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Active Flow Control: Concepts and Applications

Overview

During the past couple of decades, there have been significant developments in the active flow control (AFC) devices for modification of fluid flows that the AFC technology is now ready for many industrial applications. There have been major advances in actuators and sensors, and controllers and closed loop control architectures accompanied by significant developments in theory, modelling and simulation, and experiments. A variety of impressive flow control results have been achieved experimentally by many researchers including the vectoring of conventional propulsive jets, modification of aerodynamic characteristics of bluff bodies, control of lift and drag of airfoils/wings, drag reduction of automobiles/trucks, control and balance of convective and radiative heat transfer in buildings for energy efficiency and thermal comfort, reduction of skin-friction in boundary layer flows, enhanced mixing in circular jets and other devices such as ejectors, and control of external as well as internal flow separation and of cavity oscillations (this list is not inclusive). In addition, many of these flow fields have been simulated using a variety of numerical approaches - Unsteady Reynolds-Averaged Navier-Stokes (URANS) equations with a variety of turbulence model, Large Eddy Simulations (LES), Detached Eddy Simulation (DES) and Direct Numerical Simulation (DNS). There have been important advances in both actuator hardware and modelling. Several classes of actuators have been developed – piezoelectric, electrodynamic, plasma, and hydraulic some of which are very robust and have characteristics (low energy consumption, light weight, relatively inexpensive, tested for long operations etc.) that they are currently being used or will be used in the industrial applications in the very near future. The goal of this course is to expose the participants regarding the AFC concepts, the AFC devices and their industrial applications.

The course will begin with a brief introduction to the history of passive and active flow control followed by the physical concepts behind the flow modification. The lectures will then include a description of passive control devices such as riblets, vortex generators, vanes and micro-ramps etc. and the types of AFC actuators namely the piezoelectric, electrodynamic, hydraulic, plasma etc. followed by active control devices such as synthetic jets, pulsed jets, micro-jets, sweeping jets etc. and the sensors namely the shear stress, pressure and shear thermal stress sensors. After that two lectures will be devoted to open loop and closed loop flow control methodologies. After that a lecture will be devoted to integration, design and optimization of AFC devices using genetic algorithms and artificial neural nets. The final lecture will conclude with the current state-of-the-art, lessons learned, and directions for future experimental and modelling research in AFC. All ten lectures will be followed by ten tutorials describing and demonstrating example problems covering a wide variety of problems including a few full scale industrial applications. The course will thus provide an excellent overview of AFC concepts and applications to the students, researchers and practitioners. The foreign faculty member is an internationally known academic, researcher and practitioner with proven knowledge, experience, and demonstrable ability in teaching, consultancy, research, and training in the field of Computational Fluid Mechanics and its application to the implementation of Active Flow Control in various industrial applications. The course will be planned and offered as per the norms set by MNNIT Allahabad. The host faculty will assist in the tutorials/demonstrations who teaches Applied Mathematics and Computation, and Computational Fluid Dynamics courses at PG level regularly.

Course Objectives

The primary objectives of the course are as follows:

i) Expose the participants to Active Flow control Concepts and Applications,
ii) Build the confidence and capability amongst the participants in the application of various AFC devices by using the modelling tools to achieve the desired outcome e.g. reduction in drag or control of buffet or thrust-vectoring of propulsive jets for manoeuvring etc.,
iii) Provide exposure to full scale practical problems for obtaining the solutions to active flow problems,
iv) Enhance the capability of the participants to formulate, analyze and numerically solve the complex active flow problems.

