Contribution ID: **27** Type: **Poster Presentation**

Influence of thermophysical properties of working fluid on the design of cryogenic turboexpanders using ns-ds diagram

Wednesday, July 1, 2015 9:00 AM (2 hours)

Helium liquefaction and refrigeration plants are an essential part of nuclear fusion reactors, particle accelerators etc. The thermodynamic efficiency of these plants depends upon the performance of the turboexpander which is the main cold generating component and therefore they should be designed for higher thermodynamic efficiencies. Balje's ns –ds chart, which is a contour of isentropic efficiencies plotted against specific speed and specific diameter is commonly used for the preliminary design of cryogenic turboexpanders. But, these charts were developed based on calculations for a specific heat ratio (γ) of 1.4, and studies show that care should be taken while implementing the same for gases like helium which has higher γ of 1.67. Hence there is a need to investigate the extent of applicability of ns-ds diagram in designing helium expansion turbines.
In this paper CFD analysis of two cryogenic turboexpanders, one designed for nitrogen and the other for helium were carried out using ANSYS CFX. The turboexpanders were designed based on the design methodologies prescribed by Kun and Sentz following ns-ds diagram of Balje and Hasselgruber's technique for generating blade profile.
The computational results of the two cases were analysed to investigate the applicability of Balje's ns-ds diagram for the design of turboexpanders for helium refrigeration and liquefaction cycles. It has been found that while CFD results of turbine performance match closely with the expected design data in case of nitrogen, for helium there is a noticeable difference. Efforts have also been made to discern the modifications that should be made in the existing design techniques following Balje's chart so as to establish a streamlined design methodology for the development of helium turboexpanders with improved performance.

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Session Classification: C3PoE - Turbomachines and Helium Components

Track Classification: CEC-05 - Expanders, Pumps, Compressors, and Regenerators