WATER WAVES

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ABSTRACT

In this paper, oscillation of the horizontal cylinder on the surface of the water, vortexes and water waves that create on the surface were investigated. Till now in different articles, different shapes of the floater and Viscosity of the liquid has been studied. But In this article the parameters that depends on the cylinder`s shape, vortexes and some parameters like (frequency, amplitude and etc.) has been surveyed. In our experiments we saw that under certain conditions, the water waves drift away from or toward the floater (cylinder) and it was investigated.

Keywords : *Cylinder, Amplitude, Frequency, Drift away, Circular path*

1. Introduction

As we told, when we generate water waves with a horizontal cylinder, different shapes of water waves and vortexes creates on the Surface of the water. You can see that the waves drift away or toward from the cylinder. In other articles they changed the geometrical parameters of the shape of the floater and viscosity of liquid and got some results.

Now we did some investigations and experiments to see what will happen and changed the parameters affecting on this phenomenon.

In fact Water waves are the waves having two types. "Gravity waves and Capillary waves".

Gravity waves are waves generated in a fluid medium or at the interface between two media when the force of gravity or buoyancy tries to restore equilibrium. An example of such an interface is that between the atmosphere and the ocean, which gives rise to wind waves. When a fluid element is displaced on an interface or internally to a region with a different density, gravity will try to restore it toward equilibrium, resulting in an oscillation about the equilibrium state or wave orbit.

A capillary wave is a wave traveling along the phase boundary of a fluid, whose dynamics are dominated by the effects of surface tension. Capillary waves are common in nature, and are often referred to as ripples. The wavelength of capillary waves in water is typically less than a few centimeters, with a speed of 10-20 centimeters/second.

Also other types of waves are "Faraday waves and Plane waves".

Faraday waves, also known as Faraday ripples, are nonlinear standing waves that appear on liquids enclosed by a vibrating receptacle.

Plane waves are constant-frequency waves whose wave fronts (surfaces of constant phase) are infinite parallel planes of constant peak-to-peak amplitude normal to the phase velocity vector. They are linear waves but when we change amplitude they change to non-linear 3D waves.

2. Methodology

Our solving method was doing some experiments and changing parameters that depend on this problem, like length of the cylinder, frequency, amplitude, viscosity of liquid, material of the cylinder, density of liquid, height of the water, diameter of the container and surface tension. Some parameters like viscosity of the liquid, material of the cylinder, density of liquid were constant.

The experiments setup was made of a big container (in diameter of 2meter) a cylinder and speaker used as a vibrator (Figs.1 & 2) and particles to see the direction of the waves.

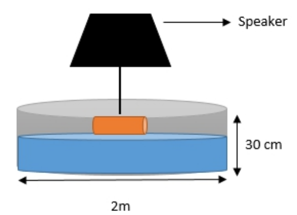


Fig.1: Experiments setup (Schematic)

Fig.2: Experiments set up

The effect of the diameter of the container is, if it doesn't be big enough the waves strike to the container's walls and it effects on waves not to be standing waves.

And the effect of containers height is that it is effective on waves. We distinguish between deep-water waves and shallow-water waves. The distinction between deep and shallow water waves has nothing to do with absolute water depth. It is determined by the ratio of the water's depth to the wavelength of the wave.

When the diameter of the cylinder changes, it's contact area with water changes and it is effective on the wave`s shapes.

Also the size and weight of the particles (Styrofoam) are important according to the amplitude and wave – length which they moved by (Fig. 3). Actually we need different amplitudes and frequency to move particles.

Fig.3: particles to show water waves

3. Results

3.1. The Theory of Direction of the Wave and Water Waves

As we said motion of the water is different than the motion of the wave. Water at each location moves in a circular path, but the motions at different locations are "out of phase", which means that when water at the left of the diagram is moving to the right, water a quarter of a wavelength to the right is moving down, and water next to it is moving to the left, and next to it is moving up, etc. (Figs. 4 & 5) .

Fig.4: Motion of the wave

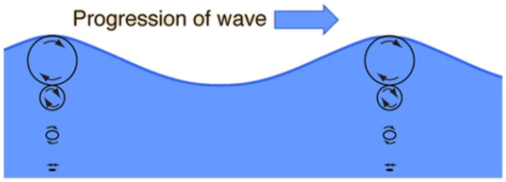


Fig.5: Difference between water's motion and wave`s motion

The overall effect is an "apparent" wave moving to the right. Thus, the velocity (speed) of a wave is not at all the same as the velocity of the water.

The experimental wave shape is described as a "trochoid". A trochoid can be defined as the curve traced out by a point on a circle as the circle is rolled along a line (Fig.6).

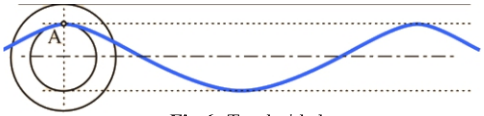


Fig.6: Trochoid shape

The discovery of the trochoidal shape came from the observation that particles in the water would execute a circular motion as a wave passed without significant net advance in their position.

