Influence of Free Surface on Turbulent Characteristic

Benjamin S. Chayayi[1], Toshimitsu Komatsu[2]
and Toshihiko Shibata[3]

Introduction

This work present findings from recent experimental investigations which were carried out with the objective of studying the influence of free surface on turbulence characteristics. The similarity on the damping effect of the water free surface and that of a solid plate were examined as well.

Measurements of turbulence were made in a small tank fitted with a vertically oscillating grid while the collected data were analyzed statistically. The results show that the vertical velocity component was much affected by the squashing effect of the free surface where as the horizontal velocity component was enhanced. The measured different turbulent quantities indicated existence of a highly inhomogeneous layer very near the surfaces.

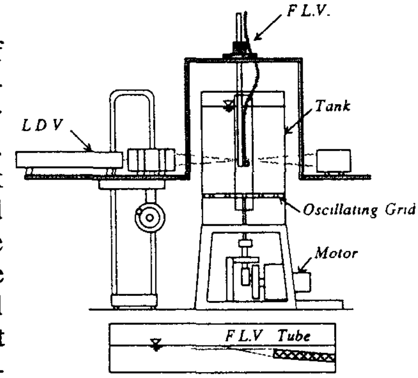

Fig.1 Experimental apparatus and FLV tube.

Experiment procedure

The experiment setup was as shown in fig.1 while turbulent measurements were made by both Fiber laser velocimeter (FLV) and Laser doppler velocimeter (LDV) for the vertical and horizontal velocity components respectively. Two cases were investigated in this study, the first one utilized two fixed water levels to investigate the influence of total volume on turbulent energy transfer mechanism. The second case investigated the influences of water free surface and solid surface on turbulence generated by an oscillating grid. In this case six different conditions were investigated in which turbulence velocities were measured from three fixed points i.e. at 10 cm, 12.5 cm and 15 cm above the mean grid location. In all cases the first reading was taken at about 3 mm below the free water and solid surfaces. The water level above the fixed measuring points was gradually increased to 30cm above the grid mean location. In all cases the FLV tube was slightly inclined upwards so that it could take measurement very near the free surface.

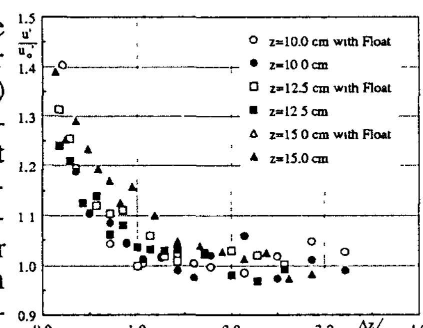

Fig.2 Normalized intensities of u in surface layer.

Experimental Results

The behavior of the horizontal and vertical velocity components and other evaluated statistical values indicated the existence of a surface influenced layer, while the damping effects of water free surface and solid surface were found to be almost the same in all investigated cases. In both

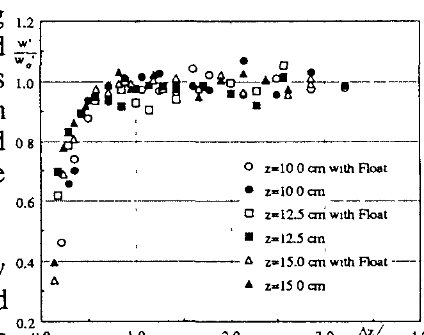

Fig.3 Normalized intensities of w in suface layer.

1. Graduate Student, Dept. of Civil Engineering(Suiko), Kyushu University .
2. Associate Professor, Dept. of Civil Engineering(Suiko), Kyushu University.
3. Technician, Dept. of Civil Engineering(Suiko), Kyushu University.

cases velocity components of turbulence and other evaluated statistical values indicated the existence of a surface influenced layer, while the damping effects of water free surface and solid surface were found to be the same in all investigated cases. In both cases the surface influenced layer was identified and was found to have a thickness of about 1.5 l, where l is the integral length scale.

