TURBULENT SOLITARY WAVE BOUNDARY LAYER

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1. INTRODUCTION

Most of flow which occurs in practical condition is turbulent, and it is also general known that some important processes occur in wave boundary layer. Because of this crucial reasons, investigation in turbulent boundary layer characteristics will be very necessary to hold up in its application for practical purposes such as sediment transport.

In the present study, turbulent boundary layer characteristics under solitary wave will be studied comprehensively based on experimental data. This study is the next investigation of solitary wave boundary layer characteristics after successfully completion of a new generation system validation in some various criteria as given in former publication (Winarta and Tanaka, 2011).

2. LABORATORY EXPERIMENT

According to Hino et al. (1976), turbulent flow regime can be classified in three types: weakly turbulent flow, conditionally turbulent flow and fully turbulent flow. They defined conditionally turbulent flow when turbulence is generated suddenly in the decelerating phases while the flow recovers to laminar in the accelerating phases. This phenomenon can be observed clearly in a case of present laboratory experiments when Reynolds number (R_e) achieved 7.34 x 10^5 as shown in **Fig. 3**. The comparison of measured free stream velocity and the exact solution is displayed in **Fig. 1**.

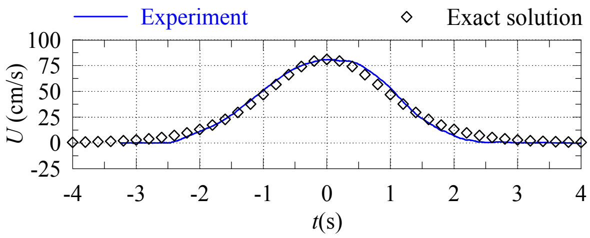

Fig. 1 The measured free stream velocity

Because of a slight deviation of free stream velocity measurement with exact solution as shown in **Fig. 1**, numerical laminar will be applied, instead of Keulegan's (1948) analytical laminar solution.

3. RESULT AND DISCUSSION

The transformation of velocity profile at Reynolds number (R_e) = 7.34 x 10^5 can be seen in **Fig. 2**. This figure describes how flow velocity profiles change in the variation of time and it is started at t = 0.00s (a point of peak velocity in a solitary wave) and then, goes to decelerating phase at t = 0.50s, 1.00s, 1.25s and 1.50s.

The interesting behavior can be found at t = 1.25s in between of z = 0.085 cm and z = 0.101 cm, in which z is cross stream distance from the bed level. A discontinue in velocity profile can be seen at these sequent elevations. The reason why this fact occurred is in connection with turbulence spike as shown in **Fig. 3**. A flow velocity fluctuation at z = 0.085 cm has higher magnitude range than those at z = 0.101 cm. This condition produces the ensemble averaging of stream wise velocity (u) over 50 wave numbers at z = 0.085 cm is bigger than at z = 0.101 cm. Furthermore, the identical flow velocity characteristic is also observed in the previous experimental studies (Sumer et al., 2010).

The flow motion is occasionally turbulent and sometimes non-turbulent in the variation of time at the same elevation point (z) as shown in the **Fig. 3**. The quantitative descriptions of intermittency is the intermittency factor $\gamma\,(z,t)$. This is defined to be $\gamma = 1$ for turbulent flow and $\gamma = 0$ for non-turbulent flow. The intermittency factor $\gamma(z,t)$ is probability that flow at (z,t) is turbulent, defined by

$$\gamma(z,t) = \mathrm{Prob}\left\{\left|u(z,t) - u_{\mathrm{lam.}}(z,t)\right| > u'_{\mathrm{thresh.}}(z)\right\} \tag{1}$$

where $u_{\mathrm{lam.}}$ is numerical laminar velocity; $u'_{\mathrm{thresh.}}$ is the thresholds of fluctuation intensity averaged during tranquil period between two peaks of solitary motion.

Figure 4 shows the intermittency factor overlaid with turbulence intensity from the present experiment. It can be noticed that in the certain time-variation during accelerating phases intermittency factor has value above of 0 ($\gamma > 0$). It is clearly indicating that flow regime is not in laminar anymore.

The turbulence intensity (I) is defined as the ratio of the root-mean-square of the velocity fluctuations (u') to the mean flow velocity. **Figure 4** depicts how turbulence develops as flow progress in phase space. And at t = 1s, the turbulence intensity is high in the vicinity of the bottom, and it is also falls out by high value of the intermittency factor (γ) = 1.

A momentum method is used to calculate bottom shear stress of the present experiment.

$$\frac{\tau_0}{\rho} = \int_0^{\infty} \frac{\partial(u-U)}{\partial t} dz \tag{2}$$

where τ_0 is bottom shear stress, ρ is fluid density and U is velocity at $z = \infty$ cm or free stream velocity.

Figure 5 shows the bottom shear stress calculation and it can be noticed that deviation from numerical laminar have occurred since in the accelerating phase, it is caused by turbulence have taken place during this phase, as seen in **Fig. 4**. Deviation in term of bottom shear stress is also an indication of relaminarization.

