Performance of Savonious Rotors for Utilizing the Orbital Motion of Ocean Waves in Shallow Waters

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Abstract: Ocean wave energy conversion technology is gaining a lot of attention due to its reliability and worldwide availability. This paper presents an experimental study on the performance of the Savonious rotor for utilizing energy from ocean waves moving in circular/elliptical orbits called orbital motion in shallow waters. Three, four and five vaned rotors were considered in this work and their performance under different submergence conditions was studied. The performance parameter selected for study was the rotor RPM. The experiment was carried out in the Wave Flume facility in the Department of Applied Mechanics at NITK Surathkal, India. From the experimental results it was found that the number of vanes on the rotor influences the output rotor RPM. Also, the rotor RPM was influenced by the depth from the still water level at which the rotor was immersed.

Keywords: Ocean wave, rotor motion, renewable energy, Savonious rotor.

1. Introduction

With the rapid depletion of fossil fuel reserves coupled by global warming, the current demand for new and renewable energy is ever increasing. Oceans have tremendous energy potential in the form of tides and waves that are clean and renewable. Tidal energy has been harnessed for a long time across the globe. However, due to its intermittent availability and the need for a large site area makes it is less attractive compared to ocean waves. Ocean waves are produced due to drag created by winds blowing over its surface. It is continuously available and has tremendous energy owing to its high density compared to air. The energy is available in the form of kinetic and potential energies of the displaced fluid masses that form waves. As many as 1000 patents are reported in the quest for an efficient ocean wave energy conversion (OWEC) device. The present study is based on the US patent: Application number DE102004060275A1 or PCT/EP2005/013507. This patent proposes the utilization of the orbital motion of the fluid particles in the ocean waves. The shape of the orbits depends on the nature of the coast and its orbital diameter is approximately same as the wave height [1].

Water particles move in circular orbits in deep water, however, in shallower water the motion becomes elliptical. This circular or elliptical motion is called orbital motion of the waves. Fig. 1 illustrates the concept of energy utilization.

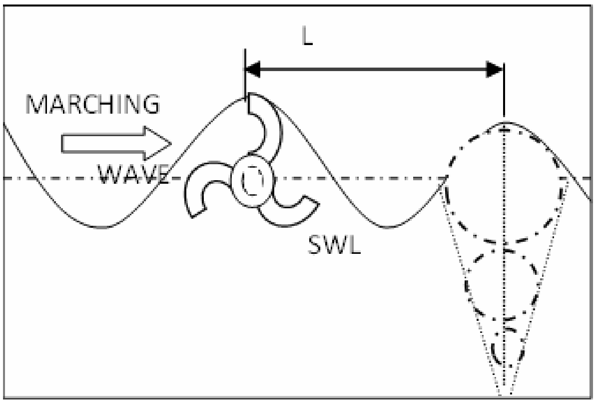


Figure 1. The Schematic Representation of a Savonious Rotor utilizing the orbital motion.

Generally, Savonious rotors have been used extensively for harnessing low wind speed [2]. In the present study, Savonious rotors are being used for harnessing energy from ocean waves. They are simple, semicircular in shape with a combination of vanes or blades that rotate on the differential drag created by moving fluid across the rotor. They are easy and inexpensive to construct. Very little literature [3-4] is available on an OWEC device which uses Savonious rotor for ocean waves. Studies [5] have shown that near shore sites also offer good exploitable wave energy potential. Work on the rotor performance in shallow waters is not available and is the motivation for the present study. Rotor performance study in shallow water can be very useful as transmission losses can be reduced due to its proximity to land.

2. Experimental

2.1 Experimental Setup

The experiment was conducted in a wave flume available in the Department of Applied of Mechanics, National Institute of Technology Karnataka with the specifications shown in Table 1.

Table1. Wave flume specifications.

Total length	50 m
Channel length	41.5 m
Width	0.71 m
Depth	1.1 m
Maximum water depth	0.7 m
Wave height	0.08 to 0.24m
Wave period	1 sec to 3 sec
Motor	Inverter driven (7.5HP, 11KW, 0-1450RPM, 0-50Hz)
Wave generator	Bottom hinge flap type

The photos of experimental setup are shown in the Fig. 2 (a & b). The wooden frame was firmly mounted on walls of wave flume. The rotor is fixed to wooden frame in such a way that it can be adjusted at the required depth. A rotor is marked with a red tape to facilitate counting the number rotations. The vanes were fabricated using PVC sheets with dimensions 480 mm width × 65 mm height. The rotor set up is shown in Fig. 3.