The water molecules of a deep-water wave move in a circular orbit. The diameter of the orbit decreases with the distance from the surface (Fig. 7). The motion is felt down to a distance of approximately one wavelength, where the wave's energy becomes negligible.

The orbits of the molecules of shallow-water waves are more elliptical (Fig. 8).

The change from deep to shallow water waves occurs when the depth of the water, d, becomes less than one half of the wavelength of the wave, λ. When d is much greater than λ/2 we have a deep-water wave or a short wave. When *d* is much less than λ/2 we have a shallow-water wave or a long wave.

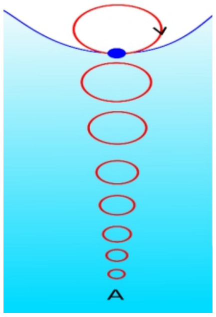


Fig.7: Water waves motion (deep water)

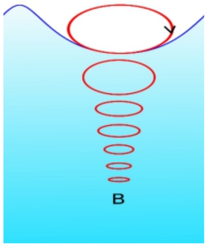


Fig.8: Water waves motion (shallow water)

Their wave speeds increase with wavelength, a behavior that is called "normal dispersion". For waves shorter than 1.73 cm, the surface tension of the water exerts a controlling force they are "capillary waves". Their speed increases as the wavelength gets shorter, a behavior that is called "anomalous dispersion". The minimum wave speed at wavelength 1.73 cm is 23.1 cm/s.

3.2. Results of the Experiments

We did experiments and changed some parameters. Parameters like amplitude, frequency, length of the cylinder. Also we changed the particles` size. And the number of these to know their movement better. Actually know the direction of the vortices.

In our experiments we understood that: Trajectories of fluid particles on the surface were described analytically only for progressing small amplitude planar waves, where particles move in the direction of wave propagation, along the prolate trochoid (Figs.9 &10) .

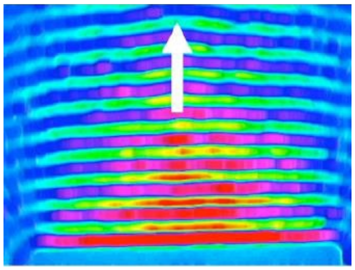
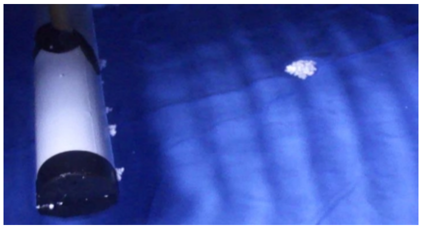


Fig.9: Plane waves (direction of wave propagation)



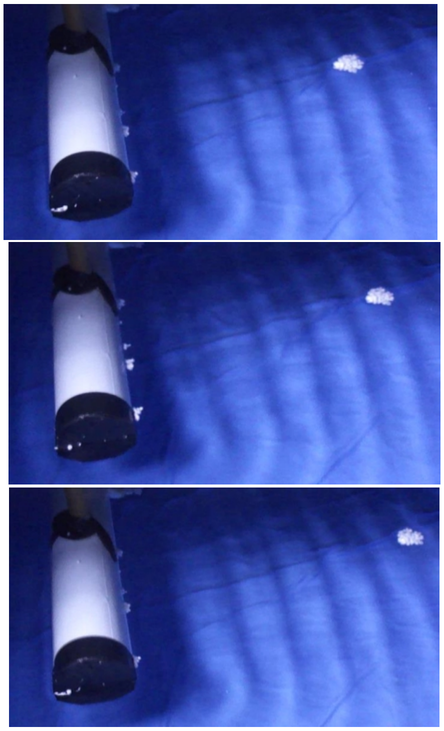


Fig.10: Moving particles in the direction of wave propagation

When we use an elongated cylinder, propagating waves have oval wave which fronts with long nearly planar parts for a cylinder, the wave fronts are modulated even at relativity low amplitude.

The maximum of the wave amplitude is at the center of the cylinder side here, floating particles are pushed in the direction of the wave propagation forming strong outward jet (Fig.11).

Water Waves (35-38)

Fig.11: maximum of the wave amplitude

The flow changes dramatically when the wave amplitude is increased above the modulation. Instability threshold at only 20-30% higher acceleration of the wave maker (cylinder).As the modulation grows and the cross wave instability breaks the wave front into the trains of propagating wave pulses, the wave field becomes 3D (Fig.12).

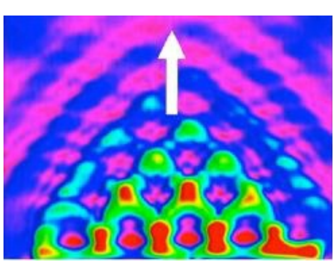


Fig.12: As the wave maker acceleration is increased (30%) the modulation instability destroys the wave planarity generating 3Dwave field shown here

Simultaneously, the direction of the central jet reverses. It now pushes floaters inward, towards the wave maker and against the wave propagation! The flow is strong enough to move small objects on the water surface, for example a ping pong ball or Styrofoam (Fig.13).

