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# An Experimental Assessment on the Effects of Forced, Free and Mixed Convection Regimes on the Water Evaporation Rate in Surface Gravity Waves

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**ABSTRACT:** experimental measurements have been done over a wide range of wave parameters, water temperatures and air velocities in different convection regimes. The measurements were performed on a large heated wave flume equipped with a wind tunnel. The effects of forced, free and mixed convection regimes on the water evaporation rate in surface gravity waves have been investigated. The results show that wave motion on the water surface increases the rate of evaporation for all airflow regimes. In addition, results reveal the evaporation rate increases with air velocity but increasing of the wavy surface parameter, has different effects on the evaporation rate. For the free convection regime, the evaporation rate increases by increasing the wavy parameter. For forced and mixed convection regime at medium values of wave parameters, the leeward airflow structures, which form a barrier for the vertical transport of vapor, decrease evaporation rate. Results reveal that the effect of induced turbulence at the wavy interfacial surfaces on the water evaporation increment is more than the effect of interfacial area increment percentage. Results reveal that the effect of induced turbulence at the wavy interfacial surfaces on the water evaporation increment is more than the effect of interfacial area increment percentage

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## 1. INTRODUCTION

Remarkable studies have been conducted to investigate the evaporation process from simple water surfaces for different flow regimes [1-5], despite numerous applications of water evaporation in many aspects of nature and industrial engineering, there exists no exact expression for the rate of water evaporation from wavy surfaces [2-3]. In some references, evaporation from wavy surfaces are seen similar to evaporation from a solid rough surface or wet surfaces and thickness of sublayer diffusion for these two are considered similar. Although the geometry of water surface severely affects evaporation rate, no studies have been made on the effect of different parameters of gravitational waves in different free, mixed, and forced convection regimes over evaporation rate. This study aims to study the effect of wind velocity, amplitude, and frequency of gravitational waves on evaporation rates for different regimes of convective flows.

## 2. EXPERIMENTAL SETUP AND MEASUREMENTS

The experiments were performed in a wave flume equipped with a wind tunnel. The main flume to allow prescribed deep-water gravity wave generation is 10.0 m long, 0.5 m wide and 0.6 m height with two passive wave absorption zones at both ends. The wind tunnel to allow airflow on the water waves is 2 m long 0.5 m wide and 0.8 m high. The air velocity within the chamber was measured using a thermal anemometer, at nine locations across the wind tunnel above the water surface. The inlet air relative humidity was controlled using a conventional air conditioning system. Air relative humidity was measured by two sensors placed near the inlet and outlet of the wind tunnel, above the water surface. In addition, the air temperature measured by thermocouples located over the wind tunnel. Immersion heaters were installed near the bottom of the flume to elevate the bulk temperature of the flume to the desired conditions. The evaporation rate was evaluated based on two methods. First, by means of the flow rate measurement and the difference between the inlet and outlet absolute humidity. Second, by means of a small pan connected to the main flume via a siphon tube. All the measuring instruments were calibrated before the experiments were performed and the data generated by these instruments were captured using a PC data acquisition system.

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## 3. RESULTS AND DISCUSSION

Results in this study show that with an increase in air velocity, evaporation rate increases; while with an increase of wavy surface parameter, evaporation rate shows a different behavior with changes in convection regime.

### *1-3.Water evaporation rate of wavy surface in the free convective regime*

Fig. 1 shows the effect of the wavy surface parameter on the evaporation rate in the free convective regime.

In Fig. 2, the increasing percentage of evaporation rate and air surface, against changes of the wavy surface parameter for the natural convective regime is shown.

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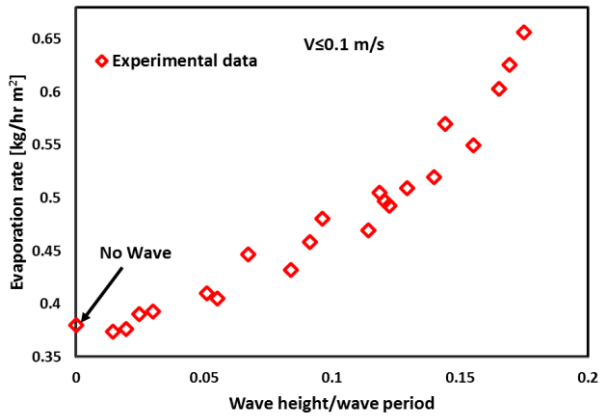


**Fig. 1: The effect of height to wave interval on evaporation rate in free convective regime**

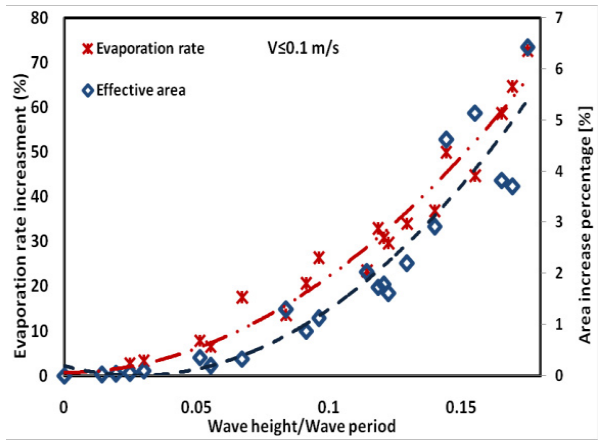


**Fig. 2: The percentage of area increase and evaporation rate against wavy surface parameters**

*2-3.Water evaporation rate of wavy surface in the mixed convective regime*

Fig. 3 shows the effect of the wavy surface parameter over the evaporation rate in the mixed convective regime.