2.2 Testing Methodology

The rotors with 3, 4 and 5 vanes on them are fixed at various depths (z) from the still water level in the wave flume to study the performance variations. Fig. 4 (a, b & c) illustrates the rotor location for various depths. The time period of the wave was fixed at 2.1 sec and the water depth (d) at 0.6 m. The wavelength (L) was calculated as 6.88 m from which the d/L ratio was found to be equal to 1/8 which is the shallow water condition, i.e., *1/ 2< d/L < 1/20*. The wave height was varied from 100 mm to 170 mm and the number of rotations was recorded for three effective waves striking the rotor during the experiment.

a.

b

Figure 2. The Savonious rotor: a. fixture frame; b. rotor with redstrip fixed on bearings.

3. Results and Discussion

The RPM of the Savonious rotors has been found to depend on the wave height and the number of the vanes for different submergence conditions.

3.1 Effect of variation of wave height on the RPM of rotors

The rotor RPM for different wave heights is shown in Fig. 5 (a & b). For z = 0 mm, it was found that the 3 vaned rotor had a significantly higher RPM than 4 and 5 vaned rotors as shown in the fig 5a. For z = - 50mm, it was found that 5 vaned rotors had a significantly higher RPM than 4 and 3 vaned rotors as shown in fig 5b. However, for z = + 50 mm, it was found that the rotation of the shaft was to and fro due to discontinuous fluid and the RPM observed for all the rotors was much less, in an order of 5. Another important observation was that the RPM increased with increase in wave height for z = 0 mm but remained almost the same for z = - 50 mm. At a wave height of 150 mm, which is also the rotor diameter, the RPM for the 3 vaned rotor reduced by 25% when the rotor location was changed from z = 0 mm to z = - 50 mm. However, for similar conditions the RPM for the 5 vaned rotor increased by 100% when the rotor location was changed from z = 0 mm to z = - 50mm. Further, for the 4 vaned rotor, the RPM variation with depth is negligible.

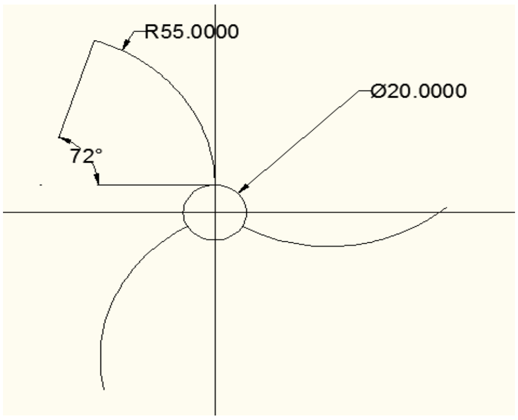
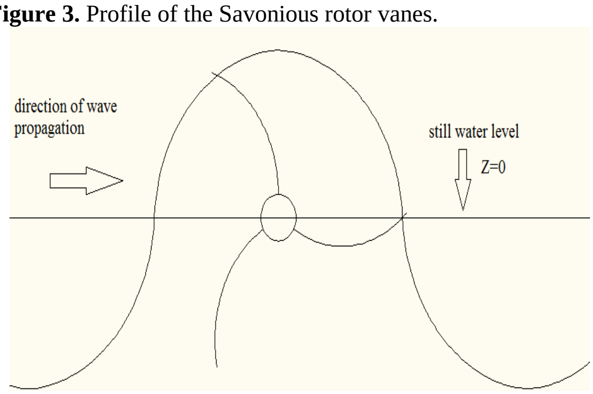
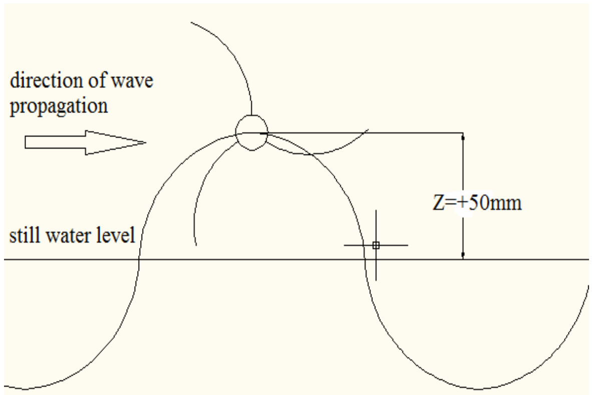


