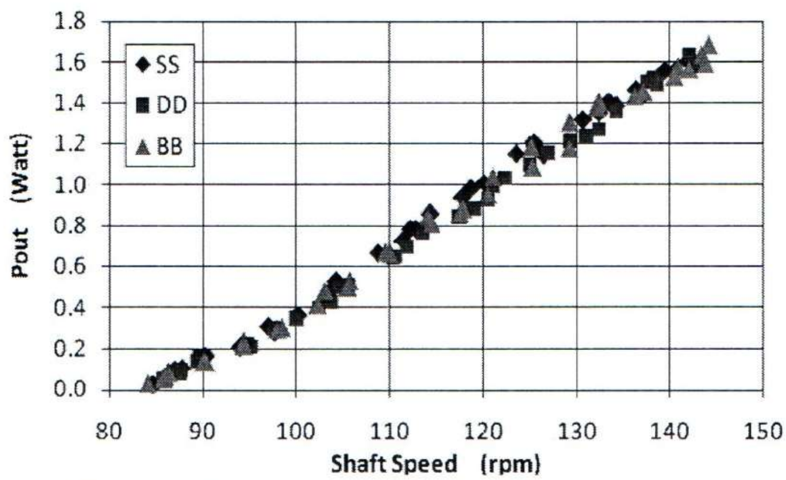


Figure 5. Pumping power outputs and shaft speed

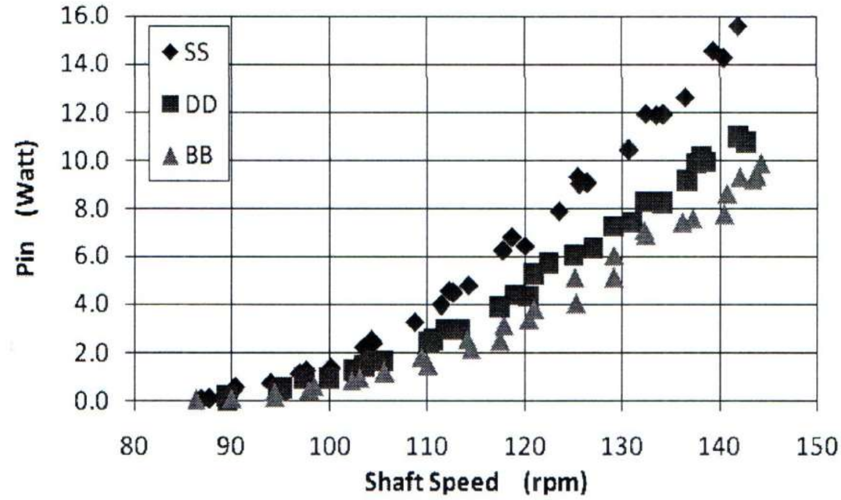


Figure 6. Shaft power inputs and shaft speed

Double-U pipe configurations were affected to the shaft power input (Pin) as Fig.6. The Pin was not coincide and linear for all of the configurations as hydraulic power. The SS and BB configurations were higher and lower Pin than the DD configuration.

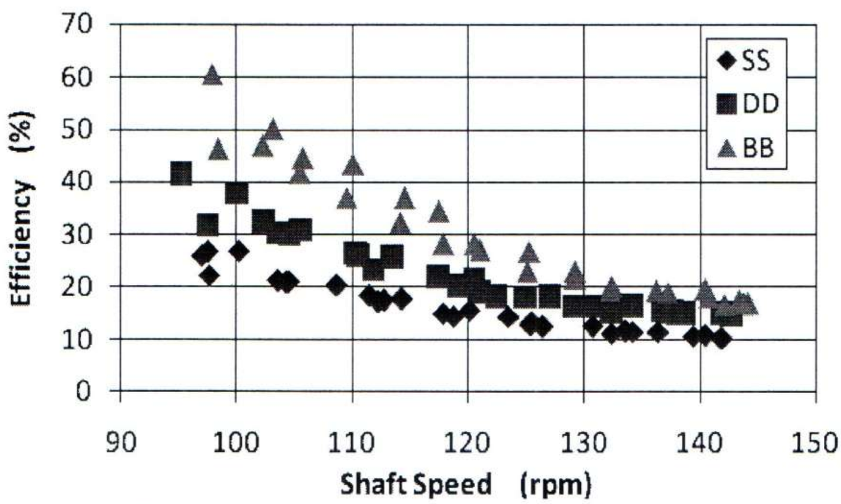


Figure 7. Pumps efficiencies and shaft speed

Shaft power inputs and hydraulic power outputs were resulted efficiencies of reaction centrifugal pumps with the three double U pipe configurations as Fig.7. The efficiencies of each configuration were not linier to the shaft speed. The efficiencies and its deviation tended to lower value for higher shaft speed. The BB configuration was the best configuration for the highest efficiency for all shaft speed evaluated. The DD configuration was better than SS configuration for the higher efficiency for all shaft speed evaluated.

For shaft speed 100 rpm down 84 rpm when the system was stopped pumping (cut-off), deviation data was higher due to foot valve was not fully opened. The uncontrolled opening foot valve was only depended on differential pressure of fluids in upper and below of foot valve.

3.2. Various outlet diameters

Based on result of the previous experiment, outlet direction for performance of centrifugal reaction pump with various diameters experiment is adjusted on BB configuration. Outlet directions of the upper U pipes were adjusted 90 deg. away from the straight pipe impeller and were also called backward-inclined blades-like.

