AEROSPACE
SHORT COURSES

Future Propulsion Systems and Energy Sources in Sustainable Aviation (AERO0590)

Instructor: Dr. Saeed Farokhi

Course Description

This course starts with a review of the aero-thermodynamics of propulsion and power systems. The review includes airbreathing cycles with a focus on components, such as air intake system, compressors and fans, combustors, turbines, mixers, afterburners, exhaust systems and cycle efficiencies. Both design and off-design engine analyses are treated. A review of aircraft aerodynamics then follows with emphasis on aircraft drag reduction and modern approaches to mitigate drag including the use of smart materials and fluidics in controls. Sustainable aviation starts with a closer look at the aviation impact on environment, especially combustion emissions. Greenhouse gases and climate change, ozone and surface air quality, contrail and aviation-induced cloudiness, radiative forcing and albedo effect are discussed. *Alternative (or drop-in) Jet Fuels,* or *biofuels*, and cryogenic fuels such as *Liquefied Natural Gas* (LNG) and *liquid hydrogen*, LH_2 are also presented. Other energy sources, such as batteries and fuel cells are introduced in the context of electrification of aircraft and promising pathways towards carbon-neutral aviation. In gas turbine propulsion, Ultra-High Bypass (UHB) geared turbofan (GTF) engines; high-pressure ratio core with flow control and open-rotor propulsion systems take on the center stage. The role of distributed combustion as well as multi-fuel (cryogenic-kerosene) hybrid propulsion system on fuel burn reduction is discussed. Wave rotor combustion in topping cycles and Pulse Detonation Engines (PDE) are treated as they offer performance enhancement and play a role in the future of propulsion and power systems. Boundary Layer Ingestion (BLI) and Distributed Propulsion (DP) concepts in connection with hybrid wing-body (HWB) or blended wing-body (BWB) aircraft configurations are presented as major advances in sustainable aviation. Hybrid-electric propulsion (HEP), fuel-cell based propulsion, electric propulsion (EP) and fusion-based nuclear propulsion are presented as pathways towards the goal of net-zero carbon aviation.

Course Highlights

- Environmental impact of aviation
- Alternative fuels from production to lifecycle impact
- UHB Geared Turbofan (GTF), Counter-Rotating Open-Rotor (CROR) architecture
- Wave rotor and pulse detonation engines and topping cycles
- Electric Propulsion (EP), High-Temperature Superconducting (HTS) Generators/Motors, Batteries and Energy storage systems; Compact Fusion Reactor (CFR)

- Boundary Layer Ingestion (BLI) and Distributed Propulsion (DP) concepts
- Advanced configurations, such as BWB, HWB, and Double-Bubble

Who Should Attend?

1. Propulsion and power engineers
2. Practicing engineers in aircraft industry
3. Engineers at NASA, FAA, DoD and DOE Labs
4. Engineering faculty, mechanical, aerospace, industrial and power engineering
5. Engineering students, undergraduates, graduate students and postdocs
6. Government officials working in aviation
7. Decision makers working on policies dealing with the future of aviation and its impact on environment

Learning Objectives

- Understand aviation impact on environment
- Understand alternative fuel options from biofuels to cryogenics, from batteries to fuel cells and fuels for Compact Fusion Reactor (CFR)
- Understand promising propulsion and power concepts in aviation
- Understand promising drag reduction concepts in Boundary Layer Ingestion (BLI), Distributed Propulsion (DP), Smart Actuators and Fluidic Controls
- Understand future aviation systems and operations such as APU and ECS; flight and operation management

Course Outline

Day 1: Review of Aircraft Propulsion

Morning Sessions

1. Review of Gas Turbines Engines: Turbojet; Ramjet; Turbofan; Scramjet; Rocket-Based Airbreathing Propulsion
2. Review of GT Components: Inlets, Fans and Compressors; Combustor; Turbine; Afterburner and Exhaust System

Afternoon Sessions

3. Gas Turbine Engine Cycle Analysis for Performance Parameters: On-Design
4. Gas Turbine Engine Cycle Analysis for Performance Parameters, Component Matching, Gas Generator Pumping Characteristics: Corrected Parameters and Off-Design Analysis

Day 2: Review of Aircraft Aerodynamics

Morning Sessions

5. Aerodynamic Forces and Moments with Emphasis on Drag, Similarity Parameters; Transition Modeling; Wind Tunnels (Subsonic, Transonic and Hypersonic)
6. Airfoil and Wing Theory; High-Lift Devices, Drag Divergence (DD), Effect of Sweep on DD, Delta Wing Aerodynamics and Vortex Lift/Breakdown, Optimal Spanloading

