# DEPARTMENT OF AEROSPACE ENGINEERING
# AND ENGINEERING MECHANICS

### SUMMER RESEARCH OPPORTUNITIES
### FOR UNDERGRADUATE WOMEN

## APPLICATION DEADLINE: MARCH 1, 2002

*The Department of Aerospace Engineering and Engineering Mechanics is pleased to offer the following research projects for the summer of 2002. Interested students are urged to contact the faculty member(s) directing the project(s) that most interest them. By contacting the faculty member, you can discover more about the project, learn what your responsibilities will be, and if possible, develop a timetable for the twelve-week research period.*

**Professor E. J. Gutmark**
**880 ERC x6-1227 Fax (513) 556-5038 Email: egutmark@uceng.uc.edu**

**Current Research Topics at the *Gas Dynamics and Propulsion Laboratory* of the Department of Aerospace Engineering and Engineering Mechanics**

**1. <u>Jet Noise-Prediction and Reduction</u>**

The advent of jet engine as a power plant for military and civil aircraft and its unavoidable counterpart, jet engine noise, initiated substantial research on the sources and causes of jet noise, as well as methods and devices for its reduction. The noise level of jet engines, particularly during takeoff and climb, is often a concern for people living near airports. Such high noise levels can limit future airport air traffic expansion, and force new airports to occupy remote sites. New requirements for lower jet noise are a continued area of interest both by governmental agencies around the world and by neighborhoods located in close proximity to airports, flight paths and to engine and flight vehicle manufacturers. Due to these concerns a need to further jet noise reduction technology is in demand. Various approaches have been proposed to overcome the noise issue. The optimal solution should be such that substantial noise suppression is achieved using a method that is easy to implement, low cost, reliable, and without substantial adverse effects on the engine performance. Development of such devise requires basic understanding of the noise generation mechanisms. The objectives of our project are to evaluate experimentally new concepts for jet noise reduction and to develop analytical or numerical tools for the prediction of jet noise and jet noise reduction techniques.

## 2. Combustion Control

Considerable amount of work in the area of passive and active combustion control for gaseous and liquid fueled combustion has been reported during the last two decades. These studies have dealt mostly with bluff-body-stabilized combustor and dump combustors where the recirculation induced by a bluff-body or by a sudden expansion is used to stabilize the flame and were more recently extended to swirl stabilized combustors. Active control strategies have been used to suppress thermo-acoustic instabilities resulting from a coupling between the heat release and the acoustic modes in the combustor. These control strategies have generally relied on modulating the fuel injection and phase shifting it so as to decouple the pressure rise and heat release with respect to each other. Control strategies have also looked at improving fuel efficiency and reducing pollutants, and in extending flammability limits. Our research deals with the control of industrial gas-turbine gaseous and spray combustors with swirlers and distributed fuel injection for rapid mixing and stabilization. It focuses on investigating the mixing patterns and flame structure in a multiple swirl stabilized combustor and develop control strategies for improved performance of industrial combustors.

## 3. Pulse Detonation Engines (PDE)

A pulse detonation engine (PDE) offers few moving parts, high efficiency, high thrust, low weight, low cost, and ease of scaling. These make the PDE an attractive alternative to jet turbine engines for small disposable engines. The near constant volume heat addition process, along with the lack of a compression cycle, lend to the high efficiency and specific impulse, simplicity, and low-cost of pulse detonation engines. Pulse detonation engines have the potential for operation at speeds ranging from static to hypersonic, with competitive efficiencies, enabling supersonic operation beyond conventional gas turbine engine technology. Currently, no single cycle engine exists which has such a broad range of operability. Computational and experimental program is conducted at UC to investigate and develop an air breathing pulse detonation engine (PDE). This research effort involves investigating such critical issues as: detonation initiation and propagation; valving, timing and control; instrumentation and diagnostics; purging, heat transfer, and repetition rate; noise and multi-tube effects; detonation and deflagration to detonation transition modeling; and performance prediction and analysis.

