RELATIONSHIP BETWEEN DISCHARGE AND BACKWARD BUCKET DIMENSIONS OF UNDERSHOT WATERWHEEL

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RELATIONSHIP BETWEEN DISCHARGE AND BACKWARD BUCKET DIMENSIONS OF UNDERSHOT WATERWHEEL

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ABSTRACT

In general, water pumps are used to help people who live in highlands, away from water resources to get water. However, the use of water pumps has disadvantages, such as: the need for power sources, such as: electricity or fuel and the high cost of pump operation and maintenance. Therefore, a waterwheel can be used as an alternative. A type of undershot water wheel is generally used in flat areas with less potential energy of water. In this situation, the amount of water that can be supplied depends on the weight of water in the bucket that can be lifted by the water wheel. The purpose of this study is to determine the relationship between bucket dimensions and discharges of waterwheel. The experiment was conducted in a flume of hydraulics laboratory. The required equipments include a waterwheel with 150 cm of arm length, bucket with various dimensions, water pump to flow water in the flume, and some hoses. The waterwheel is designed to have two-sided buckets, namely: forward buckets and backward buckets. The forward buckets are designed in a way that the flowing water in the flume can sufficiently move the waterwheel. Then the moving waterwheel can lift up water in the backward buckets and flow it through hoses as the discharge. Three various diameters: 62mm, 65mm and 70mm were used in this experiment.

The result shows that the amount of the water volume in a backward bucket of 62 mm in diameter and tilted inward the arm wheel by 10° is 32,722 ml/s. However, the amount of the water volume in 8 buckets (62mm in diameter and tilted by 10°) at a time is 261,445 ml/s.

Key words: backward bucket, undershot waterwheel, water volume.

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1. INTRODUCTION

Generally pump is used to help people who live in highlands, far away from the wellhead to get the water. Many people in the village have some difficulties from the use of water pump as it needs high cost for operations and maintenances, as well as it needs fuel to operate. In some villages, fuel is not always sufficiently available every day. In this situation, the use of waterwheels can be one of alternative solutions. Waterwheel is a wheel that can be spinning by the energy of flowing water. Water can be lifted up by the spinning waterwheel and collected by the backward buckets then released as the discharge.

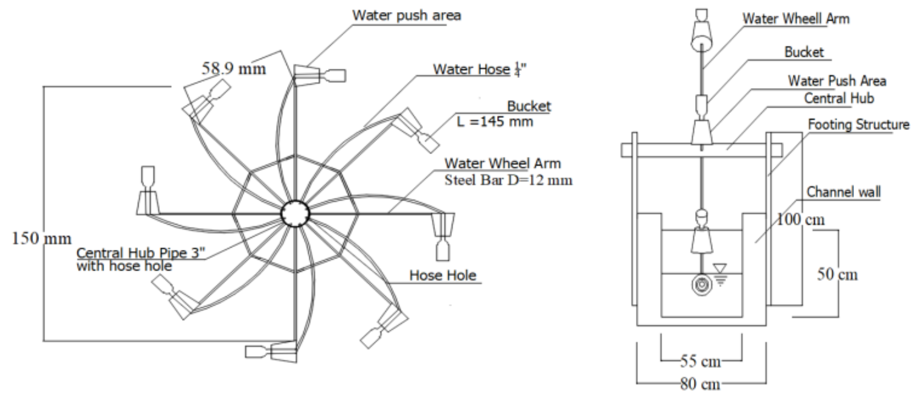
According to Dewi (2011), replacing waterwheels instead of water pumps can reasonably increase the benefits of irrigation. The waterwheel has proven by Dewi(2011) to meet the needs of water for agricultural farms. Based on the Benefit Cost Analysis, waterwheel is categorized as economically feasible for the development of agriculture sector in the future. Ismanto et al (2015) studied on Waterwheel Design as Pump Driving Action. It was found that the type of screw waterwheel can produce 40 liter/s using a constant 5 m/s of flow rate. Ismanto et al (2015) had increased the speed of spinning by 5 times into 50 rpm. The water can be easily transferred from the irrigation channels up to farms in the highlands. Oktaviana (2016) studied on “The Use of Waterwheel for Irrigation in Tanjung Pati”. She mentioned that all waterwheel used for irrigation can successfully provide enough water for agricultural farms in Tanjung Pati.

