Session Chair : Prof. T. Yasunobu, Kitakyushu Univ/Japan

W-4D-1. A STUDY ON STRAIGHT-BLADED VERTICAL AXIS WIND TURBINE WITH A DIRECTED GUIDE VANE

M. TAKAO, *Matsue National College of Technology*, *Japan*, H. KUMA, *Matsue National College of Technology*, *Japan*, S. OKUHARA, *Matsue National College of Technology*, *Japan*, T. MAEDA, *Mie University*, *Japan*, K. KAMEMOTO, *Yokohama National University*, *Japan,* A straight-bladed vertical axis wind turbine (this is named "S-VAWT" in the study) has been developed and investigated so far. According to previous studies, it was clarified that the performance of this wind turbine can be improved by means of the directed guide vane. In this case, the guide vane rotates around the rotor and is directed to the wind by aerodynamic force generated by a tail vane, so as to put the guide vane upstream of the rotor. However, mechanism of the performance improvement of the proposed S-VAWT has not been clarified to date. The objective of the study is to clarify its mechanism. First, the performance of S-VAWT with a directed guide vane was investigated by a wind tunnel and was compared with that of the original S-VAWT which has no guide vane. And then, in order to clarify mechanism of the performance improvement, flows around the wind turbine have been estimated by use of the vortex method which provides a Lagrangian simulation of unsteady and vortical flows. The results in the study are summarized as follows: (1) The performance of proposed S-VAWT was improved by means of the directed guide vane and its power coefficient was approximately 1.2 times higher than that of the original wind turbine. (2) Since the guide vane generates wake in its downstream and increases the whirl velocity of inlet flow to the rotor, the performance of S-VAWT is enhanced.

W-4D-2. OPTIMIZATION CONFIGURATION OF MULTI-ELEMENT AIRFOIL GAP WITH THE MODIFIED GENETICAL ALGORITHM

G. SUN, X. YAN, Y. C. CHEN, *Mechanics and Engineering Science Dep., Fudan Univ., China,* Compare with some traditional optimal methods, genetic algorithm(GA)is more and more widely applied in the field of engineer optimization for its robustness, randomicity as well as global optimal performance. Meanwhile, aerodynamic performance of multi-element airfoil is becoming very important for aircraft design. The configuration of gap is very important for high-lift device design. This paper presents chimera technique with Bi-directional holes for main wing and flap. To increase the flexibility in the selection of sub-domains, this implementation removes region of a mesh containing an embedded grid from that mesh. That is, an embedded mesh introduces a "hole" into the mesh in which it is embedded. Because these regions do not enter into the solution process, inter-grid communication is simplified as communication among the grids is established through the grid boundaries. It can provide enough wide overlap to make the information transfer easy and it can also improve the mesh quality of both main wing and flap wing. The modified genetic algorithm (GA) remarkably improves the efficiency. The resulting optimized multi-element has higher aerodynamic performance than the initial shapes.

W-4D-3. FORWARD FACING ARRAY OF MICROJETS FOR IMPROVING THE FILM COOLING PERFORMANCE AT HYPERSONIC MACH NUMBERS

R. SRIRAM, *Indian Institute of Science, Bangalore, India*, G. JAGADEESH, *Indian Institute of Science, Bangalore, India,* Injection of a forward facing jet (opposite to the freestream direction) from the stagnation point of a blunt body can be used for mitigating both the aerodynamic drag and heat transfer rates at hypersonic Mach numbers. If the jet has enough momentum it can push the bow shock forward, resulting in reduced drag. This will also reduce heat transfer rate over most part of the body except around the jet re-attachment region. A reattachment shock impinging on the blunt body invariably increases the local heat flux. At lower momentum flow rates the forward facing jet cannot push the bow shock ahead of the blunt body and spreads easily over the boundary layer, resulting in reduced heat transfer rates. This technique is usually referred as film cooling. While the effectiveness of the film cooling improves with mass flow rate of the jet, higher momentum flow rates can lead to a stronger reattachment leading to higher heat transfer rate at the reattachment zone. If we are able to reduce the momentum flow rate of the coolant for the same mass flow rate, the coolant coming out can easily spread over the boundary layer and it is possible to improve the effectiveness of the film cooling. Experimental investigations have been carried out in the IISc hypersonic shock tunnel to study the improvement in the effectiveness of film cooling using an array of micro-jets. A 58 deg. Apex angle blunt cone has been selected for the experimental study. Time resolved schlieren flow visualization using high speed camera, aerodynamic drag measurement using a single component free-floating accelerometer balance and measurement of surface convective heat transfer using platinum thin film sensors deposited on Macor substrate are the diagnostics used to understand the effect of an array of micro-jets on the blunt body flow features. Studies have been carried out using a single jet (2mm diameter) and an array of 46 micro-jets (300 micron jet diameter) confined to an area of 25 sq. mm in the stagnation zone of the blunt cone. All the experiments have been carried out at a nominal Mach number of 5.9 with a corresponding stagnation enthalpy of 1.82 MJ/kg. The stagnation pressure of the freesteam is measured in the shock tunnel using a pitot probe. The reservoir pressure for the micro-jet array is measured using a PCB pressure sensor located in the internal chamber inside the blunt cone model. Nitrogen is the coolant gas injected. The jet is injected with a total pressure of 54 KPa. Up to 33% reduction in heat transfer was observed with the array of micro jets near the stagnation zone when compared with the corresponding single jet. No change in drag was observed with injection of coolant and the visualizations show no changes in the flow field external to the boundary layer.