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Dates	**12th March to 17th March 2018**	
Location	**Motilal Nehru National Institute of Technology (MNNIT) Allahabad, U.P., India.**	
Course Schedule	12th March 2018 (Monday)	Inauguration: 3.00 PM-3.30 PM High Tea: 3.30 PM-4.00 PM **Lecture-1: 4:00 PM –5.00 PM** Topic: Introduction to Passive and Active Flow Control – History, Concepts and Taxonomy. Tea Break: 5.00 Noon-5.15 PM **Lecture-2: 5.15 PM-6.15 PM** Topic: Physical Concepts behind Flow Modification with Passive & Active Flow Control. **Tutorial-1: 6.15 PM-7.15 PM** Topic: Demonstration examples of Passive Flow Control (e.g. Control of Shock/Boundary Layer Interaction using Vortex Generators, Laminarization of a Turbulent Boundary Layer Using Large Eddy Break Devices and Reducing the Separated Flow Region in an S-Duct Using Micro-Ramps and Vanes). **Tutorial-2: 7.15 PM-8.15 PM** Topic: Demonstration examples of Active Flow Control (e.g. Control of Shock/Boundary Layer Interaction using Synthetic Jets, Control of Cavity Oscillations using Micro-Jets and Thrust-Vectoring of a Propulsive Jet using Synthetic/Pulsed Jets).
	13th March 2018 (Tuesday)	**Lecture-3: 4 PM –5PM** Topic: Passive Flow Control Devices: Riblets, Vortex Generators, Vanes, Micro-Ramps, Large Eddy Breakup Devices (LEBUs), Roughness Elements for Transition Delay. Tea Break: 5PM-5.15 PM **Lecture-4: 5.15 PM-6.15 PM** Topic: Types of Actuators for Active Flow Control (Piezoelectric, Electrodynamic, Hydraulic, Plasma, Combustion-Driven), their Mathematical Models, Control Authority and Energy Requirements. **Tutorial-3: 6.15 PM-7.15 PM** Topic: Problem Solving Session Using the Mathematical Models of Different Actuators and Demonstration of their Flow Control Features. **Tutorial-4: 7.15 PM-8.15 PM** Topic: Integration of Different Actuators on Objects Whose Flow Field Needs to be Controlled and Demonstration of their Flow Controlling Features When Integrated with the Objects with a Couple of Simulation Examples.
	14th March 2018 (Wednesday)	**Lecture-5: 4PM –5 PM** Topic: Active Flow Control Devices (Synthetic Jet, Pulsed Jet, Micro-Jet, Sweeping Jet, Resonance Tubes and Whistles, Splash Jet, Vortex Generator Jet etc.). Tea Break: 5PM-5.15 PM **Lecture-6: 5.15 PM-6.15 PM** Topic: Sensors for Active Flow Control (MEMS Shear Stress Sensors, Pressure Sensors and Microphones, Thermal Shear Stress Sensors). **Tutorial-5: 6.15 PM-7.15 PM** Topic: Modeling of the Internal Structure (Flow Field) of Synthetic Jet, Pulsed Jet, Micro-Jet and Sweeping Jet Actuators and Demonstration to Explain their Flow Controlling Features. **Tutorial-6: 7.15 PM-8.15 PM** Topic: Modeling of Shear Stress, Pressure, and Thermal Shear Stress Sensors and Methodology of Integration of Sensors in Flow Simulations Using RANS, LES or DNS Equations.

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	15th March 2018 (Thursday)	**Lecture-7: 4PM –5 PM** Topic: Open Loop Flow Control Using the AFC Devices. Tea Break: 5 PM-5.15 PM **Lecture-8: 5.15 PM-6.15 PM** Topic: Closed Loop Flow Control (Control Architectures and Controllers– Neural Nets, Genetic and Fuzzy, System Performance and Scaling). **Tutorial-7: 6.15 PM-7.15 PM** Topic: Examples of Open Loop Control Using the AFC Devices (e.g. Control of Wake behind a Bluff-Body, Thrust Augmentation of an Ejector, and Airfoil Virtual Aero-shaping). **Tutorial-8: 7.15 PM-8.15 PM** Topic: Examples of Closed Loop Control Using the AFC Devices (e.g. Control of Cavity Oscillations Using Micro-Jets and Reducing/Eliminating Separation Behind a Backward Facing Step, and Buffett Control for Unsteady Flow Past an Airfoil).
	16th March 2018 (Friday)	**Lecture-9: 4PM –5 PM** Topic: Integration, Design and Optimization of AFC Devices Using Genetic algorithms and Artificial Neural Nets. Tea Break: 5 PM-5.15 PM **Lecture-10: 5.15 PM-6.15 PM** Topic: Current State of the Art, Lessons Learned, Directions for Future Experimental & Modelling Research. **Tutorial-9: 6.15 PM-7.15 PM** Topic: Full Scale Demonstration of Drag Reduction of a Trailer-Tractor Truck Using a Large Array of Synthetic Jet Actuators. **Tutorial-10: 7.15 PM-8.15 PM** Topic: Experimental and CFD Demonstration of a Guided Weapon Release from an Aircraft Bay (Cavity) with AFC, and Flow Control on the Vertical Tail of Boeing 757 Using Sweeping Jets.
	17th March 2018 (Saturday)	Evaluation of Learning Outcomes (Examination/Test, Feedback) & Certificate distribution. 9.30 AM-12 Noon.

Who should attend?

UG and PG Students, Research scholars, Faculty members, Practicing Engineers, Scientists.

Course Fee

One-Time GIAN Registration: Please visit http://www.gian.iitkgp.ac.in/GREGN/ and register by paying Rs. 500/- (those who have already been paid, need not pay again).

The participation fees for attending the course is as follows:

Participants from abroad:	US$ 100
Industry/ Research Organizations:	Rs. 2000
Academic Institutions (Faculty members):	Rs. 1000
Academic Institutions (Students/Research scholars):	Rs. 500

- The above fee includes all instructional materials, computer use for tutorials & assignments (if any).
- Minimum 90% attendance necessary to be eligible for certificate of participation/attendance.
- Appearing for evaluations/examinations during the course is necessary for certificate of grades in the course.
- Accommodation in the campus can be provided subject to availability and on 'first come first served' basis. Payment for accommodation is extra.