Fig. 4 shows the increasing percentage of evaporation

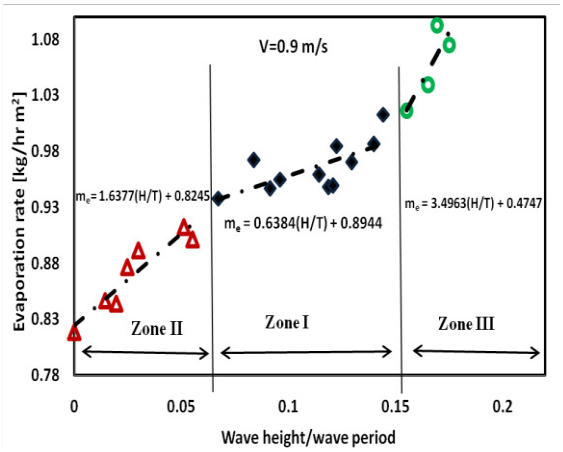


**Fig. 3: The effect of height to wave interval on evaporation rate in mixed convective regime**

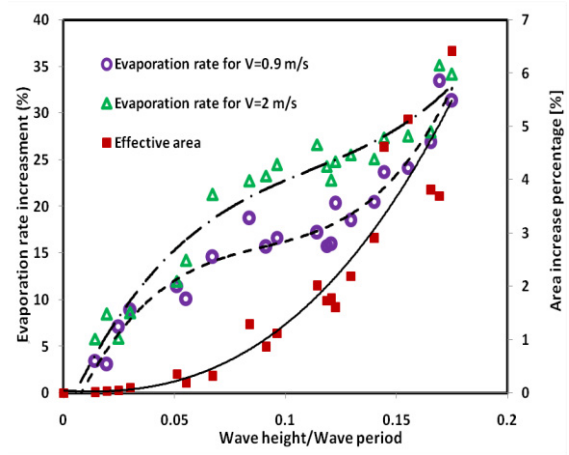


**Fig. 4: Comparison of the effect of wavy surface parameter on the increasing percentage of evaporation rate and the increasing percentage of area for mixed convective regimes**

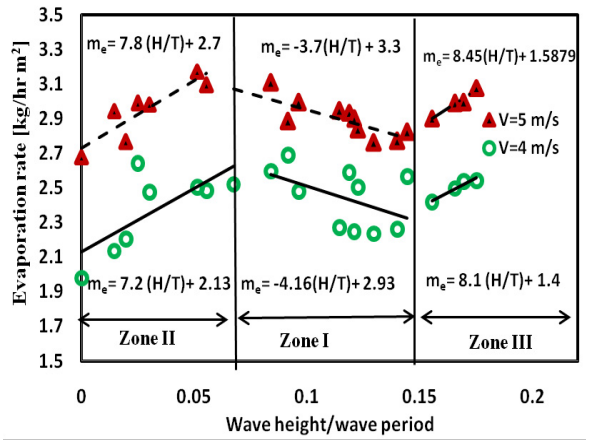


**Fig. 5: The effect of height to wave interval on evaporation rate in forced convective regime**

rate and air surface, against changes in the wavy surface parameter for the mixed convective regime. In the highest value of the wavy surface parameter, the maximum increase of evaporation rate is 35 percent. While interfacial surfaces on the water and the air about 7 percent increases compared to the still water.

*3-3.Water evaporation rate of wavy surface in the forced convective regime*

In Fig. 3, the proportion of wave height to its interval, on evaporation rate in the forced convective regime for air velocity of 4 and 5 meters per second is shown.

## 4. CONCLUSIONS

In this investigation, experimental measurements have been done to quantify evaporation rate from wavy water surfaces in free, mixed and forced convection regimes. Based on the presented results, the following conclusions may be drawn:

– The effect of wave motion for pumping vortices of air flow at the wavy interfacial surfaces on the water evaporation increment is more than the effect of interfacial area

increment percentage.

- In all flow regimes, the water evaporation rate increases by increasing the wavy surface parameter.
- For mixed convection regime due to higher air velocities, the evaporation rate increases when compared with that of free convection regime.
- For all flow regimes, at higher air velocities, spilling of the wave crest can occur at lower values of the wavy surface parameter.

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