# Abstract

Cryogenic turboexpander constitutes one of the vital components of Claude cycle based helium refrigerators and liquefiers that are gaining increasing technological importance. The unique characteristics of helium turbines like smaller dimensions and higher rotational speeds and the low residence time of helium within the flow passage make the flow features in these turbines different from other turbines. For any improvement in efficiency, a detailed study of the turbine flow field is required. This should include the identification of the sources of losses and the geometrical parameters that affect these losses. Also, the analysis can be extended to modify the established turbine design methodologies. Computational Fluid Dynamics analysis is an effective tool for the determination of the flow fields in cryogenic turbines, that is often not possible through experiments.

In the present work, three-dimensional flow field analysis of a cryogenic helium turbine was performed using Ansys CFX®, to analyse the effects of various geometrical parameters on the turbine performance and to develop physical based loss correlations that can accurately predict the performance loss.

Through the detailed analysis at the design and off-design conditions, the tip clearance height, the trailing edge profile and the straight duct length was identified as the major geometric parameters associated with the losses. The tip leakage loss characteristics in cryogenic helium turbines were found to be different from large-scale turbines as the tip leakage vortex was observed to have a greater effect on the mainstream flow. Through analysis of the effect of trailing edge thickness, the throat blockage due to boundary layer thickness was found to be negligible. An increase in trailing edge thickness above 3% pitch was found to result in a significant drop in turbine performance. The study also verified the prediction capability of existing empirical loss correlations and modifications were suggested for its applicability in helium turbines.

The thesis identified the major loss generation mechanisms and the associated geometric parameters leading to design recommendations and formalising loss correlations for meanline performance analysis. The outcomes of the thesis can be used to improve the meanline design methodology for high-speed cryogenic helium turbines.

**Keywords**: Cryogenic turboexpander, Microturbine, Computational fluid dynamics, losses, loss correlations.