Afternoon Sessions

7. Waves; Supersonic Aerodynamics; Sears-Haack Body, von Kármán Ogive; Hypersonic Aerodynamics
8. Advanced Aircraft Designs for Leaner, Greener Aviation; including Boundary Layer Ingestion (BLI) Concepts, Blended Wing-Body Aerodynamics, Double-Bubble

Day 3: Understanding Aviation Impact on Environment

Morning Sessions

9. Aviation Impacts on Environment - Fossil Fuels & Combustion Emissions
10. Aviation Impact on Environment - Ozone and Aviation-Induced-Cloudiness

Afternoon Sessions

11. Aviation Impact on Environment – Aircraft Noise
12. Aviation Impact on Environment - Aircraft Noise Certification & Vision

Day 4: Future Energy Sources for Sustainable Aviation

Morning Sessions

13. Aircraft Fuels and Fuel Systems
14. Renewable Jet Fuels – Emissions, Production & Certification

Afternoon Sessions

15. Cryogenic Fuels: LNG & LH_2 - Production, Transportation, Storage & Cost
16. Future Energy Sources – Electric and Nuclear

Day 5: Promising Propulsion & Power Systems

Morning Sessions

17. Promising Technologies – Advances in Propulsion
18. Promising Technologies – New Cycles & Aircraft Configurations

Afternoon Sessions

19. Promising Technologies - Hybrid-Electric, Electric and Nuclear Propulsion
20. Sustainable Aviation – Pathways to Commercialization

Classroom hours / CEUs

35 classroom hours
3.5 CEUs

Certificate Track

NA

Course Fees

Early registration course fee: $2,595 if you register and pay by the early registration deadline (45 days out).

Regular registration course fee: $2,795 if you register and pay after the early registration deadline.

Course Materials
Course materials, including outlines, presentation copies, and supplementary materials, will be accessible through Canvas, KU's online learning system. Instructions to access Canvas will be provided upon completed registration. Students are required to bring a computer or other electronic device with PDF-viewing capabilities with them to class each day. If you require accommodation contact us at professionalprograms@ku.edu and we will work with you on an accessible solution.

U.S. Federal Employee Discount
This course is available to U.S. federal employees at 10% off the registration fee. To receive the federal employee discount, you must enter the code **FGVT116** during the checkout process. Please note that you must validate your eligibility to receive this discount by entering your U.S. government email address (ending in .gov or .mil) when creating your online registration profile. This discount is available for both the early registration and regular registration fees.

Instructor Bio
Dr. Farokhi's most recent book (2020) is titled: *Future Propulsion Systems & Energy Sources in sustainable aviation*. This book is now available at the publisher: John Wiley & Sons, and booksellers, e.g., Amazon. Dr. Farokhi is also the author of the *Aircraft Propulsion, 2nd Ed.*, published in 2014 by John Wiley & Sons, Ltd., (UK), and its 1st Ed. is translated into Chinese by Jia-Tong University Press in Shanghai, PRC in 2012. Dr. Farokhi is also the co-author of *Introduction to Transonic Aerodynamics*, with Roelof Vos, Springer Verlag, Berlin, published in 2015. He received B.S. degree in Aero-Astro in 1975 from the U of Illinois at U-C and received M.S. and Ph.D. degrees from MIT (Gas Turbine Lab) in 1976 and 1981. His professional experience includes working as Design and Development Engineer and Project Leader in the Gas Turbine Division of Brown, Boveri, and Co. in Baden, Switzerland for four years. Dr. Farokhi joined the Aerospace Engineering Department at the University of Kansas (KU) in 1984. At KU, he has chaired more than 50 MS and PhD students' theses and dissertations. He is the lead inventor on five patent developments (US Patent Number: 5,598,990 on *Smart Supersonic Vortex Generators* (1997) and US patent Numbers: 9,541,429, 10,018,648, 10,520,523 and 10,585,109 on *Devices for Fluid Data Sensing* (2017, 2018, 2019 & 2020). He has directed more than $8M in R&D funding from the U.S. government and industry, including NASA, DoD, NSF, GE, and Raytheon among others. Dr. Farokhi is a Fellow of the Royal Aeronautical Society (UK), Fellow of ASME, an Associate Fellow of AIAA and a member of SAE, ASEE, APS, Phi Beta Delta, and the American Academy of Mechanics. On 1/1/2020 Dr. Farokhi retired and is now an Emeritus Professor of Aerospace Engineering and a consultant.

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