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Rotating Force of Vanes on Irrigation Water-Scooped Wheel

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***Abstract*— Irrigation Water Scooped-Wheel is an appropriate and environmental friendly technology to deliver water from lower river to higher land. The main source of driving power of water scooped wheel is the forces caused by water flow impact on vanes. The force has not been measured. Knowing the forces will enable to estimate the wheel potential to deliver water. The objectives of this study are to determine the force on vanes and to evaluate influencing factors. The forces are determined by moment equilibrium between the moment of vanes and the moment provided to prevent the wheel to rotate. At 0.282 m/s water velocity, magnitude of force on vane (0.3 x 0.7 m2) were 34 – 130 Newton. The force on vanes are affected by the area of vanes impacted by flowing water, the position on vanes toward flowing water and the water flow velocity.**

***Keywords*—force on vanes; irrigation; water scooped-wheel**

I. INTRODUCTION

Water scooped-wheel (*kincir air irigasi*) is still used in several parts of Indonesia. It elevates water from low river to irrigate higher paddy rice field. The traditional technology is simple and environmental friendly. It is an appropriate technology for rural area because it does not require electricity (Tjandra, 2009).

Its capacity depends on the volume rate of water can be delivered to the field. The main source of driving power of water scooped wheel is the forces caused by water flow impact on vanes. The driving force was required to carry up water from the river to basin at the top of the wheel before delivered to the field (Habeahan, 2013). Knowing the forces will enable to estimate the wheel potential to deliver water.

Limited investigation on vane force was conducted by Tjandra and Lubis (2012). Resultant force on several vanes submerged in water were measured for water scooped-wheel with plastic, bamboo and metal plate vanes.

The objectives of this study are to determine rotating force on single vane and two vanes submerged in water and to evaluate several influencing factors.

II. MATERIALS AND METHODS

Fahada (2013) used a water scooped-wheel with 3.1 m diameter and 0.7 x 0.3 m^2 metal plate vane. The water scooped-wheel with pipe frame only had vanes without tubes since we study the effect of flowing water on vanes. The water scooped-wheel was installed in irrigation canal and the water depth can be set at certain depth. The water scooped-wheel was supported by metal frame stand and located at near the left side of the canal.

Force on vane of irrigation water-scooped wheel was determined by moment equilibrium principle in static condition (Fig. 1). The sum of moment from force on vane equal to moment required to halt the wheel to rotate. The amount of force is determined by using a spring scale to halt the wheel. The sum of moments from force on vane is the force multiplied by its arm. Force on vane is obtained by dividing the moments by vane arm (wheel radius).

Water velocity were measured by current meter at 70 cm before the wheel. They were measured at three positions: on the left, the middle and the right side of the vanes.

Position angle of vane is a zenith angle of vane counterclockwise from zenith. Vane at top position when position angle 0° and at bottom position when vane angle 180°. Vane at horizontal position when position angle 90°.

III. RESULT AND DISCUSSION

Water velocity in front of the wheel shows in Table 1. The average water velocity was 0.282 m/s at 0.68 m water depth. The water velocity become greater from the left position to the right position. The right position was near the middle of the channel and the left position near the wall of the channel. For prismatic channels, the maximum water velocity always occur at a midpoint below the free surface, usually at 20-30% of the channel depth (Gerhart et. al., 1993).

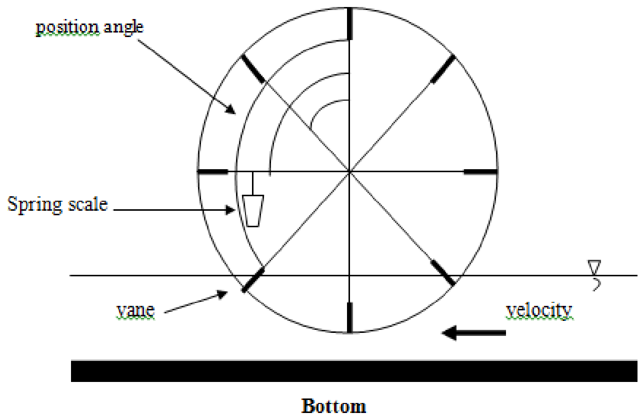

Fig 1. Spring scale use to determine moment of vane force

TABLE I
WATER VELOCITY BEFORE THE WHEEL

	left (m/s)	middle (m/s)	right (m/s)
1	0.239	0.266	0.352
2	0.233	0.268	0.354
3	0.236	0.262	0.332

Rotating force on single vane varies for different vane position angle in the water. This is shown in Fig. 2. Rotating force is a component of force resulted from flowing water perpendicular to radius and tend to push the vane, rotate the wheel. The maximum force on vane occurred at 180° vane position angle when water flow direction perpendicular to the vane. The force on vane was maximum because the area was maximum to block the fl5owing water (Fig.3). Therefore the large difference in momentum change resulted in greater force.