Based on its driving action, waterwheels are grouped into three following types, the first is a type of overshot waterwheels, the second is the type of breastshot waterwheels, and the third is the type of undershot waterwheels. Waterwheels are generally used in the flat areas with no natural slope of the land, situated on the banks of rivers as smaller streams, as the result the water flowing depends on the water volume in the bucket. The series of blades in waterwheel give usable energy transferred through the axle as torque and also impact the horizontal wheel efficiently. The thicker the blade is, the less energy can be transferred. In conclusion, the sizes of the blades can contribute an impact in converting the energy of the water to rotate the wheel (Wahyudi, S., et al, 2013). However according to Henry, O.S., et al (2013), it was found that the smaller diameter of buckets can even produce more water discharge.

Objectives of this study are to determine the maximum discharge produced by the waterwheel using available buckets in the markets and to demonstrate the use of waterwheels in the laboratory flume to represent the actual use of waterwheel in irrigation channels.

2. MATERIALS & EXPERIMENTAL PROCEDURES

The experiment was conducted in a 55×50cm flume of hydraulics laboratory. An 8-arm iron waterwheel was used in this experiment. The waterwheel was designed to have two-sided buckets, namely: forward buckets and backward buckets. The forward buckets will receive the energy of flowing water. The energy is used to spin the waterwheel. The spinning waterwheel will use backward buckets for taking and lifting up some water. The water inside backward buckets is then collected through hoses as the discharge of waterwheel (see Figure 1 and Figure 2). This study used three various diameters: 62mm, 65mm and 70mm. Water with a discharge of 0.0045 m^3/s was flowed in a flume. The experiments were conducted 6 times with the various diameters of buckets.



Side view Water wheel model
Front View

Figure 1 Water Wheel Model

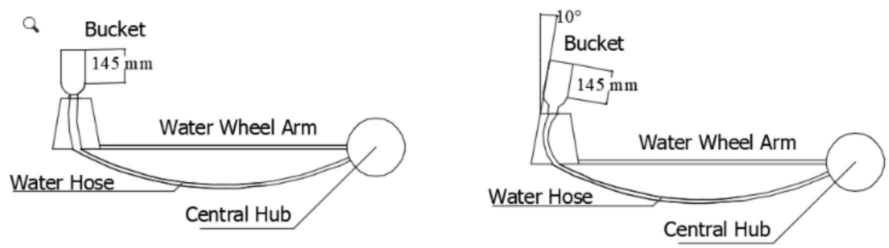


Figure 2. Detail Variation of bucket position

Momentum (p) is the product of the mass and velocity of an object. It is expressed in Eq 1 as follow.

$$p = m \times v \tag{1}$$

where:

p : Momentum (kgm/s)
m : Mass (kg)
v : velocity (m/s)

According to Triatmodjo (1993), the change in momentum can produce force that equals to the mass of water, water discharge and the change in velocity. It is expressed in Eq 1 below.

$$F = \rho \times Q \times du \tag{2}$$

where:

F : Force (kgm/s^2)
ρ : density (kg/m^3)
Q : Water discharge (m^3/s)
d*u* : velocity (m/s)

Based on the two formulas above, the result shows that the momentum is 5.424 kgm/s and the force is 4.434 kgm/s^2.

The spinning speed rate of waterwheel was calculated based on an angular velocity equation that is expressed in Equation 3 as follow.

$$\omega = \frac{s}{rt} \dots \quad (3)$$

where:

ω : Angular velocity (rad/s)
s : Length of arm (m)
r : radius of circle (°)
t : time (s)

3. RESULTS AND DISCUSSION

The water in the flume was set at 0.9861 m/s of water velocity to consistently spin the waterwheel. Results of experiments were shown in Table 1 and Table 2.

Table 1 The Angular Velocity

Position	**the size of diameter**	**driving surface 1 backward bucket**		**driving surface 8 backward buckets**	
	Bucket **(mm)**	**Time (seconds)**	**ω (rad/s)**	**Time (seconds)**	**ω (rad/s)**
Vertical wheel with horizontal axis	62	7.47	0.841	8.7	0.722
	65	8.06	0.780	9.82	0.640
	70	10.02	0.627	10.74	0.585
Tilted inward the arm wheel by 10°	62	7.99	0.787	9.03	0.696
	65	8.61	0.730	9.8	0.641
	70	10.1	0.622	11.05	0.569

As illustrated in Table 1, the size of the diameter and the number of backward buckets was inversely proportional to the angular velocity as a larger diameter and more number of backward buckets produces a smaller angular velocity.