## 4. Aerodynamics and Flow Control of Compressors and Turbines

Flow patterns in the compressors and turbines are three-dimensional and unsteady. They occur in a harsh environment at high free stream turbulence levels and a wide range of Reynolds numbers. Consequently, the flow is characterized by complex flow phenomena such as relaminarization, separation bubbles, transition, reattachment, and unsteady wake-boundary layer interaction. These complex fluid dynamics issues are not well understood and cannot be adequately predicted. The aim of the project is to develop better physical understanding of these processes and ability to predict the events to achieve improved design methods for efficient compressors and turbines. An additional objective is to develop flow control methods including micro systems to modify the flow patterns and achieve improved performance.

## 5. Heat transfer for Turbine Blade Cooling

The performance and efficiency of gas-turbine engines can be significantly improved by increasing the combustion temperature. The major problems associated with this increased temperature are the increased thermal stresses on the turbine blades that could lead to their failure. To allow higher combustion temperatures, blades of gas turbines should be protected from the hot gases. One of the method to protect gas turbine blades are the film cooling techniques that have been investigated during the last four decays. Other methods include trailing edge blowing and internal cooling.
Our research is performed in a unique facility at UC comprising of a transonic cascade in which cooling air is simulated by heavy gases and heat transfer efficiency and its effect on the blade aerodynamics is investigated in advanced blade geometries.

## 6. Novel Hydraulic System for Oil-Well Drilling

This project aims to design, construct, and conduct testing in a new facility at the Fluid Mechanic and Propulsion Laboratory at the University of Cincinnati. The facility is used to study the hydrodynamics of Halliburton roller cone and PDC drill bits for oil explorations. The acquisition of the pressure map under the drill bit and the measurements and visualization of the flow field around the bit for different nozzles and for a wide range of operating conditions are the main objectives of the investigation. Improved hydrodynamic performance will be translated into tremendous savings in the cost of oil drilling operations. The goal of the current project is to test new nozzles in a realistic drilling environment including high flow rates used in drilling operations. The results will show the influences of different nozzle geometries on drill bit performance in actual bottom hole environment. The experimental work will include both testing in an existing tank assembly for single nozzle tests and in a new tank assembly that will be built in order to simulate the 12 ¼” bottom hole assembly and pattern. The tests include optimization of bit internal and nozzle geometry for predetermined pressure and momentum distribution with high discharge coefficient with low pressure-drop, pressure distribution over the impingement plate. Other measurements include the velocity field measured by PIV (Particle Image Velocimetry). In addition to the experimental component, Computational Fluid Dynamics (CFD) is used to study the flow in the new nozzles and around the 12 ¼” modular roller cone bit.

## 7. Flight Control of Delta Wing Aircrafts Using Vortex Actuators

Lift force on delta wings at a high angle of attack relies on large-scale vortices that separate at the leading edges of the wing. At high angle of attack these vortices loose gradually their coherence due to intrinsic flow instabilities that lead to vortex breakdown. At these conditions, the lift produced by the vortices is reduced causing loss of controllability and stall.

Recent tests showed that small continuous or pulsating jets that are injected into the vortex core from certain locations on the wing surface could control the behavior of these vortices. Depending on the orientation of the injected jet, the vortex breakdown can be delayed or accelerated and the vortex location relative to the wing surface can be altered. The jet injection can therefore be used for flight control without the conventional control surfaces. Controlled actuation of different combinations of jets based on feedback from sensors distributed over the wing surface can yield desired pitch, yaw, and roll moments. The pulsating jets do not require tubing and pumps as they are based on an acoustic resonance concept. Moreover, this method incurs little or no drag penalty. The control system will rely on rational activation of pulsating jets. Static and dynamic modeling of the flow topology, aerodynamic responses and actuator characteristics are required for closed-loop control system design. Advanced external flow control and aircraft attitude control architectures and algorithms are needed to cope with the highly coupled, time-varying, uncertain and complex nonlinear aerodynamics that are dynamically and structurally unstable. The present concept is applicable to attitude control of tailless fighters, reentry vehicles and UAVs, especially micro UAVs, without requiring control surfaces such as ailerons, rudder, elevator, or flaps. This type of controlled vortical lift can also be used to enhance performance of lifting bodies. The advantage of such a system lies in its aerodynamic simplicity, reduced radar cross-section and ease of miniaturization.