Figure 3. Profile of the Savonious rotor vanes.



a



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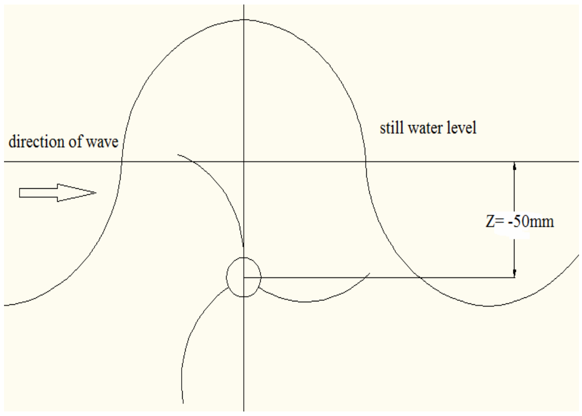

c

Figure 4. Experimental Set-up: a. z = 0 mm; b. z = +50 mm; c. z = -50 mm.

3.2 Effect of variation of number of vanes on the RPM of rotors

The effect of number of vanes on the rotor RPM at various wave heights is found to be dependent on the submergence condition (z). From Fig. 5 (a & b) it is clear that at z = 0 mm, the RPM of the 3 vaned rotor is much larger than that of the 4 and 5 vaned rotors. However, at z = - 50 mm, the trend reverses.

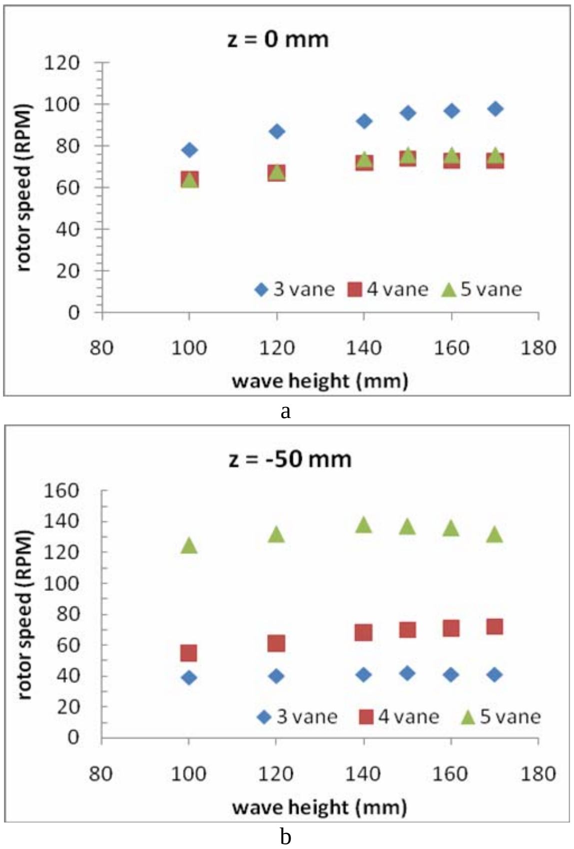

Figure 5. Wave height versus RPM; a comparison between 3, 4 & 5 vaned rotors: a. z = 0 mm; b. z = -50 mm.

4. Conclusion

The number of vanes on the rotor influences its RPM and further varies with the rotor location (z). The wave height variation influences the RPM of the rotor significantly when the rotor is at the center of orbit of the waves i.e., at z = 0 mm and is found to be almost constant for z = - 50 mm. The rotor RPM found by present method (experimental) gives an average value for given time but in reality, the rotor has different speeds (RPM) at different angles. The angular dependency can be better understood by more sophisticated methods like Particle Image Velocimetry (PIV) or Computational Fluid Dynamics (CFD) software simulation.

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Nomenclature

Symbol	Meaning	unit
d	Depth of water in the wave flume	m
H	Wave height	m
L	Wavelength	m
RPM	Rotations per minute	Per min.
SWL	Still water level	m
T	Wave time period	Sec
z	Distance from the still water level in the wave flume	m

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