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C1Po1B-09 [07]: CFD Analysis of Vortex Tube with Two-phase Air at Cryogenic Temperature

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Ranque Hilsch vortex tube is commonly used with compressed air at atmospheric temperature for refrigeration purpose in various industrial applications. Literature shows that vortex tube can also be used as a potential device to separate compressed partially condensed air at cryogenic temperature into its main constituents – oxygen and nitrogen. When compressed partially condensed air is used as the working fluid, both energy separation and phase separation occur in the vortex tube. Due to turbulent mass transfer between the liquid phase and the vapor phase of air inside the tube, oxygen rich fluid stream comes out from the hot outlet and nitrogen rich fluid stream comes out from the cold outlet of vortex tube. Cryogenic vortex tube can be a potential device for use in an in-flight air collection and enrichment system of air breathing propulsion. However, literature on the CFD analysis of vortex tube with two-phase air flow at cryogenic temperature is very limited.

In this work, CFD simulation is conducted using the CFD software FLUENT to investigate energy separation and phase separation in vortex tube with partially condensed air at cryogenic temperature using the Eulerian multiphase model. Flow parameters inside the vortex tube operating with two-phase air are investigated and compared with those obtained for single phase vortex tube flow. Temperature separation with two-phase air is found to be less than that with the gaseous air. A thin layer of liquid is observed near the wall of the vortex tube in case of two-phase flow indicating phase separation in the vortex tube. Liquid mass fraction at the hot outlet is seen to be higher than that at the inlet. This indicates to oxygen enrichment of air at the hot outlet, because oxygen concentration is higher in the warmer liquid phase due to its lower volatility than nitrogen. Flow through the cold outlet is found to be predominantly gaseous with negligible liquid mass fraction, which indicates to nitrogen rich flow through the cold outlet.

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