Session Chair : Prof. M. H. Sohn, KAFA/Korea

W-2D-1. VORTEX BREAKDOWN DUE TO FLAPS ON A 60°DELTA WING- BODY

N. GOPINATH, R. SRIDHARAN, *National Trisonic Aerodynamic Facilities National Aerospace Laboratories, Bangalore, India,* Pitch up is a major concern for aircrafts with delta plan forms. One of the characteristics of slender delta wings is a sudden loss in lift due to vortex breakdown at the trailing edge region of the wing. The corresponding sudden increase in pitching moment gives rise to pitch up. In a tailless delta wing aircraft flaps/ elevons play, a dual role firstly acts as a lift-enhancing surfaces and secondly as a control device Depending on their chord-wise and span-wise extent vis a vis primary vortex, when deflected, the flaps alter the vortex flow as well as the inboard attached flow on the wing. This leads to early vortex breakdown, which directly influences the basic aerodynamic characteristics of the configuration. To investigate the effect of these parameters a flat plate, cropped 60° delta wing body with sharp leading edge was fitted with part span flaps with three different types of geometries. Areas of all these flaps are kept constant around 13.5 cm^2. These tests were conducted in the 0.6 m transonic wind tunnel at N.A.L in the Mach Numbers range of 0.3 to 1.2 and through incidence range of –4° to 20°. The flaps were deflected through 0°to 25° in step of 5°. Force and moments were measured, surface flow visualization tests using oil flow were also conducted. This paper presents results on rectangular plan form flaps/elevons on the delta wing at three flap deflections 5°, 15° and 25°. Results show that vortex breakdown is induced due to flap deflection, resulting in mild to severe pitch up depending on angle of attack, geometry of the flap and Mach number.

W-2D-2. INVERSE DESIGN OF 2D DUCTS USING FLEXIBLE STRING ALGORITHM

M. Nili. A, *Sharif University*, *Iran*, M. DURALI, *Sharif University*, *Iran*, A. HAJILOUY, *Sharif University*, *Iran,* F. GHADAK, *Emam Hossein University, Iran,* The duct inverse design in fluid flow problems usually involves finding the wall shape associated with a prescribed distribution of wall pressure or velocity. In this investigation, an iterative inverse design method for 2D ducts with incompressible flow is presented. In the proposed method, the duct walls shape is changed under an algorithm based on deformation of a virtual flexible string in flow. The deformation of the string due to the local flow conditions resulting from changes in wall geometry is observed until the target shape satisfying the prescribed walls pressure distribution is reached. At each iteration step, the difference between current and target wall pressure distributions is applied to the string. The flow field at each step is analyzed using Navier-Stokes equations and collocated solution method. The method is quick converging and can utilize commercial flow analysis software easily and efficiently.

W-2D-3. A STEP FORWARD IN STEALTH TECHNOLOGY – THEORATICAL INVESTIGATION OF PRESSURE DIFFERENTIAL ANGLE OF ATTACK MEASURING SYSTEM

U. N. MUGHAL, *Department of Mechanical Engineering, NED UET, Karachi, Parkistan,* J. MASUD*, Institute of Avionics & Aeronautics, Air University, Islamabad, Pakistan,* This paper is towards identifying the location to install Flush Port Air Data System (FADS) on various aerodynamic shapes which is typically used on Stealth Aircraft. ADS are required on aircraft as part of the flight control system which further require the addition of air data pressure sensors on exterior of aircraft to measure AOA. FADS systems have typically in excess of 10 pressure ports/sensors. Flush Port Pressure Sensors are symmetrically placed on the airframe. Pressure measured at each port varies as airframe manoeuvres. Pressure differences, ΔP between symmetrical ports correspond to changes in angle of attack. Pressure data is derived from wind tunnel and flight tests. The air data computation routines in the FCC then determine AOA and various other parameters. Potential flow theory is used for the analysis of aerodynamic shapes e.g. rankine half body, cylinders, wedges and aerofoil. Various locations on aerospace vehicles can be locally approximated by these simple shapes. These flow patterns are simulated in MatLab to calculate the non-dimensialized ΔP variation w.r.t AOA. These ΔP variations are then compared with one another to check whether the front part of these surfaces correspond to the same non dimensialized ΔP or not. On the basis of this, the location to install the Pressure Differential Angle of Attack measuring instrument is suggested. It is concluded from the Non-Dimensialized ΔP Curves w.r.t AOA on different aerodynamic bodies at different Mach Numbers that, ΔP varies linearly with AOA on all bodies & Non Dimensialized ΔP w.r.t P_o-P gives most favourable results.

