calculated using second order accurate central difference formulae. We employed IB (immersed boundary) technique for the implementation of boundary conditions and semi-implicit fractional-step method for solving the Stokes equations. The flow field and the ionic concentration distributions obtained shows that the electoosmotic effect is predominant in the thin region around the electrode. The initial flow field observed under the application of DC field disappears with the time and under steady state the electrolyte comes to rest. Under AC field the heterocharge layer around the electrodes changes with the frequency of the field. A continuous fluid flow around the electrodes is observed, which can enhance the mixing in the domain. The AC flow field is frequency dependent, a strong flow field is observed in the frequency range 400-600Hz.

11:00 ~ 12:20 (Room103)

Turbulent Boundary Layers

Session Chair : Prof. J. Dey, IIS/India

M-1C-1. ANALYSIS AND PREDICTION OF THE TURBULENT CHARACTERISTICS OF NEAR-SURFACE UNSTEADY WINDS

Jinghong ZHANG, *Key Laboratory of Mechanics on Western Disaster and Environment, Lanzhou University, China,* Xiaojing ZHENG, *Key Laboratory of Mechanics on Western Disaster and Environment, Lanzhou University, China,* Sand saltation movement driven by wind and aeolian sand flow are directly correlated with the characteristics of air flow near earth surface, especially the wind field about 10 cm above it. Wind flow in near-surface atmospheric boundary layer shows evident turbulent characters, and both the lateral wind intensity and its distribution in height are varying with time. In order to make the theoretical prediction of the sediment flux more natural, we carried on experiments performed in bare ground and dune crest at the edge of Badain Jaran desert and Tengger Desert, in China, in which continuous, synchronous measurements of turbulent velocity fluctuations, wind direction, and sediment transport intensity at different height were made. Statistical analysis of the experimental data show that the probability density of the lateral wind gusts approach normal distribution at all heights; turbulence intensity, skewness and kurtosis of the gusty winds all decrease with the increase in height; and sediment transport intensity shows a property of strong unsteadiness and intermittency. Analysis of the fluctuation structure of the wind and the sediment transport intensity was made with VITA method, we found the correspondence were poor, then after smoothing the experimental data, calculation of the correlation coefficient of the localized variance of wind velocity and sediment transport intensity was done, a highest value was found when 3 minutes moving average interval was applied, which reveals a new time scale in the wind erosion process. Finally, we proposed a wind prediction model which can predict wind speed variations of 1Hz at any height below two meters, a good agreement was found when comparing the predicted results and the experimental data.

M-1C-2. RECONSIDERATION OF KARMAN-SHOENHERR SKIN FRICTION FRMULA IN HIGH-RE-NUMBER TURBULENT BOUNDARY LAYER

Hiroki IMANISHI, Kiyoto MORI, Tuji YOSHIYUKI, *Nagoya University*, *Japan,* Tomohiro HATTORI, Masaharu MATSUBARA, *Shinshu University*, *Japan*, Sinsuke MOCHIZUKI, *Ymaguchi University*, *Japan*, Masaru INADA, Tadashi KASHIWAGI, *Kyushu University*, *Japan,* The total and local skin friction of a flat plate is directly measured by using a towing tank up to Reynolds number $Re_L=10^7$ (or $R_\theta=10^4$). Schoenherr (1932) suggested an empirical formula. It is the so-called Karman-Schoenherr formula for total and local frictional resistance. And it is widespread in the shipbuilding research filed and has been highly reliability so far. However, Osaka et al. (1996) showed that the local skin friction, which was measured by the floating element technique, became smaller than the value of Karman-Schoenherr formula. We assume that this discrepancy is due to the Schoenherr's experimental technique. He has ignored the wave-making drag driving from the test plate, the form drag of the plate. In this study, we try to improve Schoenherr's experimental technique, and evaluate the skin-friction coefficient by using the towing tank. Our test plates L=3.30~8.15m in length are towed in still water, balancing the vertical weight by small floats, the draft was varied, where draft is defined as the distance from the bottom of the plate to the surface and the drag force is measured by a highly efficient load cell. We used a tripping wire to promote the laminar-to-turbulent transition of the boundary layer. The experiments were carried out in the towing tank at the Deep Ocean Laboratory of Research Institute for Kyushu University. We have developed the new technique to correct wave-making resistance. The measured total drag is converted into local drag; it is found that the local frictional resistance is 6% smaller than that given by the Karman-Schoenherr formula. This is mainly because he did not correct the additional forces which overestimate the plate resistance. We present the simple correction technique to remove those additional forces, and the corrected local skin friction resistance becomes consistent with that measured by the floating element method.

