ÖMER SAVAŞ **February, 2013**

CURRENT RESEARCH SUMMARY

My research effort has been nearly equally partitioned among aerodynamics, biofluid mechanics, energy & environment, turbulence, and vortex dynamics. It is primarily experimental, with some numerical components carried out in collaboration with colleagues.

Artificial Photosynthesis

DOE is looking for a new paradigm of solar energy by producing hydrocarbon fuels directly from the Sun by supporting a large effort spread over three main campuses: Caltech, LBNL, and UC Berkeley. Our laboratory participates in system design for transporting chemical species over a large range of scales. We have built self-similar flow channel designs to provide parallel multiscale transport of multiple fluid species. The self-similar characteristic of these designs simplifies manufacturing and allows for flexible scalability. We are currently focusing is on harnessing hydrogen bubbles at the evolution-stage. Since the catalytic surface potential affects both the contact angle and bubble detachment diameter, surface geometries can be designed to expedite bubble detachment for collection. The complexity of the prototype designs will also affect the efficiency of product collection after detachment. Currently, bubble transport through different configurations of microrod arrays are investigated.

Convective Cloud Physics

The importance of clouds in the life of our planet is obvious; they are essential elements of the hydrological and radiative cycles of the life on earth. Condensation of water vapor into water droplets and their subsequent growth, through collisions and coalescence, all take place at micro scales which eventually determine the cloud properties at macro scales, such as precipitation efficiency and optical characteristics. There is evidence that intermittent events at the dissipative scales of turbulence is the key agent in the amalgamation and coalescence of the droplets. We are constructing an Eaton box to explore the dynamics of droplets at Kolmogorov scales. The focus is on the growth of water droplets at high Reynolds numbers, following their formation through nucleation. This is a collaborative work between KAUST (Prof. Thoroddsen) and Berkeley (Profs. Marcus and Savaş).

Ocean Wave Energy

In current prototypes, buoy-type ocean wave energy converters are used which exhibit resonant responses when subject to excitation by ocean waves. We have proposed a novel excitation scheme which has the potential to improve the energy harvesting capabilities of these converters. The scheme uses incident waves to modulate the mass of the device in a manner which amplifies its potential harvesting capabilities. To illustrate the novel excitation scheme, a simple one-degree of freedom model was developed for the wave energy converter. After the stability regime of this system has been established, the model is then used to show that the excitation scheme improves the power harvesting capabilities even when amplitude restrictions are present. It is also demonstrated that the sensitivity of the device’s power harvesting capabilities to changes in damping becomes much smaller when the novel excitation scheme is used. A prototype has been experimentally tested in our tow tank facility at Richmond Fled Station to verify the prediction of this proposed new mechanism. This is a collaborative work with Prof. O’Reilly.

Rotating Flows

Rotating platforms offer intriguing ways of observing vortex interactions. Our laboratory has the capability to generate and observe flow conditions on a rotating platform. Examples of recent work are generation of multiple vortices by specific transient flow history and eventual dynamics of the vortices. Also in the works is generating grid turbulence in the rotating platform and observe its decay in various rotation histories.

Rotorcraft Ground Effects

Velocity measurements in our towing tank offer insight into the characteristics of both the confined ground vortices and the large recirculation zones that can lead to brownout conditions when a rotorcraft is in the close proximity of ground. As these vortices amalgamate into a strong ground vortex or more diffuse recirculation region, a stagnation point flow is created at the leading edge of the circulation region, entraining these particles into the flow. The addition of pitch to the rotor disk indicates that the angled downwash can displace the ground vortex from its original position and cause a slightly more diffuse recirculation. However, since the vortex is still relatively strong, particle entrainment is probably only enhanced by pitching maneuvers rather than alleviated.

