Contribution ID: **96** Type: **Contributed Oral**

C2Or4C-05: Development and validation of a 1D oil-injected screw compressor model for helium cryogenic system applications

Tuesday 20 May 2025 17:15 (15 minutes)

Oil-Injected twin screw compressors are widely used in cryogenic helium refrigeration systems as the prime mover. They provide all the thermodynamic availability for the cryogenic refrigeration system and account for more than one-half of the input power losses and two-thirds of total system availability losses. These machines are generally designed for freon or other common refrigerants and are retrofitted for helium applications. Oil is injected into the compression cavity to address the high heat of compression of helium and lubricate and seal the rotating components during the compression process. These systems were not explicitly studied for helium compression application, suffer from relatively low system efficiencies, and can largely benefit from improvements in the compression process. To better understand the compression process of helium-oil mixtures through an oil-injected screw compressor, a steady-state, one-dimensional, non-equilibrium model has been developed and validated using published datasets. The 1D model is derived from an energy and mass balance of the gas and oil mixture, including empirical correlations of heat transfer and gas leakage internal to the compressor. Primary parameters investigated in the present study include oil-gas mass ratio, pressure ratio, discharge temperature, and isothermal efficiency. The simulations are compared against experimental data obtained from a hermetically sealed oil-injected helium screw compressor test bench. Such a predictive model for the compression process applies to the design of compressor skids used in either small or large-scale helium cryogenic systems. It can be utilized with a refrigeration system process model to evaluate the cryogenic system efficiency and optimum operating modes under various operating process conditions.

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Session Classification: C2Or4C - Cryogenic Components III