60th Annual Meeting of the Divison of Fluid Dynamics

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12:01PM GR.00008 Axisymmetric interaction between a laminar vortex ring and a sphere – stationary sphere case.[1] , PAULO FERREIRA DE SOUSA, JAMES ALLEN, New Mexico State University — The interaction between a vortex ring and a neutrally buoyant sphere centered in the axis of travel of the ring is one of the simplest fluid-structure interactions and was commented on by Lord Kelvin. A starting case in order to calculate this case is to have a laminar vortex ring interact with a stationary sphere. In order to calculate this interaction, a high-order 3D immersed boundary flow solver was used. The momentum equations are spatially discretized on a staggered mesh by finite differences and all derivatives are evaluated with implicit 10th order compact finite difference schemes. The fourth order accurate Runge-Kutta scheme was used for temporal discretization. The immersed boundary was implemented through a direct forcing procedure. It is shown that as the vortex approaches the sphere, significant secondary vorticity is generated on the surface of the sphere. As the interaction continues and the vortex ring diameter increases in response to the presence of the sphere, a secondary vorticity ring wraps around the front of the advancing vortex. This secondary ring separates from the surface and breaks up as it interacts with the primary ring. For Reynolds number around 1000, a three-dimensional azimuthal instability, which appears to be of centrifugal nature, grows on the secondary vorticity ring.

[1]Support for Paulo Ferreira de Sousa was provided by FCT(SFRH/BPD/21778/2005)

12:14PM GR.00009 The Vortices Trapped above Low-aspect-ratio Wings , JIAN TANG — A stationary vortex trapped above the nondelta, low-aspect-ratio wings was first obtained in 3D unsteady numerical simulation. Flow visualization was conducted in water-channel using hydrogen bubble. The results verify that there is a vortex trapped above the low-aspect-ratio wings and the stationary vortex is consisted of two semi-ball, anti-rotation vortices which are different from the leading edge vortices on the delta wing. This stationary vortex trapped above the nondelta, low-aspect-ratio wings is a new phenomenon, which is different from the leading edge vortex on the delta wing. The numerical results show that lift coefficient increase to 0.8 when incidence increases form $0°$ to $30°$, the lift coefficient keeps this value up to $45°$–a very high stall angle. The numerical results indicate that the trapped vortex might be the source of the high stall angle of attack and nonlinear lift at high incidence. Accompanied with the low-aspect-ratio wing, the existence of the stationary vortex is thought to be related to the strong effects of tip vortices. Further experimental and numerical works have been undertaken, the results show that trapped vortices have variant shapes and different critical angels of attack.

12:27PM GR.00010 Tilt-induced instability of a vortex in a stratified fluid , PATRICE MEUNIER, NICOLAS BOULANGER, STÉPHANE LE DIZES, IRPHE — The dynamics and stability of a vortex in a linearly stratified fluid is studied experimentally and theoretically when the axis of the vortex is slightly inclined with respect to the direction of stratification. For Froude numbers larger than one, the tilt of the axis induces strong density gradients and an intense axial flow in a rim around the vortex, at the radius where the angular velocity of the vortex is equal to the Brunt-Vaisala frequency. This critical layer can be studied theoretically in the viscous regime, which shows that the axial flow changes from a jet to a shear layer when turning around the vortex, in excellent agreement with the PIV measurements. For high Reynolds numbers, this axial flow creates a Kelvin-Helmholtz instability and a jet instability, leading to secondary vortices rolled-up around the primary vortex. The growth rates of these instabilities have been measured and compared to predictions from a linear stability analysis. These three-dimensional instabilities of the tilted vortex does not lead to the destruction of the vortex, but it decreases its core size if the Froude number is larger but close to one.

