# BOTTOM SHEAR STRESS BENEATH SOLITARY WAVE

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## 1. INTRODUCTION

Bottom shear stress is one of important parameters in practical application purposes such as sediment transport calculation. Local bottom shear stress can be estimated by using application of Prandtl- von Kármán law (P-vK law). Liu *et al.* (2004) used a wave flume with PIV system for measurement of velocity in the thin boundary layer. It is found that while the horizontal component of the free stream velocity outside the boundary layer always moves in the direction of wave propagation, the fluid particle velocity near the bottom inside the boundary layer reverses direction as the wave decelerates and the consequence is the bed shear stress also changes sign during the deceleration phase. In this study boundary layer characteristics beneath solitary wave are investigated through experimental set up performed in conduit water tunnel equipped by a Laser Doppler Veloci-meter (LDV) for the velocity measurement. The result of experiment is checked by BSL *k-ω* model proposed by Menter (1994) and it can be concluded that an excellent agreement is achieved between experimental data and BSL *k-ω* model result.

## 2. LABORATORY EXPERIMENT SET-UP

Boundary layer flow experiment under solitary wave was carried out in a conduit water tunnel. The velocity was measured at 17 points in the vertical direction by LDV installed at 1.3 m from the downstream end. A general sketch of the experimental set-up is given in **Fig. 1.** The experimental set-up consisted of overflows head tank, downstream gate, flow velocity measurement device (LDV) and conduit water tunnel. The conduit water tunnel has dimension 15 cm of width, 10 cm of depth and it has length 400 cm. The overflow head tank keeps a constant pressure head and then flows into measurement section along conduit part. The downstream gate can be raised up and dropped down regularly using a mechanism of rotating circular disc connected with the motor. In this experiment generation system circular disc shape has an important function because it will control opening and closing downstream gate. To achieve a generation system which enables investigating fully turbulent boundary layer under solitary wave, a circular disc was designed based on solitary wave formula.

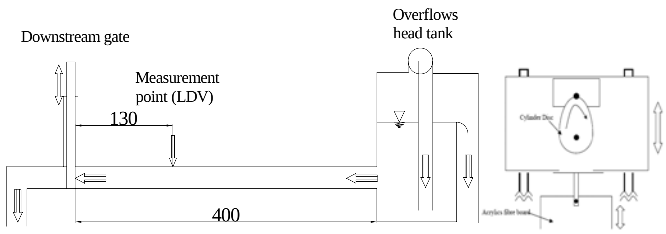


**Fig. 1** Sketch of the experimental generation system

The shape of circular disc used in this generation method as drawn in **Fig. 2.**

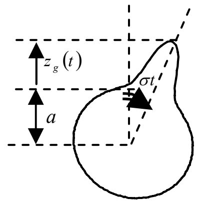


**Fig. 2** The circular disc shape

The conditions of present laboratory experiment were $U_c$ is velocity under wave crest ($U_c$ =38.4 *cm/s)* and $\upsilon$ is kinematics viscosity ($\upsilon$ = 0.01 $cm^2/s$).

## 3. TURBULENCE MODEL

The BSL *k-ω* model has been used for computing bottom boundary layer under solitary wave. Menter (1994) proposed the basic idea of the BSL *k-ω* model in order to retain the robust and accurate formulation of the Wilcox (1988) *k-ω* model in the near wall region and to take advantage of the free stream independence of *k-ε* model in the outer part of boundary layer. The BSL *k-ω* model gives results similar to the *k-ω* model of Wilcox (1988) in the inner of boundary layer but changes gradually to the *k-ε* model of Jones and Launder towards to the outer boundary layer and the free stream velocity. In order to be able to perform the computations within one set of equations, the Jones and Launder (1972) model was first transformed into the *k-ω* formulation. The blending between two regions is done by a blending function F1changing gradually from one to zero is desired region. The BSL model has the different formulations with the original *k-ω* model i.e. an additional cross diffusion term appears in the *ω*-equation and the modeling constants are different.

In order to achieve better accuracy near the wall, the grid spacing was allowed to increase exponentially, in space is 100 and in time is 7200 steps per wave cycle.

## 4. BOTTOM SHEAR STRESS ESTIMATION

P-vK law is used for doing calculation of local bottom shear stress for smooth bed turbulence by using logarithmic relation of the friction velocity and the variation of velocity with height. P-vK law is derived by assuming that total shear stress throughout the flow is due to turbulence and defined by:

$$\frac{u}{U^*} = \frac{1}{\kappa}\ln\left(\frac{U^* z}{\nu}\right) + 5.5 \tag{1}$$

where:
$u$ : the flow velocity in boundary layer measured by LDV

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$\kappa$ : von Kármán's constant (= 0.4)
$z$ : the cross stream distance from bed elevation
$U^*$ : friction velocity and in connection with the bottom shear stress ($\tau_0$) $= \rho U^* |U^*|$
$\rho$ : fluid density

## 4. RESULT AND DISCUSSION

The experimental data of mean velocity distribution at selected phases are compared with BSL *k-ω* model result as shown in **Fig. 3.** A good agreement is achieved especially during acceleration phase at A, B, C, D, E, we can also notice that while the velocity outside the boundary layer remains always positive and move in the same direction of wave propagation, the fluid particle velocity near the bottom inside boundary layer reverses the direction, it is caused by deceleration of wave. That condition can be observed clearly at phase F, G, H and I.