Based on Fig.8, increasing diameter of the arm pipes could increase capacity of centrifugal reaction pump. Increase diameter of pipes to nominal diameter 0.75 increased capacity of the pump for shaft speed 130 rpm and up, compared to nominal diameter 0.5 inch. Increase diameter of pipes to nominal diameter 1.0 increased capacity of the pump significantly for all speed range of experiment, compare to nominal diameter 0.5 and 0.75 inch. The pump characteristics were similar with Eq. 2. The fluid mass and mass flow rate in channel were larger for larger pipe diameter.

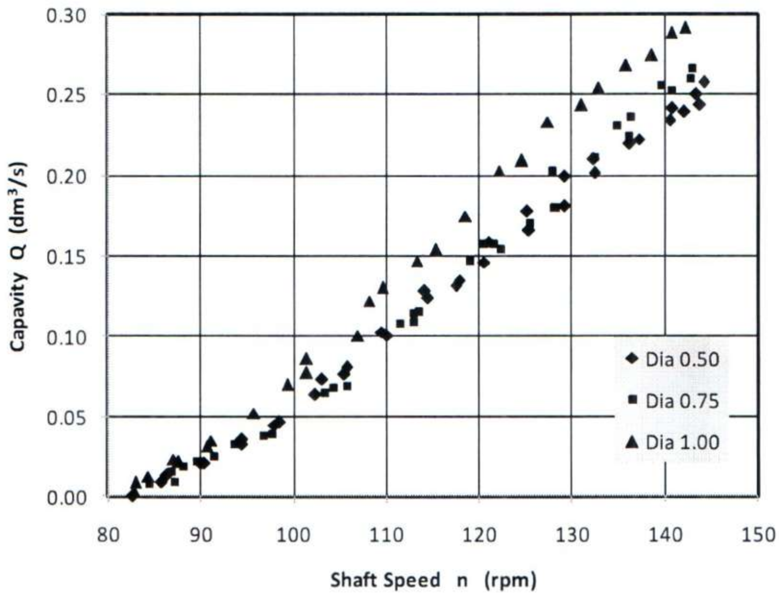


Figure 8. Pumps capacity and shaft speed

Experiments of the pumps showed that the efficiencies tends similar for various arm pipes diameters, especially for shaft speed range 120 up to 145 rpm (Fig.9). For various arm pipes diameters, the pump efficiency deviation was higher in shaft speed below 120 rpm as foot valve was not opened fully and the opening of the valve could not be controlled. Increase nominal diameter of arm pipes, although increase the pump capacity, was not increase the efficiency. It meant that the increasing of shaft power as power input to the pump was followed by the increasing of hydraulic power as power output of the pump and its power losses. The power losses came from T-junction, vertically inlet pipe, double U pipes and foot-valve as fixed parts on whole experiment. One of the losses comes from secondary flow in channels. Compare to non-rotating channels flow, effect of rotation is significant to the secondary flow (Colleti, et al, 2014; Roy, et al, 2013).

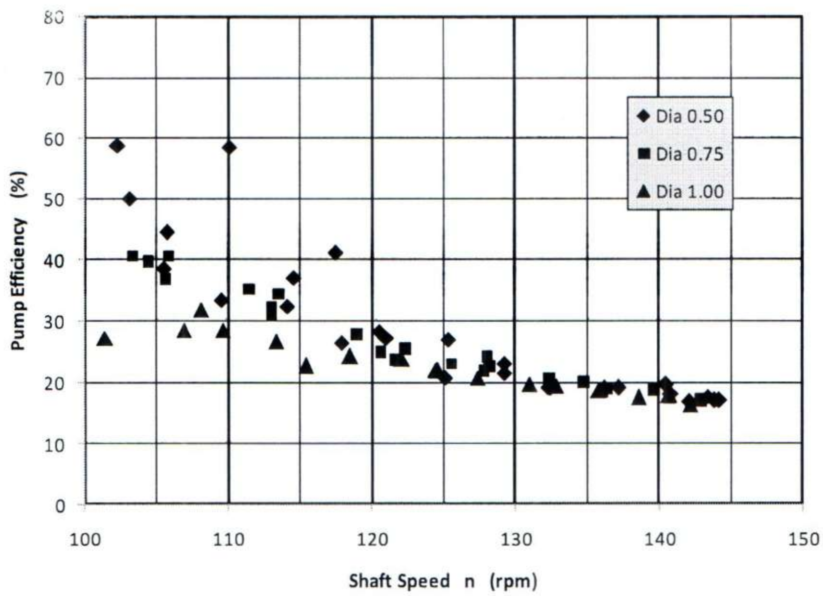


Figure 9. Pumps efficiency and shaft speed

4. CONCLUSION

The experiment study show that double U configuration with 90 deg, 0 deg and 90 deg outlet directions to the straight impeller blades and with 18.5, 22.5 and 28.0 mm (0.5, 0.75 and 1.0 inches) pipes nominal diameter of outer arms were successfully applied to the centrifugal reaction pump. The configurations can be used to replace a pair of fixed and sliding orifice as water gate restricts the air to flow into pipe impeller channel.

The result shows that the configuration has higher effects to the hydraulic power output than the shaft power output. The best efficiency is backward-inclined-blades-like, forward-inclined-blades-like and straight-blades-like respectively. Increasing nominal diameter of arm pipes significantly affect to increase of the pump capacity but has no significant effect to the pumps efficiency.

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