Table 2 The Result of Discharge

Position	**the size of diameter**	**driving surface 1 backward bucket**		**driving surface 8 backward buckets**	
	bucket (mm)	**water volume (ml)**	**Discharge (ml/s)**	**water volume (ml)**	**Discharge (ml/s)**
Vertical wheel with horizontal axis	62	231.667	31.058	2216.7	245.61
	65	231.667	28.742	2274	232.05
	70	256.67	26.00	2187	204.27
Tilted inward the arm wheel by 10°	62	261.333	32.722	2360	261.445
	65	252.667	29.353	2343.3	239.23
	70	285	28.212	2463.3	223.00

Table 2 shows that although larger diameter of backward bucket can lift more water, actually in this waterwheel study, larger diameters of bucket produced smaller discharges. This is because more water in backward buckets produces heavier total weight of water and bucket; therefore, the spinning speed of waterwheel is becoming slower. Figure 3 and Figure 4 show relationship between discharge and backward bucket diameter at 1 and 8 buckets, respectively.

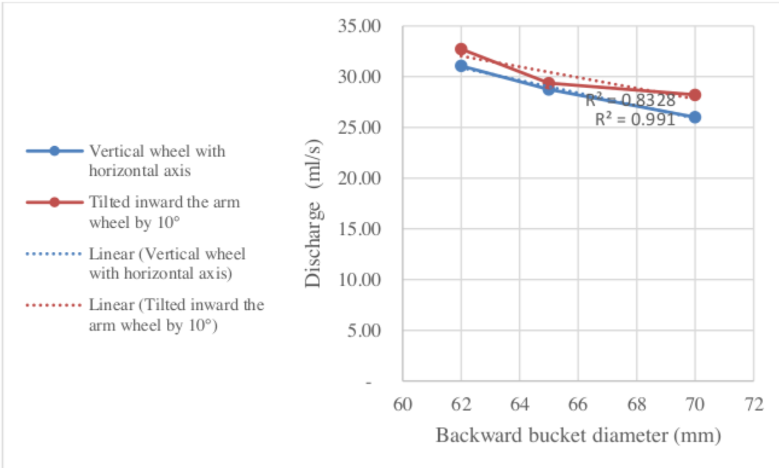


Figure 3 Relationship between discharge and diameter of 1 backward bucket

Figure 3 shows that a smaller bucket diameter produces a larger discharge. It means that more water is produced by a waterwheel with smaller backward bucket diameter.

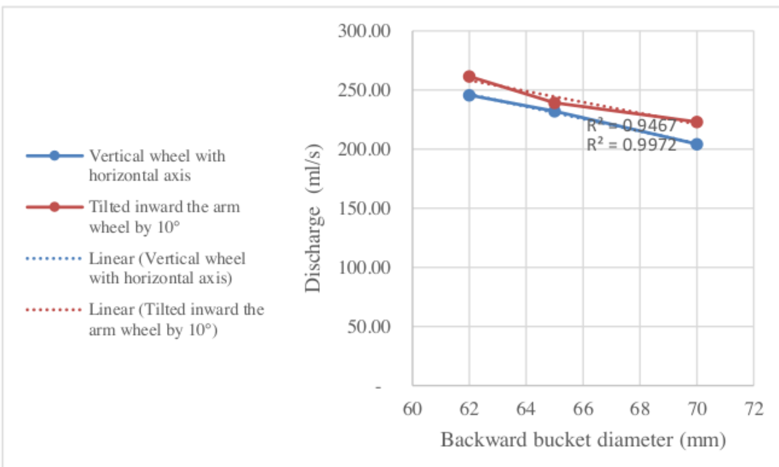


Figure 4 Relationship between discharge and diameter of 8 backward buckets

Similar to Figure 3, Figure 4 shows that more water is produced by a waterwheel with smaller backward bucket diameter.

4. CONCLUSIONS

According to the waterwheel study, larger diameter of backward buckets produce smaller amount of discharge. This is due to the spinning speed of the wheel. A larger backward bucket can lift more water but the spinning speed of the wheel is slower than the spinning speed of wheel produced by a smaller backward bucket.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6