CHAPTER 135

SURFACE OSCILLATIONS IN A WATER TANK CAUSED BY A SUBMERGED JET

By

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ABSTRACT

In this paper are studied the surface oscillations that form in a water tank when a jet emerges from the bottom

The experimental system consisted of a circular water tank with the water intake at the bottom close to its circunference Surface oscillations were recorded for different situations

The experimental results are presented in both dimensional and dimensionless plottings where the oscillations amplitud is related with water depth and jet diameter and velocity

The dimensionless graphs show that the oscillation amplification is, within the variables ranges studied, mostly independent of tank diameter

INTRODUCTION

When water flows into a shallow tank, in the form of a jet emerging from the bottom, small surface oscillations appear as a result of jet diffusion and supply pipe turbulence These oscillations are reflected in the tank walls increasing the water surface movement which interferes with the jet flow, starting a horizontal oscillation of the latter A complex surface oscillation results, which under determined conditions is continuously amplified until wave breaking puts a limit on wave height

The oscillation pattern, no mather the degree of amplification,

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is a complex and unsteady one, with standing wave type movement being dominant, with nodes and antinodes continuously changing their location

VARIABLES INVOLVED AND THEIR RELATIVE IMPORTANCE

According to the physical description of the phenomenon, the amplification is a function of the magnitudes that describe the boundary geometry and surface movement, i e tank and supply pipe geometry and Froude Number In the amplification processes inertia and gravity forces are obviously much more important than viscous forces The wave breaking is determined by oscillation characteristics Thus the amplification and its upper limit will not be a function of Reynolds Number

The amplification must result from a resonant combination of jet movement, surface movement and tank geometry However, and due to the surface oscillation variability, the tank geometry plays a secondary role as shown in Fig 1

To back this experimental conclusion we may consider several reasons First, the boundary conditions imposed by the circular vertical walls of the tank, determinant of the oscillation pattern in the steady case, are now almost irrelevant since a great number of intantaneous patterns will exist, some of them being close to the maximum amplification situation for the existing set of depth and jet variables This is specially true when tank diameter is several times the mean wave length As a matter of fact, it was observed in the experiments that the jet always followed a random secuence of quiet and oscillation periods Second specially at resonance situations, when breaking takes place, waves are non-linear and, therefore, continuously changing wave heights will cause that a range of frecuencies be allowed with the circular boundary for every oscillation mode As it can be seen in the sample record shown in Fig 5, energy is mainly related to a wave frecuency, but nevertheless, the oscillation is not monochromatic

Dimensionless parameters

The variables thus involued are wave height H, jet diameter d, water depth h, jet velocity V and gravity force per unit mass g With these five secondary magnitudes, the theorem shows that, since only length and time are involved, there will exist a function ϕ such that

$$\phi \; (\Pi_1 , \Pi_2 , \Pi_3) = 0$$

where Π_1 , Π_2 , and Π_3 are independent dimensionless combinations of the above listed variables For ghaphical representation a convenient set of expresions is

$$\Pi_1 = \frac{H}{d} \quad , \quad \Pi_2 = \frac{V}{\sqrt{gd}} \quad , \quad \Pi_3 = \frac{V}{\sqrt{gh}}$$