W-4D-4. AERODYNAMIC STUDY ABOUT FORWARD FLIGHT OF A NEW BIONICS FLAPPING STYLE

BAI Peng, CUI Er-jie, ZHAN Hui-Ling, *China Academy of Aerospace Aerodynamics, China,* Firstly, a new kind of bionic flapping style, based on the research about the high unsteady lift mechanisms of the general fruit fly hovering flight, was introduced in this paper. The high aerodynamic lift mechanisms of this new flapping style were explained, and from the viewpoint of the aerodynamic lift and drag, the advantages of this new style comparing to the fruit fly flapping were also introduced. Secondly, The effects of the flapping parameters, the time of accelerating flapping: $\Delta\tau_t$, the time of accelerating rotating: $\Delta\tau_r$ and the angle of attack at constant flapping velocity: α, to the aerodynamic characteristics were studied. And the benefit of the wing flex to the new flapping style aerodynamic characteristics was also studied. It is obvious that wing flex is unuseful for the fruit fly flapping style. Finally, assuming the weight, flapping frequency, drag, wing area and wing average chord are all same with the fruit fly, the numerical simulation method was used to study the forward flight aerodynamic characteristics of this new bionic flapping style. And the mechanisms of the aerodynamic lift and thrust were analyzed carefully. The conclusion could be drawn that this new bionic flapping style can obtain enough aerodynamic lift and thrust to realize forward fly. And the stabilization of this flapping method need to be studied further.

15:00 ~ 16:20 (Room105)

Geophysical Fluid Dynamics (III)

Session Chair : Prof. Van Groesen, Twente Univ/Netherlands

W-4E-1. A NEW METHOD FOR QUASI-THREE DIMENSIONAL VISUALIZATION OF CLOUDS FROM SATELLITE IMAGES

T. N. VENKATESH, *National Aerospace Laboratories, India,* In the field of atmospheric science, visualization is crucial for understanding the underlying processes. While the use of dyes and imaging techniques have advanced to a high degree in laboratory experiments, direct experiments are difficult in the atmosphere. Fortunately, clouds form natural markers and indicate large-scale flows. The main objective of the present work is to construct animated three-dimensional views of large cloud systems from available satellite imagery to understand their dynamics better. The key idea is that since the infra-red (IR) radiation is a measure of the cloud top temperature which in turn is a function of the altitude, it should be possible to infer the three-dimensional nature of the surface of the cloud top. A novel technique for construction of quasi-three dimensional images of clouds from available two dimensional IR satellite images has been developed. Software has been developed using the OpenGL library to render this inferred three-dimensional surface over the globe. To the best of our knowledge, no work of this kind has been reported before. This technique has been applied for a number of cases using IR images from METEOSAT and GOES series of satellites. These cases include tropical cyclones (1999 Bay of Bengal super-cyclone and hurricane Katrina, 2005 etc.) as well as other cloud systems. Animations of the Indian summer monsoon cloud systems for the complete season (June to September) for many years have also been done and have been very useful in gaining an understanding of the monsoon.