W-2D-4. PHASE-LOCKED PIV STUDIES ON AN OSCILLATING AIRFOIL

R. MUKUND, L. VENKATAKRISHNAN and K. T. MADHAVAN*, Experimental Aerodynamics Division, National Aerospace Laboratories, India,* The study of oscillating airfoils is of interest in order to gain a deeper understanding of the unsteady flow aerodynamics present in such flows as well as the dynamic stall mechanism occurring at high incidence angles of the airfoil. Flow field measurements were conducted using phase locked 2D PIV on an oscillating airfoil at low speeds. The measurements were made at different phase angles during both up stroke and down stroke of the airfoil yielding statistically significant number of velocity fields. The phase-averaged velocity field clearly shows the formation of the dynamic vortex, its growth and its shedding. An interesting feature is that the measurements reveal a secondary vortex at the maximum angle. The spatial correlation of vorticity was calculated from the phase-averaged velocity field data and the results show strong negative correlation with the reference point which decreases with increasing incidence up to the maximum angle and reappears during the down stroke. The reappearance of the ensemble-averaged correlation in the separated region indicates that the flow field is not totally irreproducible as was indicated by earlier studies.

10:40 ~ 12:00 (Room105)

Geophysical Fluid Dynamics (I)

Session Chair : Prof. N. Sekishita, Toyohashi Univ of Tech/Japan

W-2E-1. WIND RESOURCE ASSESSMENT OF THE ANTARCTIC KING SEJONG STATION BY COMPUTATIONAL FLOW ANALYSIS

S. W. KIM, *KIER, Korea Institute of Energy Research, Korea*, H. G. KIM, *KIER, Korea,* It was 17 February 1988 when the King Sejong Station (62º13'S, 58º47'W) located in Barton Peninsular, King George Island commenced to function as a permanent research station for Korea Antarctic Research Program. According to the Protocol on Environmental Protection to the Antarctic Treaty known as the Madrid Protocol, many Antarctic stations are actively accommodating a wind power system. In fact, most stations are heavily depending on fossil fuel use for power production, but it would contaminate the environment by oil spill, soil pollution and exhaust gas. In this regard, renewable energy such as wind and solar could be a practical alternative at the Antarctic. KIER (Korea Institute of Energy Research) has performed wind resource micrositing around the met-masts in 2005 and has installed an 10kW wind turbine in February 2006. The wind turbine has been successfully operated and produced about 32MWh of electricity so far. At the beginning of the project, the wind turbine was planned to install near by the wharf but the site was moved during the detail engineering to near the warehouse, which was about 625m away from the main building of the station along the costal line in east. The previous candidate site near the wharf was too close to the oil tanks so that it could be a great danger, especially in a winter season because of icing on blades. Ice on rotor blade would subsequently be thrown away during operation with high speed and it could damage the fuel tanks. The current location of the wind turbine has different geographic surroundings from the previous candidate site considered in 2005 and that makes re-evaluation of wind resource at the current site including geographic effects necessary. Especially, strong wind flow derived by steep and complex terrain is dominant in the Antarctica so that CFA(Computational Flow Analysis) is required. In this study, CFA based micrositing software, WindSim is employed and a grid system of 140x130x25 covering 5km x 5km area is used after testing grid dependency. The wind rose measured at the previous and current installation location are identical with strong meteorological correlation but prevailing directions of wind power density are different because of local wind acceleration due to complex terrain. Numerical analysis explains which effects bring this discordance between the two sites, and a design guideline required for additional wind turbine installation has been secured.