M-1C-3. TURBULENT HYDRAULIC JUMP OVER A ROUGH BED RECTANGULAR CHANNEL

Noor AFZAL, *Faculty of Engineering, Aligarh Muslim University, India*, A. BUSHRA, *Department of Civil Engineering, University of Nibraska, USA,* The information concerning the effects of boundary roughness on the hydraulic jump is incomplete (Carollo, Ferro and Pampalone 2007, J. Hydraulic Eng. 133(9), pp. 989−999). In the present paper the axial flow structure of turbulent hydraulic jump has been proposed by depth averaged Reynolds mean momentum equations over a rough bed rectangular channel. The averaged normal Reynolds stress closure model of constant eddy viscosity in terms of depth averaged axial velocity in axial distance is proposed. The closed form solution for sequent depth ratio, jump and roller length have been obtained. The sequent depth ratio depends on bed roughness and upstream Froude number. The length jump and roller length as function of sequent depth, are universal relations, which are explicitly independent of bed roughness friction factor. An effective upstream Froude number is also defined where the sequent depth ratio and other hydraulic jump characteristics can be directly deduced from classical hydraulic jump theory, provided the upstream Froude number is replaced by effective upstream Froude number.

M-1C-4. STUDY ON SECONDARY INSTABILITY OF A PLANAR SUPERSONIC MIXING LAYER AT MC=0.5 IN DIRECT NUMERICAL SIMULATION

Faming GUAN, Qing SHEN, *China Academy of Aerospace Aerodynamics, Beijing, China,* There are many approaches to transition in the compressible shear layers, such as secondary instability, bypass and three waves resonant. The secondary instability is one important approach that natural transition. In incompressible shear layer, many works focused on the secondary instability researches. A supersonic planar free shear layer at Mc=0.5 is studied in DNS (direct numerical simulation) methods in present study. The Navier-Stokes equations in perturbation form are solved with a finite difference method of the third order accuracy. The secondary instability is found in the impressible shear layer. Based on the secondary instability, the three-dimensional disturbance wave instability is studied. The developments of the hairpin vortex are simulated. The legs and the heads of the hairpin vortex are bent and drawn in the shear layer when the secondary instability develops and the three-dimensional perturbation waves grow up. In the end of the development of secondary instability, the hairpin vortexes are broken and the frequency splitting happened in the shear layer.

11:00 ~ 12:20 (Room104)

Industrial Applications and Material Processing Flows (I)

Session Chair : Prof. J. Sung, SNUT/Korea

M-1D-1. FLOW DISTRIBUTIONS IN CENTRIFUGAL IMPELLER DEVELOPED FOR AIR-WATER TWO-PHASE FLOW OPERATION

Naoki MATSUSHITA, Tomomichi HASUI, Akinori FURUKAWA, Satoshi WATANABE, Kusuo OKUMA, *Department of Mechanical Eng. Science, Kyushu Univ., Japan,* Centrifugal pumps are utilized in various industrial fields due to its simple structure and easy maintenance, and there is a strong demand to develop a usable one even in the high inlet void fraction under the air-water two-phase flow condition. However conventional pump does not achieve this demand as an impossibility of a pumping-up appears at an inlet void fraction less than about 10%. Authors have investigated air-water two-phase flow performances and clarified several powerful methods to obtain good two-phase flow performances. As the result, a multi-bladed impeller with thin blades, higher outlet blade angle, tandem arrangement of double rotating circular cascades and an installation of diffuser cascade downstream of impeller outlet has been proposed. However, the installation of diffuser cascade downstream of impeller causes the increase of shaft power under the case of water single-phase flow and air-water two-phase flow. It is considered that the increase of circumferential absolute flow velocity due to the installation of diffuser cascade causes the increase of shaft power. Then the flow distribution in the impeller was measured by LDV, and we examined the relation between the increase of shaft power and flow distribution at the impeller outlet. By comparing the results by LDV measurement between the flow distribution in the impeller with diffuser