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INTRODUCTION TO CYCLE DESIGN OF CONVENTIONAL AND HYBRID-ELECTRIC AERO ENGINES

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OBJECTIVE

Classic gas turbine design relies on the definition of a design point, and the subsequent assessment of the design on a range of off-design conditions. With this approach, it is however difficult to capture the contradicting requirements on the full operating envelope. Thus, practical design efforts often rely on various multi-point design approaches. We introduce cycle design based on such multi-point design approaches in this tutorial.

TUTORIAL OUTLINE

The tutorial introduces cycle design of conventional and hybrid-electric aero engines. The goal of cycle design and analysis of gas turbines is "to obtain estimates of the performance parameters (primarily thrust and specific fuel consumption) in terms of the design limitations (such as the maximum allowable turbine temperature), the flight conditions (the ambient pressure and temperature and the Mach number) and design choices (such as the compressor pressure ratio, fan pressure ratio, by-pass ratio, etc.)" per Oates [1].

Classic gas turbine design relies on the definition of a design point, and the subsequent assessment of the design on a range of off-design conditions. On the design point, both component sizing (e.g., in terms of physical dimensions or in terms of map scaling parameters) and a solution to the off-design governing equations are established. This approach is discussed in other ASME TurboExpo tutorials but introduces limitations as it becomes difficult to capture the contradicting requirements on the full operating envelope. Thus, practical design efforts often rely on various multi-point design approaches. The objective of this tutorial is to build on other tutorials on classic cycle design, and allow attendees to

- Recognize pros and cons of classic cycle design and multi-design point strategies,
- Know synthesis tables as a simple yet powerful means to communicate multi-point design schemes,
- Understand specific examples of multi-design point strategies in terms of all additional closure equations,
- See how turbojet and geared turbofan models are built and sized using a multi-design point strategy.

Part 1: Introduction and lecture on classic cycle design with demo

- Goals of cycle design analysis of gas turbines
- Difference of design point (performance) problem and the off-design (performance) problem
- Typical cycle model detail
- Discussion of advantages and disadvantages of the approaches

- Demo of classic cycle design on turbojet
- Q&A

Part 2: Lecture 1 on elements of modern cycle design with demo
- Introduction to multi-point design and its advantages
- Synthesis matching table notation and examples
- Demo of simple multi-point design on turbojet
- Q&A

Part 3: Lecture 2 on elements of modern cycle design with demo
- Introduction and comparison of two multi point design approaches
    - Cranfield/MDH Kyprianidis
    - NASA-Glenn
- Application to hybrid-electric concepts using a parallel hybrid
- Demo of multi-point design on geared turbofan
- Q&A

Part 4: Collaboration techniques and hands-on web app experiments
- Introduction of collaboration techniques
- Users run Cranfield/MDH and NASA-Glenn approaches to multi-point design problem in browser-based web app
    - They extract key cycle results such as thrust, specific fuel consumption, combustor temperature, turbine uniform blade temperatures, bypass ratio, jet velocity ratio, specific thrust.
    - Users generate a parametric plot of these results as a function of overall pressure ratio and can identify the minimal SFC design.
    - Users find best compromise between the SFC improving according to theory with thermal efficiency, and the parasitic effects such as excessive turbine cooling flows or small last stage HPC blade length.
- Q&A

Conclusion and key learnings

On completion of the tutorial the attendees will have:
- Learned about classic thermodynamic cycle design for aero engines and its pros and cons
- Learned about multi-design point strategies and how these build on classic cycle design and evaluate pros and cons of the latter.
- Learned about specific examples of multi-design point strategies in terms of all additional closure equations (conventional and hybrid-electric aero engines).
- Learned how to run a geared turbofan model and size/analyze it using a multi-design point strategy in a browser-based web app.

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