Characterization and development of Ni-based superalloys for supercritical Carbon Dioxide applications.

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Abstract

The advent of supercritical CO_2 (sCO_2) as a new heat-exchange medium has seen strong interest from the power industry and the energy research field recently. It is advantageous in comparison with other heat-exchange cycles, as it can be operated safely at much higher temperatures and pressures, thus increasing the thermal efficiency greatly. In turn, the system size can be reduced and CO_2 emissions lowered. In general, the process conditions are temperatures of up to 700 °C and pressures of up to 30 MPa. Here, only high-temperature alloys, such as Ni-based superalloys, are a viable option. However, there is a lack of knowledge and information on the performance of such materials in an sCO_2 environment. Therefore, a thorough understanding of the alloy systems that are targeted for use in sCO_2 applications is necessary, from their corrosion performance over their workability into heat-exchanger parts to the conception of custom-designed alloys. In this work, commercially available, candidate alloys for sCO_2 use were investigated for their corrosion behavior under sCO_2 conditions, and the influences on the microstructure analyzed. The results were compared for different exposure times, and with other environments, in order to understand the particular effect of sCO_2. Next, the hot-working behavior of selected Ni-based superalloys was analyzed, where the deformation conditions during the fabrication process were mimicked. This aided in outlining safe and efficient working zones for materials to be formed. Lastly, development for novel alloy systems for sCO_2 use was pursued, where the design criteria were based on the high temperature strength and corrosion performance of the most promising commercially available alloys. Optimization of the alloy was performed through thermodynamic modeling, heat-treating and characterization, allowing the final composition to be cast and hot-rolled. Mechanical testing results suggested very promising properties and compared well with other commercially available alloy systems.

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