The evaluated velocity intensities from these experiments indicated that close to the surfaces the velocity intensities of the horizontal components were enlarged while the vertical components were reduced drastically. Figs.2 and 3 shows the relationship of the normalized velocity intensities drawn against the dimensionless depths below the free surfaces in whch u_0' and w_0' are the horizontal and vertical velocity intensities and l was the integral length scale evaluated in the homogeneous layer respectively while Δz was the distance below the free surface. The symbols u' and w' represents the intensities of the horizontal and vertical velocities.

The normalized time scales are given in figs. 4 and 5 in which T_0 are the integral time scales for the horizontal and vertical velocity components measured in the homogeneous layer. These figures indicates that the time scale of u' was not affected by the surface squashing effect while that of w' was very much affected in the surface influenced layer. The free surface effect on the turbulent components was further reveailed by the power spectra in the low frequency zone in which the u components were amplified while those of w were suppressed. The appearence of -5/3 power law as shown in figs.6 and 7 was observed on both u and w components measured in the homgeneous layer.

Conclusions

Influence of total volume under the experimental conditions was found to be negligible. The squashing effect of free surface resulted into magnifying the horizontal velocity component while that of w was reduced. The influence of the water free surface was found to be the same to that of the solid plate and near the free surface existence of a highly inhomogeneous layer was noted while far from the surface zone the evaluated statistical quantities assumed constant values. The results obtained from this study could be used in numerical simulations treating free surfase effect problems.

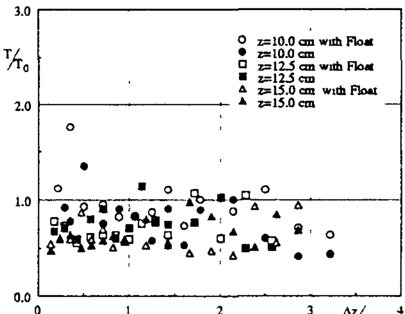

Fig.4 normalized time scale of u in surface zone.

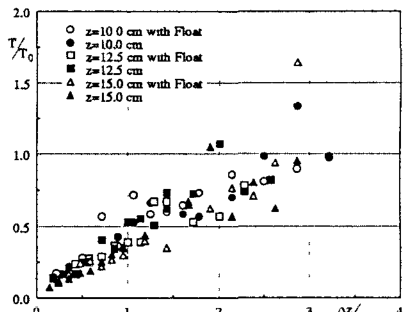

Fig.5 Normalized time scales of w in surface zone.

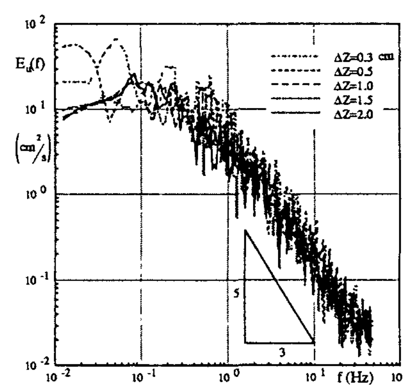

Fig.6 Spectra of u in surface zone.

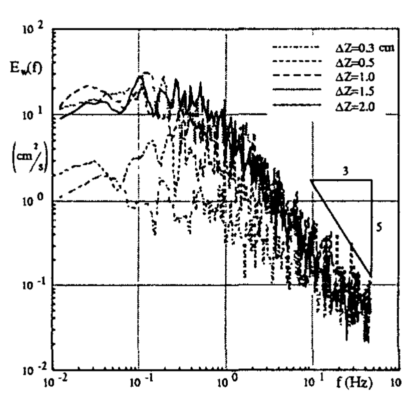

Fig 7 Spectra of w in surface zone

References

1. Brumley B. H.and Jirka G. H.: Near surface turbulence in a grid stired tank, J. Fluid Mechanics,Vol.183,1987.

2. Ura M. , Komatsu T. and Matsunaga N.: Entrainment due to oscilating-grid turbulence in two-layerd fluid, Turbulence measurement and flow modeling ,1985.