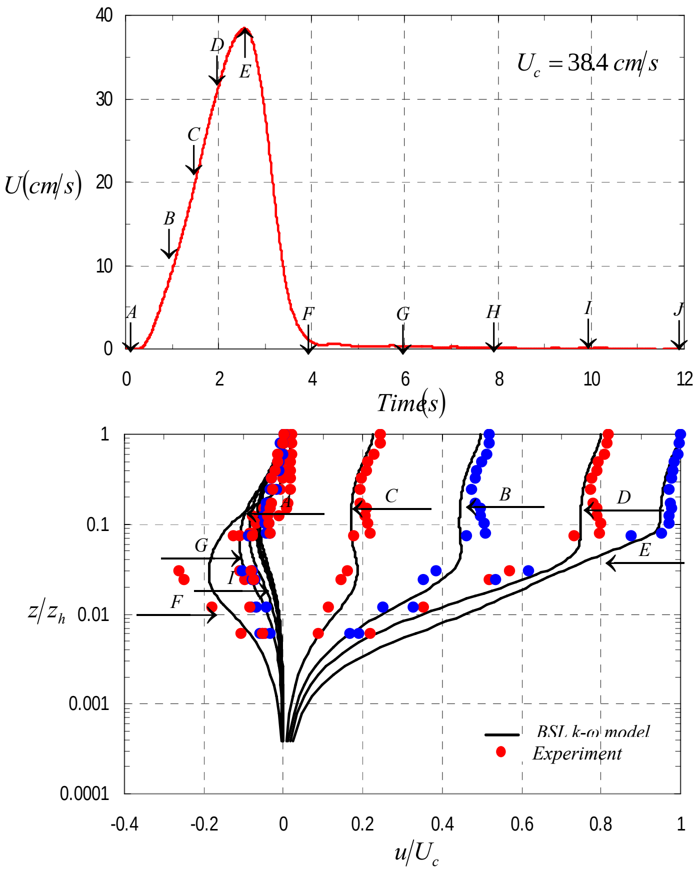


**Fig. 3** Comparison velocity profile between BSL *k-ω* model result and experiment data

**Fig. 4** shows comparison among the experimental data and BSL *k-ω* model result of mean bottom shear stress and an excellent agreement is obtained among them. As be mentioned previously that while the velocity outside boundary layer remains always positive and move in the same direction with wave propagation, the fluid particle velocity near the bottom inside the boundary layer reverses the direction because of deceleration of wave and then as a consequence the bottom shear stress also change the sign during the deceleration phase. We can observe that kind of condition in **Fig. 4**, although velocity outside boundary layer always positive (**Fig. 4(a)**) but starting at time (s) = 3.25 bottom shear stress has negative value (**Fig. 4(b)**) as a consequence of velocity direction near the bottom inside boundary layer.

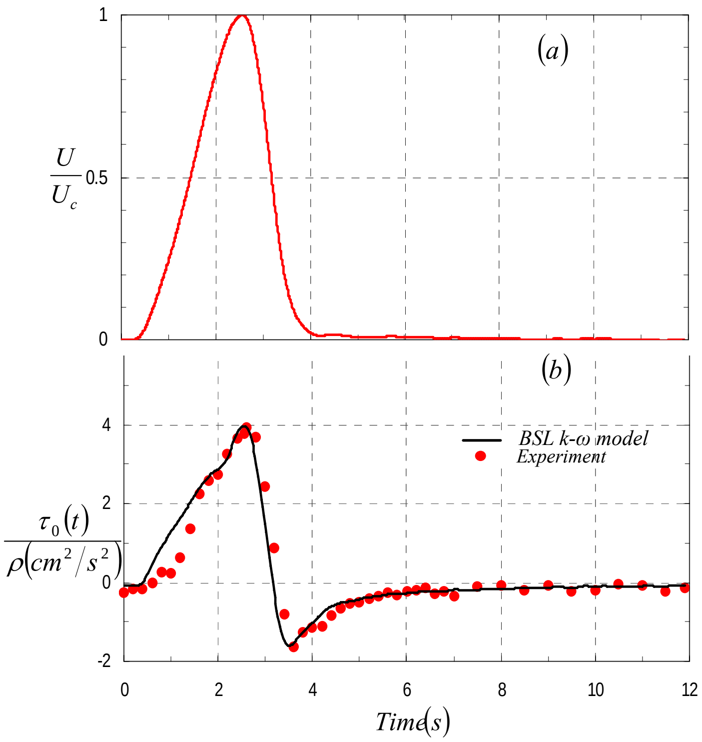


**Fig. 4** Comparison bottom shear stress between BSL *k-ω* model result and experiment data

## CONCLUSION

There are some methods for calculating bottom shear stress. In this study, bottom shear stress of experiment is estimated by application of Prandtl-von Kármán law and an excellent agreement is achieved with BSL *k-ω* model result.


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