Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 116 (2015) 663 – 669
Procedia Engineering
www.elsevier.com/locate/procedia

8th International Conference on Asian and Pacific Coasts (APAC 2015)

Application of Thermal Shear Stress Gauge in Study on Shear Stress Measurement on Underwater Bed Surface

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Abstract

Although bed shear stress is one of the important ways to research the basic theory of sediment movement under the action of complex hydrodynamic force, the effective method for measurement of bed shear stress hasn’t formed yet. By application of the new micro-nanotechnology-based thermal shear stress gauge, this paper experimentally researches the bed shear stress measurement in wave flume. The research shows that the thermal shear stress gauge is with high response frequency and good stability and, the measurement results present the basic laws of variation of bed shear stresses under wave action and confirm the feasibility of measuring bed shear stress with thermal shear stress gauge on condition of complex hydrodynamic force.

Peer- Review under responsibility of organizing committee , IIT Madras , and International Steering Committee of APAC 2015

Key words: bed shear stress; micro-nanotechnology; thermal shear stress gauge; wave action

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1877-7058
Peer- Review under responsibility of organizing committee , IIT Madras , and International Steering Committee of APAC 2015
doi:10.1016/j.proeng.2015.08.347

1. Foreword

1.1. Research background

Shear stress measurement on underwater bed surface is always one of the key and difficult problems in the hydrodynamic research area. Because bed shear stress is directly related to sediment transport, bed shear stress is the important way to study basic theory of sediment movement, especially under complicate hydrodynamic actions such as wave, wave and current, breaking wave, unsteady flow and so on. If engineers want to do good forecasting of bed erosion and siltation caused by silt transport in project construction, it is necessary to understand sediment transport mechanics clearly. The shear stress measurement on underwater bed surface has the following difficulties: the small amount, quick-changing frequency and tough environment, the effective method for measurement of bed shear stress in wave or complex hydrodynamic force hasn't formed yet. To some extent, it restricts theoretical research of sediment transport. So it is of considerably practical and theoretical sense to research on bed shear stress measurement in complex hydrodynamic force.

1.2. Research advances

At present, it mainly has two methods called direct measurement and indirect measurement to measure bed shear stress. Direct measurement is to calculate the shear stress by measuring displacement of the stress plate(Qin Chongren 1999, Huo Guang 2007, Mirfenderesk and Young 2003). Indirect measurement is to calculate the shear stress by theoretical formula after measuring the fluctuation velocity in the boundary layer on the bottom of water body(Sleath 1988). Because the fluctuation velocity measurement in the boundary layer is very difficult and less accurate, the indirect measurement is infrequently applied in the actual research. When directly measuring bed shear stress by stress plate, it exists the following problem that the pressure change caused by wave surface has effect on the measuring accuracy of shear stress under. Thus it can be seen that it is lack of some effective method to measure bed shear stress underwater under wave action.In the 1980s, researchers begun to study and use thermosensitive shear stress gauge based on the micro-nanotechnology to measure wall shear stress in the airflow, and to some extent promoted the development of aerodynamics (Haritonidis J.H. et al. 1989, Jonathan W. N. et al. 2002). With the development of the Micro Electro Mechanical System (MEMS), micro thermosensitive shear stress gauge has been gradually applied to measure shear stress underwater and achieved some research achievements(Xu Yong et al. 2005, Liang Ting et al. 2010). However it still needs to do more profound research work to apply micro thermosensitive shear stress gauge under complex hydrodynamic force.

2. Testing method

2.1. Operating principle of thermosensitive shear stress gauge

This test used the thermosensitive shear stress gauge based on the micro-nanotechnology to measure bed shear stress. The operating pinciple of micro thermosensitive shear stress gauge is that when passing the thermosensitive gauge surface, the water takes away heat quantity, and then the output voltage of thermosensitive gauge will change correspondly. It has two operating modes called the constant current mode and the constant temperature method. The constant current operating mode is now applied in this test. In the constant current operating mode, the electric current passing the sensor remains constant

The thickness of gauge is about 50 micrometers and its maximum output frequency can reach over 100 HZ. The gauge was sticked to the bed surface in the flume test, shown in Fig.1.Compared with the shear stress plate measuring method, the themosensitive stress gauge has some advantages, such as high response frequency, no pressure influence by wave surface and convenient operation. In the constant current operating mode, the heat balance equation (Xu Yong, 2002) is writen as following:

$$U = A + B\tau^n \tag{1}$$