W-4E-2. EFFECTS OF NUTRIENTS ON ALGAL BLOOMING IN

EUTROPHIC WATER BODY

T. YUAN, J. C. LI and J. F. ZHOU, *Institute of Mechanics, CAS, China*, In eutrophic waters, phytoplankton or unicellular microalgae can grow rapidly to very high concentrations under favorable environmental conditions, occasionally resulting in harmful algal blooms. This kind of extreme environmental events have been worsening marine ecosystems and causing great economic loss. A dynamic eutrophication model is described to simulate algal growth and nutrient cycling during algal blooming in the present paper. It involves crucial influential factors including water temperature, nutrient supply and light density. Moreover, it takes non-predatory mortality, endogenous respiration and settling into consideration as controlling factors for alga decay. We have endeavored to elucidate the influence of some of these factors on algal blooming including temperature and the two crucial nutrient factors (P, N) by numerical results. In addition, nonlinear qualitative analysis is used to study the mechanism of the algal blooms occurrence. To begin with, we only focus on the examination of the most important nutrient element, phosphorus (P) effect. Based on numerical simulations, the threshold of phosphorus at different temperature may be delineated by the 3D isoquant contours of algal growth rate. It is apparently seen that the larger the phosphorus concentration, and the higher the water temperature, the greater the algal growth rate is, which may explain why alga blooming disasters are prone to occur in polluted water body in a fine summer day. Furthermore, the threshold is reduced when half-saturation constant K_{MP}, a parameter to indicate algae ability to digest nutrient, decreases. The result means that such kind of algae with smaller half-saturation constant grows faster and very probably becomes overwhelming species during algae blooms. The analysis on the phase plot clearly exhibits nonlinear behavior of the system during the process and further verifies the conclusions drawn by numerical simulation. Then, an additional nutrient element, namely nitrogen (N) is involved. Both nonlinear analysis and numerical simulation demonstrate the influence of the initial N/P ratio on the nutrient limitation. Three regions of nitrogen limitation, transitional and phosphorus limitation are identified as the ratio of N over P is rising. In the water body having higher ratio, phosphorus becomes a crucial factor and the algal growth is mainly limited by less supply of P. However, the role of N can't be neglected any more as this ratio drops. The fact means that P limitation is gradually replaced to N limitation, which is in accord with what was found by Sakamoto. In summary, we have investigated the effects of ambient water temperature and nutrients supply on algae blooming. In addition, half-saturation constant is also a decisive factor affecting algae blooming and selecting overwhelming species. Usually phosphorus is a decisive nutrient though, the role of nitrogen should be considered when the ratio of N over P drops to a certain amount in this kind of marine ecosystem disaster.

W-4E-3. A NUMERICAL STUDY OF THE ROLE OF VERTICAL STRUCTURE OF VORTICITY DURING TROPICAL CYCLONE GENESIS

T. N. VENKATESH, *National Aerospace Laboratories, Bangalore, India,* J. MATHEW, *Indian Institute of Science, Bangalore, India,* Understanding the processes leading to tropical cyclone genesis presents a challenge to fluid dynamicists. Of particular interest is the role of mid-level vorticity during early stages of cyclone genesis. An eight-level axisymmetric model with simple parameterizations for clouds and the atmospheric boundary layer was developed to examine the evolution of vortices that are precursors to tropical cyclones. The effect of vertical distributions of vorticity has been studied. To obtain a reasonable representation of the flow structure and physics, axisymmetry is assumed and hydrostatic and gradient wind balance approximations made. The effects of clouds, radiation, boundary layer and sea-surface are parameterized. The prognostic equations in the interior for the azimuthal velocity and the saturation equivalent potential temperature are solved. A Poisson equation is solved for the secondary flow. Non-linear terms are integrated using the second-order Adams-Bashforth scheme and the diffusion terms treated implicitly. The basic model has been validated with analytical results available for the spin-down of vortices. With the inclusion of the cloud and boundary layer parameterizations, the evolution of deep vortices into hurricanes and the subsequent decay is simulated quite well. The finite amplitude nature, dependence on various parameters, like sea surface temperature, Coriolis parameter, initial vortex strength etc. have been studied and these compare well with other simulations. The novel feature of this study is that the evolution of mid-level vortices has been studied. A new finding is the manner in which mid-level vortices decay and how, on simulated merger of these mid-level vortices, the resulting vortex amplifies to hurricane strength in a realistic time-frame. These results form an important part of the evidence in favour of the authors' model for tropical cyclone genesis.

W-4E-4. IN WHAT SENSE IS A LOW-REYNOLDS MIXING LAYER STABLE?