When tube position angle of vane greater or less than 180°, the lesser force on vane because the smaller effective area of vane block the flowing water.

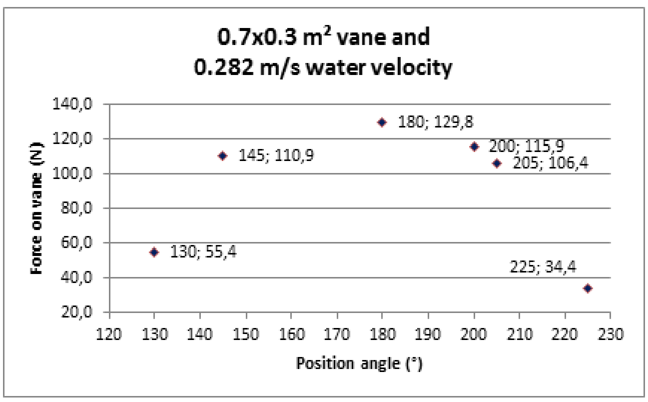

Fig 2. Force on single vane for different vane position angle

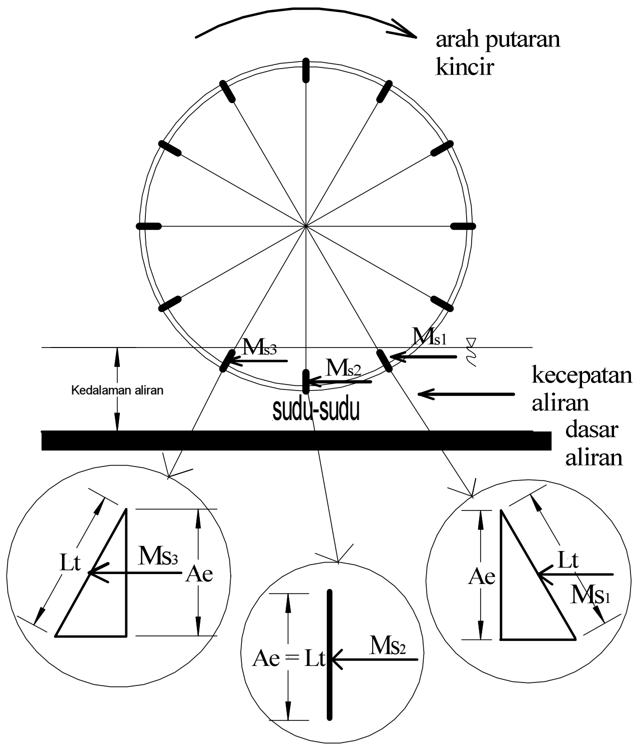

Fig 3. Area of vane toward water flow at different vane position angle

Rotating force for two submerged vanes is shown in Table 2. One vane at position behind 180^{o}, the other in front of 180^{o}. Resultant rotating force range from 141.42 to 188.11 N which were greater than rotating force on single vane. On two submerged vanes the larger area blocked water flow than on single vane cause the greater rotating force.

The greater vertical angle of the front vane gave greater rotating force. Position number 2 with front vane vertical angle 35°, rotating force was 188.11 N. Position number 1 with front vane vertical angle 25°**,** rotating force was 180.50 N. Position number 3 with front vertical angle 15°, rotating force was 141.42 N. The rear vane more effective to control rotating force.

In this study, it is more important to determine minimum rotating force since this is the available power to carry water in tubes and to rotate the water scooped-wheel.

TABLE III
ROTATING FORCE OF 2 SUBMERGED VANES FOR DIFFERENT POSITION ANGLE

No	Position angle vane 1 (^{o})	Postion angle vane 2 (^{o})	Rotating force (N)
1	160	205	180.50
2	170	215	188.11
3	150	195	141.42
4	145	190	155.09

IV. CONCLUSIONS

At 0.282 m/s average water velocity, magnitude of force on single vane (0.3 x 0.7 m^2) were 34 – 130 Newton. The force on vanes are affected by the area of vanes impacted by flowing water, the position of vanes toward flowing water and the water flow velocity. On two vanes submerged in water, resultant rotating force range 141-188 N, which were greater than on single vane.

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