Superhydrophobic Drag Reduction

To be able to reduce drag in turbulent flows has great economic and technological implications. Sharks achieve that with their precision skins. Humans have tried numerous schemes on their machines to reduce turbulent drag, with very limited success. Now, there is great excitement and substantial effort to utilize superhydrophobic surfaces to achieve this goal. Even though the concept has been demonstrated at micrometer scales in the laboratory, its application to the larger engineering systems, e.g. marine transport, requires an innate understanding of the turbulent flow structure on textured hydrophobic surfaces. We are constructing a test bed to explore possible methodologies to achieve drag reduction in a turbulent boundary layer on a cylindrical model in a tow tank at moderate Reynolds numbers.

Turbulent Discharge

During the height of the Gulf of Mexico oil spill in 2010, we participated in the deliberations of the Flow Rate Technical Group (FRTG) formed by the USGS to provide estimates of leakage rate. It was clear that there were no established methods to estimate the flow rate in accidental discharges. We embarked on a series experiments in water at the tow tank at the Richmond Field Station to study the visible flow features in the near field of turbulent jets and to assess their usefulness in estimating the discharge rate of a turbulent jet. The large eddies at the core of the flow and the smaller eddies at the edge show disparate, independent length scales. Their convection speeds are more than an order of magnitude apart. Discharge rate estimates based on large scale core features are useful. However, their reliability depends on a priori knowledge of the state of the bulk flow upstream of the discharge location. In collaboration with Dr. Franklin Shaffer of NETL/DOE, a fellow FRTG member, we have carried out further experiments with the expressed purpose of developing correlation techniques to estimate accidental discharge rates in the field.

Turbulent Flow Structure

Flow structure in the viscous sublayer of a turbulent boundary layer is well studied. The flow in the viscous sublayer of turbulent pipe flow exhibits similar behavior to the viscous sublayer in turbulent boundary layer. Flow visualization experiments show that this similarity in the inner layer structure extends to swirling flows in pipe flow. The goal of this series of experiments is to establish similarities and differences between flow with and without swirl. A parallel goal is to map out the swirl decay and its wall signature in turbulent pipe flow.

Vortex Filament Instabilities

Our most recent work on vortex dynamics has been on the stability characteristics of helical vortex filaments in the wake of a hovering rotorcraft. Soon after their formation, the vortex filaments in the wake of the rotor develop long and short wave instabilities. In the long wave instability mode, two of the three vortices coming off the rotor orbit around each other and merge in about 0.4 of the theoretical orbit time, after which the third vortex joins the merger to form a single, apparently turbulent helical vortex filament. The wavelengths of the short wave instabilities are about 0.4 of the wake radius, about 17 cycles over the circumference. The short waves exhibit a linear growth rate during the first half of their orbital motion, and an exponential growth prior to merging. These results corroborate and further support the classical paper of Widnall (1972).

Vortex Ring State

In vortex ring state (VRS), the vortex filaments trailed off the blades of a rotorcraft coalesce around the rotor disk forming an unsteady über ring. This vortex ring detaches into the wake periodically, causing extreme oscillations in thrust, with periods on the order of several tens of rotor revolutions. Over the leading edge, the vorticity remains in a compact zone and the local flow topology remains relatively unchanged. The flow over the trailing edge exhibits large variations in topology and vorticity distribution in the flow; ranging from an open wake during the phase of increasing thrust to a compact, closed wake during the phase of decreasing thrust during the VRS thrust cycle. Maxima of the VRS thrust oscillations correlate well with the maxima of circulation, enstrophy, and minima of enstrophy dispersion radius observed in the vicinity of the rotor disk.

Vortex-Wake Interactions with Walls

Vortex ring state formed in ground effect is a serious concern for brown out for the pilot. If no pilot, then, brownout is not a concern anymore except for engine ingestion. However, the ground vortex interaction at close proximity affects the vortex wake development behavior, hence trust and handling characteristics. When UAV's operate in close proximity of objects, the lateral wall interaction with the wake vortex system is a serious aerodynamics concern. Even more serious is the operation of UAV in a corner or in a parallel channel. The goal of this study is to investigate the dynamics of vortex wake in close proximity of impermeable walls.