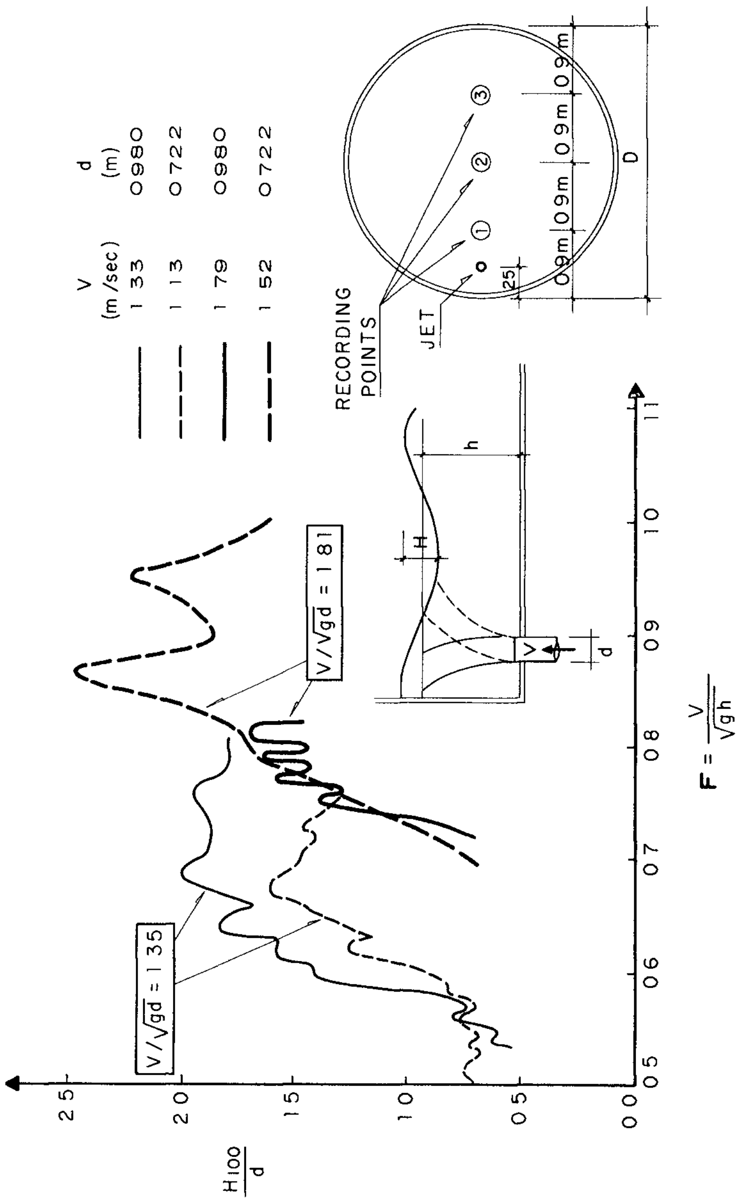

FIG 1 DIMENSIONLESS GRAPH OF SURFACE OSCILLATION

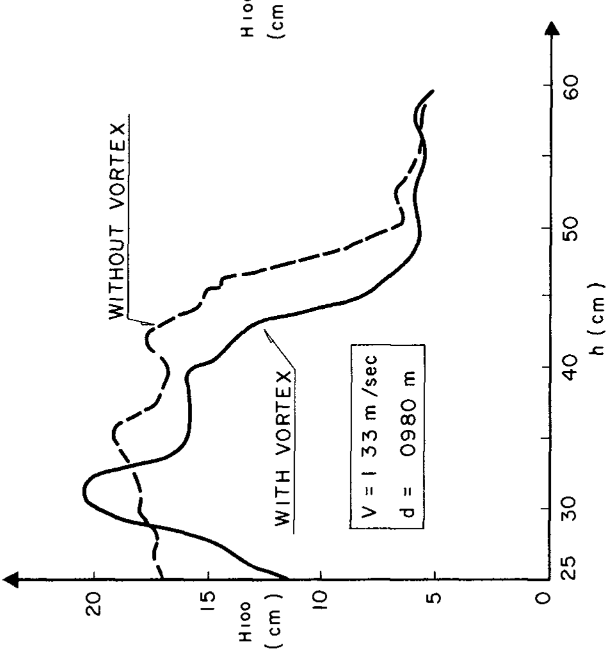

FIG 2 EFFECT OF A VORTEX AT THE SUPPLY PIPE ENTRANCE

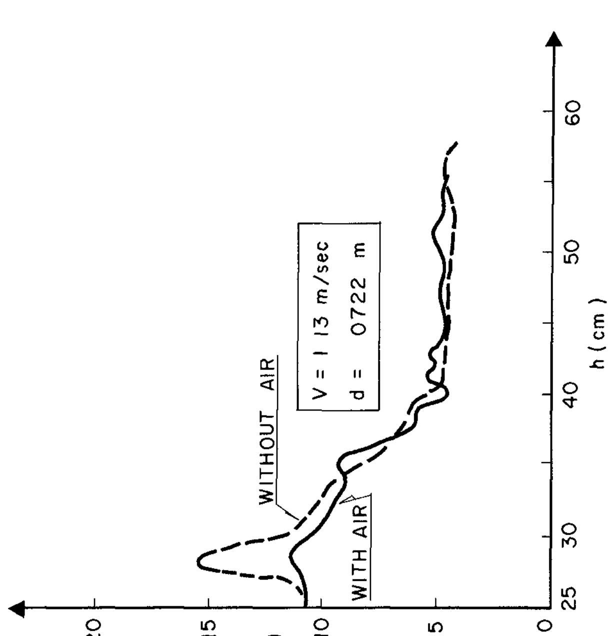

FIG 3 EFFECT OF AIR INTRUSION IN THE SUPPLY PIPE

EXPERIMENTAL CONDITIONS

For a description of the experimental set-up see figures 1, 5, and 6

Tests were run starting with the tank full of water, and allowing the outflow to be a little larger than the inflow such that water depth would slow and continuously decrease, until the possible minimum was attained, the water discharge was held constant through the experiment by means of a weir controled elevated supply tank Two supply pipe diameters were used with two different velocities por each one Velocity was measured indirectly in terms of discharge by weir and elbow meters, previously calibrated in the experimental system with a weir meter

The water surface elevation was recorded continuosly at the three points shown in Fig 1

As an indication of surface oscillation H_{100} has been defined as the average of the one percent largest wave of the two recordings taken at electrodes N° 2 and N° 3

Influence of supply pipe disturbances

To investigate the influence of water flow disturbances in the supply pipe, one test was run allowing the formation of a vortex in the supply tank In another test air was allowed to enter in the supply pipe Figures N° 2 and 3 show the results with these conditions

Oscillation damping

In one of the tests, after maximum amplification was reached, water outflow and inflow were stoped and the water surface was continuously recorded until oscillation nearly desapeared At the beggining, a rather fast damping took place as a result of wave breaking, thereafter having a very weak damping Calling H_{100} t = 0 the one percent highest wave at an arbitrary time when wave breaking is over, the damping factor, in terms of the highest one perent height, has been plotted in fig 3 This graph shows that laminar type danping takes place As a matter of fact Reynolds numbers computed for both bothom and tank walls, in the manner shown in fig 3, fall below the critical Reynolds numbers given by several authors (Li, Ref 2, Jonsson, Ref 1) for transition from laminar to turbulent regime on a smooth boundary Conparison of the Reynolds numbers for the bottom and the tank wall, and the respective areas of these boundaries, leads to the conclusion that wall friction is much more important than bottom friction in this specific case, and therefore that the tank diameter plays an important role in the free oscillation damping

CONCLUSIONS

1 The oscillation in the water surface that takes place in a water tank when a jet emerges from the bottom is a very complex one, with many frecuencias superimposed and nonlineari-

