Short Course: Introduction to sCO2 Power Cycles, Applications, Turbomachinery, Heat Exchangers, and Research Programs

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Abstract

The recent interest to use supercritical CO_2 (sCO_2) in power cycle applications over the past decade has resulted in a large amount of literature that focuses on specific areas related to sCO_2 power cycles in great detail. Such focus areas are demonstration test facilities, heat exchangers, turbomachinery, materials, and fluid properties of CO_2 and CO_2 mixtures, to name a few. As work related to sCO_2 power cycles continues, more technical depth will be emphasized in each focus area, whereas those unfamiliar with the topic are left to undertake the large task of understanding fundamentals on their own. This short course aims to remedy this problem by providing an introduction to the following aspects this new and exciting field.

1. **sCO_2 power cycle basics and proposed sCO_2 cycles**
   This section will discuss the basics of sCO2 power cycles and how they differ from cycles utilizing other fluids. The unique aspects of these cycles will be discussed, and a brief overview of the different proposed cycles will be given.

2. **sCO2 power cycle applications**
   Since sCO2 power cycles are applicable to a wide range of applications, and each application has different constraints such as size/weight, temperature limits, heat addition method, and dry-cooling, this naturally leads to applications with different turbomachinery, cycle models, and temperatures. This section provides an introduction to using sCO_2 in various power cycle applications, aimed at those who are unfamiliar or only somewhat familiar with the topic, and discusses some of the proposed cycle implementations and their unique properties.

3. **sCO_2 Turbomachinery**
   sCO2 power cycles offer high efficiency and power density relative to the incumbent Steam Rankine and Air Brayton cycles for power generation over a wide range of applications, including waste heat recovery, concentrating solar power, nuclear, and fossil energy. One significant advantage of sCO2 cycles over other Brayton cycles is that the high fluid density results in very compact turbomachinery for compression and expansion. This compactness reduces material costs and is also beneficial in low-space and potentially low-weight applications.

   The combinations of pressure, temperature, and density in sCO2 power cycles are outside the experience base of existing turbomachines such as gas turbines, steam turbines, and even high-pressure gas compressors, and sCO2 turbomachinery design is a significant challenge for realizing these cycles. This short course helps frame the resulting operating requirements and design concepts for the pumps, compressors, and expanders required for various cycle configurations. This leads naturally into a discussion on the most common challenges to sCO2 turbomachines including rotordynamics, pressure containment, sealing, and transient/off-design operation. Additional challenges include thermal management, over speed risk, aerodynamic performance, and range requirements.

4. **sCO_2 Materials**
   A brief overview of the different materials used in sCO2 power cycles will be provided. Since sCO2 cycles operate at high pressure and temperature, most of this discussion will focus on the properties of proposed materials at elevated temperatures.

5. **sCO_2 Heat Exchangers**
   This section provides an introduction to heat exchangers used in supercritical CO2 (sCO2) applications. Then a system-level overview of heat exchangers for sCO2 applications is given. Finally, design topics are discussed for mechanical, hydraulic, and heat transfer considerations.

6. **sCO_2 Research**
   In conclusion, an overview of existing prototype turbomachinery in various laboratory facilities is provided along with a summary of the results provided to date. Specific research facilities/projects to be discussed include the following:

   a. **Bechtel**

   b. **Sandia – sCO2 Brayton Cycle Test Loop**

   c. **NET Power**

   d. **SwRI/GE/Thar – Sunshot Turbine Project**

   e. **SwRI/Hanwha – Wide Range Integrally Geared Compander**

   f. **GE/SwRI – SEALS Rig**

   g. **GTI/SwRI/GE – STEP Facility**