Bank Details

Account Name: Active Flow Control-2018. **Account No.:** 718400301000291.
Bank Name: Vijaya Bank. **Branch:** MNNIT Allahabad. U.P. India.
IFSC Code: VIJB0007184.
Last Date of Registration: 24th February 2018.

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International Expert

Professor Ramesh K. Agarwal is the William Palm Professor of Engineering in the department of Mechanical Engineering and Materials Science at Washington University in St. Louis (USA). From 1994 to 2001, he was the Sam Bloomfield Distinguished Professor and Executive Director of the National Institute for Aviation Research at Wichita State University in Kansas (USA). From 1978 to 1994, he was the Program Director and McDonnell Douglas Fellow at McDonnell Douglas Research Laboratories in St. Louis (USA). Dr. Agarwal received PhD in Aeronautical Sciences from Stanford University (USA) in 1975, M.S. in Aeronautical Engineering from the University of Minnesota (USA) in 1969 and B.S. in Mechanical Engineering from Indian Institute of Technology Kharagpur (India) in 1968. Over a period of 40+ years, Professor Agarwal has worked in various areas of Computational Science and Engineering - Computational Fluid Dynamics (CFD) and Heat Transfer, Computational Electromagnetics (CEM) and Acoustics, Multidisciplinary Design and Optimization. Over the years he has also worked on all kinds of parallel and supercomputing platforms (both SIMD, MIMD) to perform large scale engineering computations for industrial applications. For past fifteen years he has been engaged in research in Active Flow Control (AFC) for drag reduction of aircraft wings and trucks using various AFC devices. He has conducted both basic research as well as AFC simulations for full scale industrial applications. His Research in AFC has been funded by NASA, AFOSR, NSF, Boeing and Ford Motor Company. He is the author and coauthor of over 500 journal and refereed conference publications. He has given many plenary, keynote and invited lectures at various national and international conferences worldwide in over fifty countries. Professor Agarwal continues to serve on many academic, government, and industrial advisory committees. Dr. Agarwal is a Fellow eighteen societies including the American Association for Advancement of Science (AAAS), American Institute of Aeronautics and Astronautics (AIAA), American Physical Society (APS), American Society of Mechanical Engineers (ASME), Institute of Electrical and Electronics Engineers (IEEE), Royal Aeronautical Society, Chinese Society of Aeronautics and Astronautics (CSAA), Society of Manufacturing Engineers (SME) and American Society for Engineering Education (ASEE). He has received many prestigious honors and national/international awards from various professional societies and organizations for his research contributions.

Host Faculty:

Dr. Anuj Jain is Professor in the Department of Applied Mechanics, Motilal Nehru National Institute of Technology Allahabad (India). He served as Head in the Department of Applied Mechanics during 2013-15 and as Dean (Research & Consultancy) during 2010-12. Prof. Jain has obtained his Ph.D. degree in multiphase flows through cyclone separators from IIT Roorkee. He has more than 30 years of teaching and research experience. He has published over 100 research papers. Besides, he has co-authored one textbook on Strength of materials for undergraduate level students. Five students have been awarded Ph.D. degree under his guidance so far. He has guided 74 M. Tech. theses. Prof. Jain is presently working on two externally funded research projects in the area of Bio-Fluid Dynamics as the principal investigator. He conducts Faculty Development Programme on CFD regularly. His current research interests include application of CFD for various challenging problems. Prof. Jain was the Chair of 6th International & 43rd National Conference on Fluid Mechanics and Fluid Power (FMFP-2016) and is the Vice-President of the National Society of Fluid Mechanics and Fluid Power, India.

Dr. Akshoy Ranjan Paul is Assistant Professor in the Department of Applied Mechanics, Motilal Nehru National Institute of Technology Allahabad (India). Dr. Paul has 15 years of combined teaching and research experience and is actively involved in research in the areas of fluid mechanics, especially flow control, turbulence and CFD. He obtained his Ph.D. in Aerodynamics in 2013 from MNNIT Allahabad. He has published over 80 research papers. Besides, he has written four textbooks on fluid mechanics and solid mechanics for undergraduate level students. Six Ph.D. students are presently working under his guidance. Besides, he has guided over 35 M.Tech. theses. Dr. Paul is a panel reviewer of many international journals and is presently working in three research projects sponsored by various Govt. Agencies in the area of Fluid Dynamics as an investigator. Dr. Paul was the Organising Secretary of 6th International & 43rd National Conference on Fluid Mechanics and Fluid Power (FMFP-2016).

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Contact:

Principal Course Coordinator	Course Coordinator	Local GIAN Coordinator
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