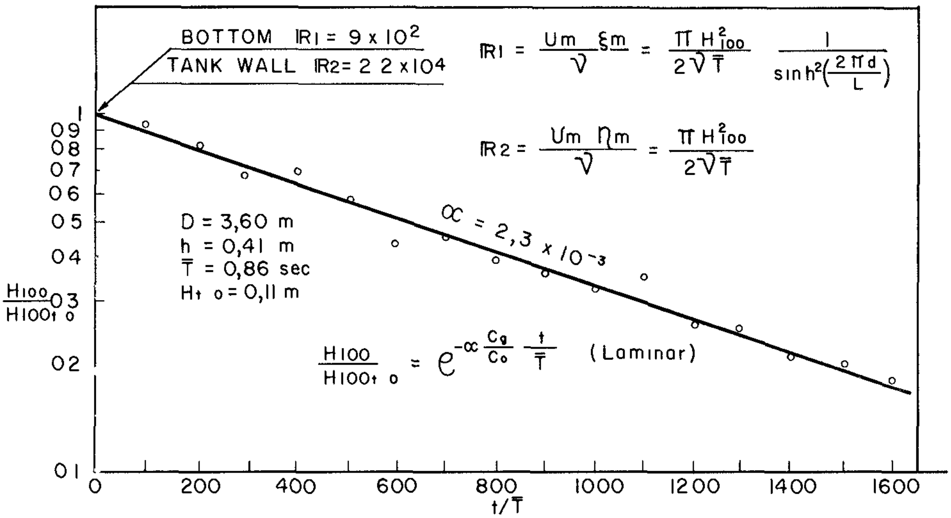

FIG 3 FREE OSCILLATION DAMPING

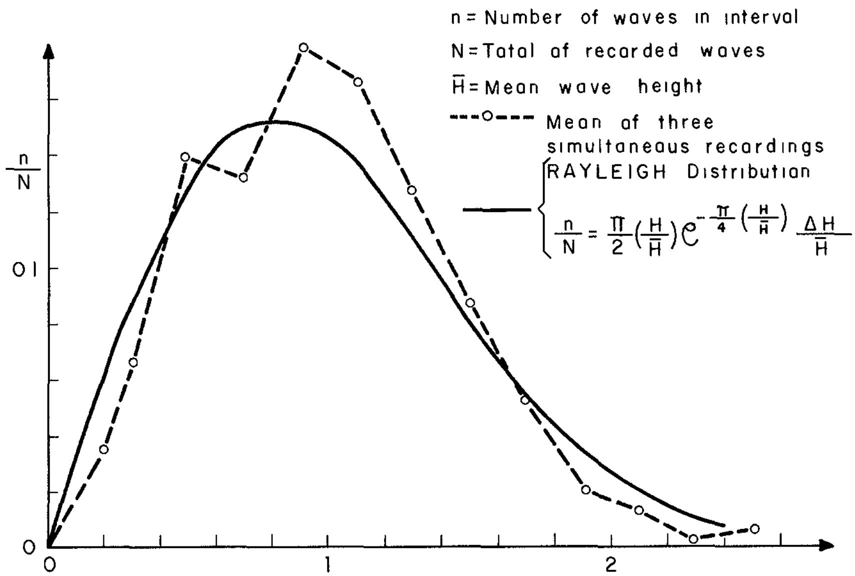

FIG 4 WAVE HEIGHTS HISTOGRAPH

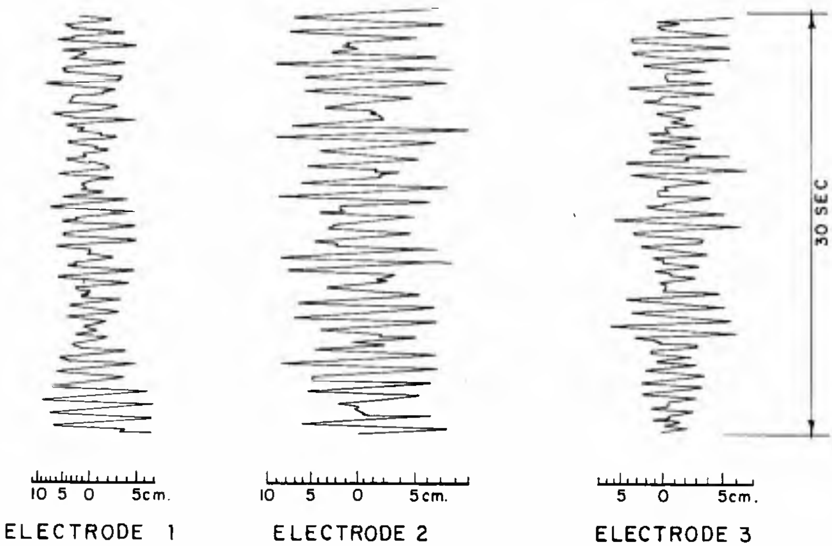

FIG. 5 SAMPLE SURFACE RECORDS

FIG. 6 VIEW OF LABORATORY SET-UP

ties characteristic of impulsive wave generation and breaking Wave breaking puts a limit to wave height in resonant situations

2 The maximum amplification that reaches the oscillation is mainly due to a resonance among the emerging jet and the free surface movement

3 The experimental results summarized in Fig 1 show that the resonance depends mostly on jet characteristics and water depth, rather than on tank diameter

4 Flow disturbances in the supply pipe, such as longitudinal vorticity and air intrusion, are of second order importance in the amplification phenomena

5 Once the jet flow has been stoped, the wave breaking disappear shortly and after that, the oscillation damping is very slow

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