Keywords: Turbulent flow regime, solitary wave, boundary layer
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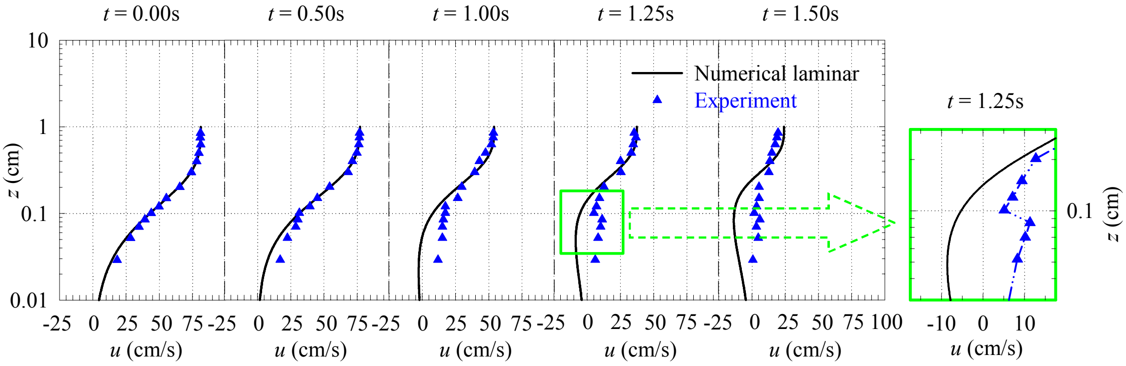

Fig. 2 The transformasion of velocity profile in the variation of time in turbulent flow

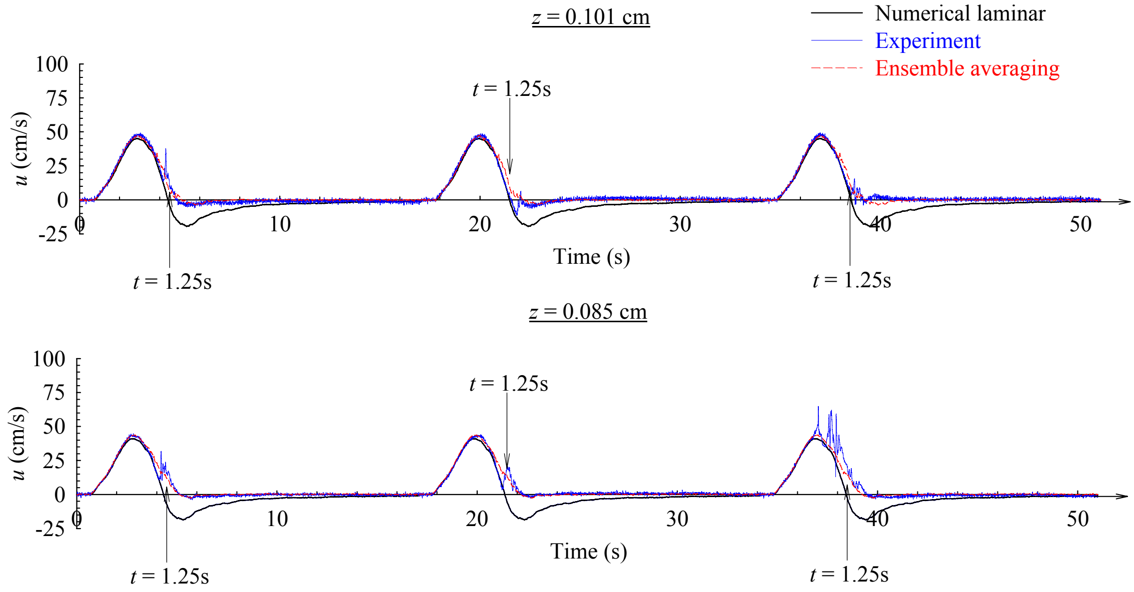

Fig. 3 Instantaneous fluctuation velocity at z = 0.085 cm and z = 0.101 cm

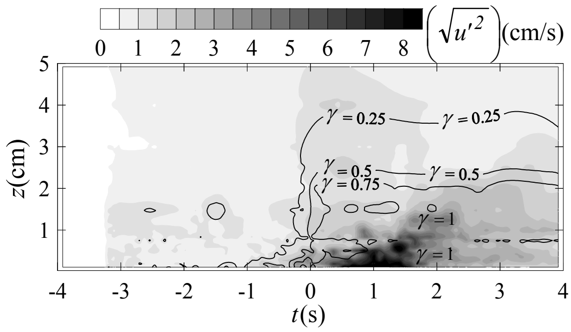

Fig. 4 Turbulence intensity overlaid with intermittency factor (γ)

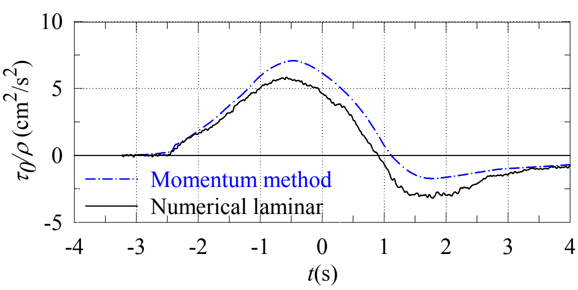

Fig. 5 Bottom shear stress

CONCLUSION

Investigation of turbulent flow regime behavior under solitary wave has been done based on the present experiments data. Intermittency factor, turbulence intensity and bottom shear stress are our concern in order to observe turbulence flow regime characteristics. Moreover, interesting phenomenon can be observed during investigation in connection with discontinue flow velocity profile. This observable fact is also found in the previous experimental study.

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