W-2E-2. WIND ACCELERATION PROCESS IN THE DUNE FIELD MODEL

BO Tianli, ZHU Wei, ZHENG Xiaojing, *Key Laboratory of Mechanics on Western Disaster and Environment, Lanzhou University, China,* A modification of existing dune field model with particular emphasis on the influence of the windward slope on the wind acceleration process in dune's windward side will be proposed in terms of the variance of windward slope with dune height, and the effect of wind speed on the thickness and transport length of sand slabs in the dune field model. In the existing model, the wind speed-up factor is introduced as a function of migration speed of

dune, while the migration speed is always an unsteady quantity controlled by wind speed and diameter of sand particles, which is still not clear. Considering the limitations of existing dune field model, this work reports on a three-dimension model with several modifications involved: (1) Inspired by the field measurements of Finkel (1959) and Sauermann et.al (2000) in Peru and Morocco, we introduce the relationship between dune height and windward slope angle; (2) According to Lancaster's conclusion (1995) that wind speed-up factor changes with windward slope angle and dune height, we put forward a logarithm relation between wind speed-up factor α and the dune height; and (3) We take account of the effect of wind acceleration process on formation and evolution of dune field not only in determining the transport length L_{ij}^{t} but also the thickness h_{ij}^{t} of sand slabs. Such modification is proved to be significant in simulating the realistic character of wind-formed features. Moreover, the evolution process of dune field in different desert region is proved to have obvious discrepancy.

W-2E-3. EFFECTS OF AEROSOL SIZE AND DEFORMATION ON CLOUD FORMATION IN THE ATMOSPHERE

N. DEVARAJU and N. RUDRAIAH, *UGC-Centre for Advanced Studies in Fluid Mechanics, Bangalore University, India,* There is a growing concern that human activities may alter the climate by releasing a large amount of soot and other pollutants into the atmosphere in the form of ultra fine dust particles which are suspended in the atmosphere called aerosols. Atmospheric aerosols play the important role in the atmospheric processes of favoring cloud formation and also negatively linked to a number of undesirable phenomena ranging from visibility reduction to adverse effects on human body depending on their size due to coagulation. The coagulation causes aerosol hit each other leading either to stick each other resulting in increase in size and decrease in number or collide each other, leading to the formation of tiny particles resulting in decrease in size and increase in number but in both the cases mass concentration remains the same. Knowing the complexity of aerosols due to coagulation, their favorable or unfavorable effects and the desire to control atmospheric aerosol, the study dispersion of aerosols is crucial. This is done in this paper considering large size aerosols as the mixture of agglomeration and coalescence in the atmosphere and modeled them as fluid saturated sparsely packed porous media. Using this assumption and considering aerosols as deformable the required basic equations are derived incorporating advection and diffusion using mixture theory and Saffman dusty fluid model. The solutions of the basic equations are obtained using regular perturbation technique together with Saffman slip condition on velocity and the permeable condition on concentration. The Taylor dispersion coefficient D_r is obtained and is computed for different values of dimensionless number $R_i (i = 1,2,3)$ and the results are tabulated. From this table we conclude that D_r decreases with an increase in R_4 where R_4 has the dimension reciprocal of Reynolds number.

W-2E-4. A NUMERICAL SIMULATION OF DUST DEVIL AND ELECTRIC FIELD IN IT

N. HUANG, G. W. YUE, X. J. ZHENG, *Key Laboratory of Mechanics on Western Disaster and Environment, Lanzhou University, China,* On a hot and dry day in arid regions, it's common to see swirls of dust race across the landscape. The strong electric field of dust devils may be a possible nuisance or hazard to future human explorers on the surface of planets (Farrell et al., 2004), and therefore it is important to study electric field of field dust devils. Because it is difficult to get the detailed information of the electric field in dust devils through measurement, the simulation becomes an effective way to study the electric field of field dust devils. In this paper, based on the surface energy-balance equation and atmospheric movement equations, and Coulomb's law, the whole process of dust devil development and the electric field in dust devil is numerically simulated, then the simulated results of electric field are discussed and compared with field measurements. It is found that the simulated electric field agrees well with the measured result when the charge-mass ratio of sand grains with diameters of 0.15mm、0.2mm and 0.25mm are taken as $-120\mu C/kg$、$60\mu C/kg$ and $57\mu C/kg$, respectively. The results also show that for electric field in dust devil, it needs about 80s from the moment when some sand particles begin to be lifted off from bed (t=0) to the stage that the value of electric field becomes relatively stable. The absolute value of electric field at a given height always increases as the radius decreases and it will reach a maximum value at the center of dust devil. The absolute value of electric field in dust devil increases first and reaches a maximum at the height of 20m and then decreases with height.

