ABSTRACT

The conventional cooling and heating devices employ equipment with moving parts and chemicals. The devices need regular maintenance and the chemicals produce many adverse effects on the environment. Vortex tube (VT) is a simple device which has no moving parts and uses no chemicals to generate cooling and heating effects. Inflow pressure is the only source of energy which converts into thermal energy. Improvement of cooling performance of VT has been studied intensely in the last few decades but the use of hot gas is rarely reported. To achieve maximum efficient energy utilization and improved performance the concept of hot cascading of vortex tube is explored and numerically investigated in this study. Exergy or available energy is chosen as the primary parameter to assess the effectiveness of cascading. In hot cascade type Ranque-Hilsch vortex tube (RHVT), hot gas exergy efficiency variation shows that the degradation is more for energy loss at higher cold fraction than that at lower cold fraction. To investigate the mechanism of thermal separation in the second stage vortex tube the effects of heat and work transfer due to shear are explored in this study. The sensible heat transfer along axial direction is from the hot to cold fluid everywhere except in the region very close to the hot exit. An axisymmetric computational model based on the Reynolds-Averaged Navier-Stokes equations, available in the commercial package Fluent, is used to simulate the compressible turbulent flow in the vortex tubes. Two popularly used two-equation turbulence models in the vortex tube research, namely the standard k-ε and the RNG k-ε models, are used and their accuracy in predicting the vortex tube is assessed. The comparison of the models based on exergy analysis in a vortex tube shows standard k-ε model predicts results closer to the experimental data. Three-dimensional simulations are performed to assess the accuracy of the axisymmetric assumption and also to study the effects of number of inlet nozzles and cross sectional area on the energy separation in a RHVT. Cooling effect increases as the nozzle number increases from 2 to 8 even though the cold fraction decreases. Possibility of improvement in thermal separation due to conical angle of the tube is also studied in the thesis. The convergent tube is found to produce higher thermal separation the straight and divergent tubes.

Keywords: Two-equation turbulence models; exergy study; work and heat transfer, cascade type Ranque-Hilsch vortex tube; converging/diverging tubes, multiple nozzles.