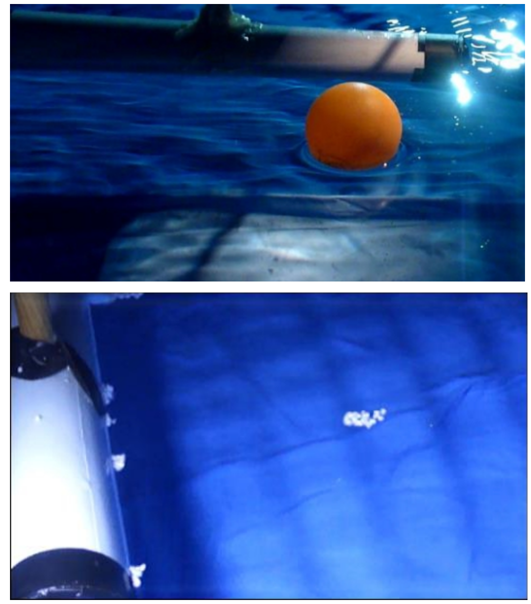


Fig.13: The flow is strong enough to move small objects on the water surface

We find that these waves are produced by the nonlinear 3D waves in the range from long gravity waves (8Hz) to short capillary waves (50Hz).

A quadruple pattern made of 4 large counter-rotating vortices . A quadruple pattern is formed around the cylinder made of 4counter-rotating vortices. Two jets develop in the direction away from the wave maker (Fig.14).

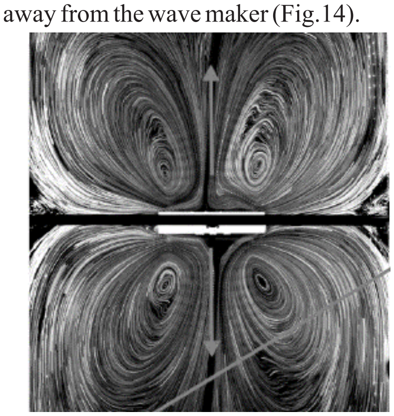


Fig.14: A quadruple pattern is formed around the cylinder made of 4counter-rotating vortices. Two jets develop in the direction away from the wave maker

The direction of the vortex rotation however reverses with the increase of modulation .This reversal at higher wave amplitudes is always correlated with the generation of stochastic Lagrangian trajectories within a flow region in front of the wave maker (Fig.14) .This complex chaotic flow efficiently transports fluid in the direction perpendicular to the propagation of the wave pulses.

Also after specific amplitude, particles absorb to the cylinder. Actually at higher amplitudes particles absorb to the cylinder and at lower amplitudes they drift away the cylinder. In fact we can say that the frequency moves the waves in their direction but amplitude changes their direction.

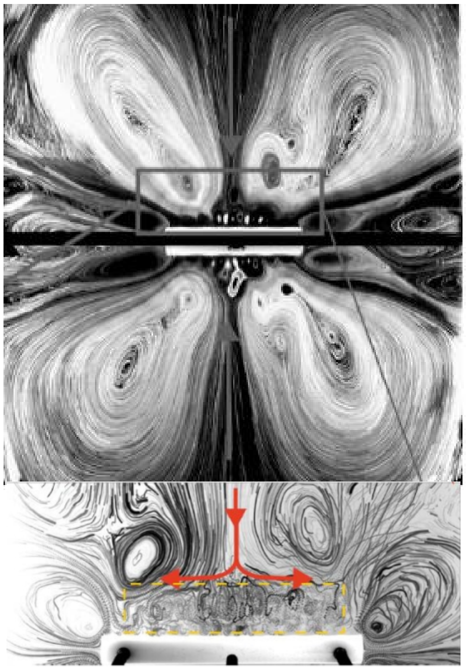


Fig.14 : Particle streaks in the vicinity of the cylindrical wave maker visualize a region of Lagrangian stochastic transport (yellow dashed box).Turbulence pumps particles away in the direction of red arrows, orthogonal to the wave propagation

Frequency is independent of the movement of the particles (direction of the wave`s movement. After specific frequency we cannot have the same amplitude like before, because of the Inertia force of the speaker. And we can`t see the changes in the direction of the waves after this.
It means that when we increase the frequency, amplitude decreases.

4. Conclusion

The investigation was about the surface waves creating on the water that they create by a cylinder. Our method were doing experiments. And we changed some parameter like amplitude, frequency, length of the cylinder etc.
A particle moving in a circular way, but it doesn't have a vector the same as other particles (actually the molecules doesn't traverse same ways).so it causes the move in different ways.

If the amplitude and frequency be constant the water molecules Travers their circular way completely, but when we increase them their speed goes up and they don't have time to travers all the way and as a result we see that they go up and down and throw out and get different shapes.
We understood that frequency isn't effective on the drifting away of the waves and it's the effect of amplitude . Also the direction of molecules movement depends on the depth of the water.

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