10:40-12:00 (Room106)

Granular Flows

Session Chair : Prof. K. Hirata, Doshisha Univ/Japan

W-2F-1. NONLINEAR STABILITY OF GRANULAR SHEAR FLOW: LANDAU EQUATION AND SHEAR-BANDING

Priyanka SHUKLA, *Engineering Mechanics Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, India,* Meheboob ALAM, *Engineering Mechanics Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, India*, Starting from the continuum equations of rapid granular flows, we derived Landau equation for the plane Couette flow using both the amplitude-expansion method and the center-manifold reduction. Our amplitude `order-parameter' equation describes the onset and the subsequent dynamics of shear-band formation near the critical point. To find the actual behavior of flow due to finite-amplitude disturbances, we need to calculate Landau coefficient which can be expressed in terms of a suitable inner-product of the nonlinear terms and the eigenfunctions of the related adjoint problem. The numerical results on Landau coefficients suggest that there is a sub-critical *finite-amplitude* instability for dilute flows even though the dilute flow is stable according to the linear stability theory. This result is in agreement with previous molecular dynamics simulations of granular Couette flow as well as with the direct solution of nonlinear continuum equations. The scaling of equilibrium amplitudes with different control parameters as well as the effects of mean-flow distortion will be discussed.

W-2F-2. LARGE-SCALE STRUCTURES AND FLUCTUATIONS IN 3D GRANULAR POISEUILLE FLOW

Ashish MALIK and Meheboob ALAM, *Engineering Mechanics Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, India,* Various macro- and micro-structural features of a gravity driven three-dimensional (3D) granular Poiseuille flow are studied in the rapid flow regime using event-driven simulation. A monodisperse system of rough, inelastic hard spheres interacting via hard core potential is considered. The collisions are assumed to be binary and instantaneous in which only momentum is conserved but the energy is non-conserved quantity. The wall-particle interactions are modeled using same collision dynamics as for particle-particle interaction. The structure formation in the form of large-scale density waves takes place under certain conditions. These density waves are affected by various parameters like the volume fraction, the coefficient of restitution and the aspect ratio of the simulation domain. In particular, these structures are driven by inelastic collisions of particles and hence these are dissipation-induced structures.

W-2F-3. INFERENCE OF FACTOR OF TRANSPORTATION EFFICIENCY IMPROVEMENT BY ROTARY FEEDER IN PLUG CONVEYING

K. KOFU, M. OCHI and M. TAKEI, *Department of Mechanical Engineering, College of Science & Technology, Nihon University, Japan,* In plug conveying system, it is desired that the transportation efficiency is improved. Then a rotary feeder is often used these days. However, the reason of the transportation efficiency improvement has not been clarified. Therefore this reason has been investigated experimentally. Two kinds of pipe diameters, i.e., 38 and 50 mm, were used. The pipe line length was about 11.4 m. Four kinds of particle-air mixing devices were used, and feeders were changed to a rotary feeder and a vessel in each experimental condition. As a result, there is no improvement of transportation efficiency by the rotary feeder in all experimental conditions, because there is little difference between the largest particle mass flow rate by the rotary feeder and that by the vessel. However, the deviation of plug length and velocity in a rotary feeder is smaller than that in a vessel under all experimental conditions. This is assumed as the improvement reason. In short, the number of incorporated plugs during transportation in a rotary feeder is smaller than that in a vessel. In this case, plug length are short, large air mass flow rate is not required to transport particles in a rotary feeder and transportation efficiency becomes large. It is thought there is no improvement because the total pipe length is short and combinations of plugs are seldom used in this study. Additionally, it is said that the effect by pipe diameter and volume of particle-air mixing device on transportation efficiency improvement is small. Some experimental conditions show that particle mass flow rate is not dependent on the number of vane rotation of a rotary feeder. This reason is also considered from the result of the particle velocity measured by the high speed camera and PIV in the particle-air mixing device. Particles in the upper part move smoothly in spite of the experimental conditions and kinds of particle-air mixing device, although it