Monday, November 19, 2007 10:30AM - 12:27PM – Session GS Turbulence: Mixing II Salt Palace Convention Center Ballroom EG

10:30AM GS.00001 Large eddy simulations and experiments on mixing in a confined rectangular turbulent jet , BO KONG, ANUP GOKARN, FRANCINE BATTAGLIA, MICHAEL OLSEN, RODNEY FOX, JAMES HILL, Iowa State University — Large eddy simulations were performed for a confined rectangular co-flowing liquid jet at Reynolds number 20,000 based on the average velocity and hydraulic diameter of the channel. An incompressible finite-difference formulation of the filtered Navier-Stokes and mass conservation equations on a partially-staggered grid was used. The effects of grid resolution, numerical schemes, and subgrid models on the LES solutions were studied. Validation was performed by comparing LES statistics with those obtained from low- and high-speed particle image velocimetry and laser-induced fluorescence measurements. These statistics include mean, velocity and scalar variances, Reynolds stress, one- and two-point correlation coefficients, skewness, and kurtosis; all compare well with experimental data. The good agreement with two-point spatial correlations suggests that structures in the LES field are similar to those in the actual flow.

10:43AM GS.00002 Investigation of large fluctuations of scalar dissipation related to coherent vortices and flow topology , BERTRAND ROLLIN, YVES DUBIEF, The University of Vermont — For Schmidt numbers greater than one, turbulent mixing of passive scalars produces large fluctuations of scalar dissipation contained in thin and elongated volumes. Recent research has shown that those sheet-like structures form in biaxial extensional flows. The first objective of this study is to relate this particular topology of turbulent flows to coherent vortices. Next, the dynamics of the regions of strong scalar dissipation is investigated as a function of the surrounding vortices and biaxial extensional flows. The study is based on direct numerical simulation of a turbulent Kolmogorov flow at low Reynolds number, with the adequate resolution for Schmidt number larger than unity. The local topology of the flow is characterized by the invariants and eigenvalues of the velocity gradient tensors. We use algorithms of vortex skeleton identification to examine the spatio- temporal correlation between the topology of the regions of strong scalar gradients and the neighboring vortices.

10:56AM GS.00003 Turbulence Measurements of a High Reynolds Number Inclined Jet in Crossflow using PIV and FRAP , VIPLUV AGA, CLAUDIO FELICIANI, NDAONA CHOKANI, REZA ABHARI, ETH Zurich — The TKE, turbulence intensity and Reynolds shear stress for a jet inclined at $30°$ to the freestream with a blowing ratio of 2 and Reynolds numbers, based on hole diameter, (Re_d) of 30000 are measured using 3-D Stereoscopic PIV and a miniature Fast Response Aerodynamic Probe ($FRAP$). The Maximum Entropy Method is used to compose a spectrum for variance calculations from PIV data, thereby ameliorating the low sampling rate and systematic noise. The PIV measurements are compared with those from the $FRAP$ and found to be within error estimates. TKE contours indicate that the two main sites of turbulence production are the counter rotating vortex pair and the shearing surface of the jet. It is observed that the turbulence within the vortex pair is higher and dissipates slower than that in the jet shear surface. The eddy diffusivities of momentum in different cardinal directions are also compared and found to have an anistropic distribution. The mechanisms of turbulent mixing in this complex flow and their relevance to turbulence modeling are commented upon.

11:09AM GS.00004 Experimental validation of a new closure scheme for scalar diffusion. , PARTHA SARATHI, Faculty of Engineering, University of Western Ontario, ROI GURKA, PAUL SULLIVAN, GREGORY KOPP — The study of contaminant diffusion in environmental flows is important to the assessment of the hazards that result from pollutants released into atmosphere. The reduction of scalar concentration is only due to molecular diffusion and this is usually described through a probability density function. Approximations that are made for terms in the differential equations that govern the evolution of the moments of the probability density function of scalar concentration are shown to have solutions that provide qualitative agreement with observed distributions of the first four moments. It is expected that a reasonable approximation of the probability density function is derived through inversion of the first four moments. The new closure scheme for both the convective and diffusive terms has produced some promising qualitative results. Simultaneous measurements of velocity and scalar concentrations, using particle image velocimetry (PIV) and planer laser-induced fluorescence (PLIF) respectively, on a plume in a grid-turbulence water tunnel experiment are used to quantitatively explore this closure scheme. The velocity and concentration fields are measured and analyzed in order to characterize the flow statistics such as turbulent fluxes and distributed moments.