Roddam NARASIMHA, Pinaki BHATTACHARYA, Rama GOVINDARAJAN, *Engineering Mechanics Unit, JNCASR, Bangalore, India*, The Orr–Sommerfeld equation governs the evolution of linear disturbance modes in a strictly parallel flow. For the plane incompressible mixing-layer this equation yields a critical Reynolds number equal to zero [1]. This result has been difficult to understand for a long time, for 'energy' theories indicate that there must be a non-zero Reynolds number (however small), below which viscosity would damp out any disturbance. Recently, we have used a non-parallel analysis to show that the critical Reynolds number *R*cr for the mixing-layer is not zero [2]. When expressed with the velocity difference D and vorticity thickness __ as velocity and length scales respectively, it is found that *R*cr is about 30. The analysis therein follows the minimal composite theory developed in [3]. We investigate here the physical behaviour of the disturbance kinetic energy in order to gain insight into the character of the stability of the flow. The mean flow in the incompressible mixing-layer we consider possesses a similarity solution. We simulate the flow as it might be observed in a wave-maker experiment. To this end a single disturbance mode, of dimensional frequency _*d*, is introduced into the flow at an appropriate station. The local kinetic energy density of the disturbance, averaged over one period, is denoted by <*kd*>, and fixing the amplitude level of the disturbance to be *A*0 at the location where it is introduced, we further define $\kappa \equiv \frac{\langle k_d \rangle}{|A_0|^2 \Delta^2}$, as the non-dimensional disturbance kinetic energy. Two integral quantities are also defined as follows

$$K = \int_{-\infty}^{\infty} \kappa \, \mathrm{d}y,$$

$$\overline{K} = \int_{-\infty}^{\infty} \kappa \, \mathrm{d}\left(\frac{y_d \Delta}{\nu}\right). \qquad \frac{1}{\overline{K}} \frac{\mathrm{d}\overline{K}}{\mathrm{d}x} = \frac{1}{K} \frac{\mathrm{d}K}{\mathrm{d}x} + \frac{p}{R},$$

where *p* is a constant depending on the velocity ratio parameter L = D/(2U_−D). As illustration we show the contours of _ in the two extremes of L = 49/50 and nearly shearless flow L = 1/39 is shown in figures 1 and 2. It is apparent that upstream (/downstream) of the streamwise location corresponding to R _ 39, there is hardly any streamline in the core of the flow along which energy decays (/grows) in the streamwise direction. Thus the picture is intuitively faithful to the concept of stability (/instability). For the same flows and the same frequency _d considered above, the variation of the two integrated kinetic energies is shown in figures 3 and 4. We see that *K* decays upto *R* _ 30 and then amplifies, but at a relatively slow rate. On the other hand amplifies monotonically at all *R*. These results show that the integral over *yd* grows continuously from very low *R*, and hence points towards instability. On the other hand integral *K* over the similarity coordinate y shows stability upto *R* _ 30. It is in this sense that the mixing-layer has a non-zero critical Reynolds number. Thus the maximum disturbance kinetic energy density _max may drop substantially over a given streamwise extent of the flow (figure 1), but its integral in *yd* may increase if the flow is rapidly thickening (see figure 3). Stability thus depends on how the norm is defined.

15:00 ~ 16:20 (Room106)

Convection and Buoyancy – Driven Flows (II)

Session Chair : Prof. K. Mansour, Amirkabir Univ of Tech/Iran

W-4F-1. OBERBECK CONVECTION IN CHIRAL FLUID THROUGH A VERTICAL CHANNEL IN THE PRESENCE OF TRANSVERSE MAGNETIC FIELD

NAGARAJU, *Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumkur, India* B. M. RAJPRAKASH, *Department of Mechanical Engineering, University Visveswaraya College of Engineering, Bangalore, India* N. RUDRAIAH, *National Research Institute for Applied Mathematics, Bangalore, India,* Conventionally, fans and regular fluids are used to improve the cooling process in mechanical, electrical and electronic devices but they increase the device weight, size and bulk. These days the industries are changed to find the miniature and portable devices for this purpose. Therefore, there is an urgent need of suitable materials to overcome these thermal problems. At present nano and smart materials are becoming popular for use in such cases. As an alternative to these materials we propose in this paper the use of chiral material. At present solid chiral materials have been used to manufacture devices like antennas, but much attention has not been given to chiral fluids like turpentine, sugarcane solution, body fluids and so on. By definition chiral material is one which cannot be brought into congruence by its mirror image by translation and rotation having the property of either left-handed