Hybrid membrane process for cryogenic air separation unit

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Abstract

Pure oxygen and nitrogen are applied to various industrial sectors such as chemical, food and power industries for multiple purposes. Therefore, air separation technology becomes a required unit in those sectors to produce oxygen and nitrogen in desired specification. In general, cryogenic air separation, an oldest but mature method, is able to produce ultra-high purity products with high flow rate requirement. However, the by-product, low purity nitrogen stream, occupies almost 70% in total product stream when the ultra-high purity nitrogen specification is set to be 99.999% (3400((STP) m^3/hr)) and high purity oxygen specification 99.9% (8000((STP) m^3/ hr), which means the majority of energy consuming by compressors at the air-feed entrance are wasted to compress worthless by-product. On the other side, Polymer membranes on air separation have recently been developed to solve energy problems. Most of the previous researches, however, focus on independent membrane process for separation, and there are limited researches about the hybrid membrane process in cryogenic air separation system.

In this study, membrane unit is developed in Aspen Custom Modeler (ACM) and serves as a pre-treatment in the cryogenic unit. Considering simplicity in custom membrane simulation, complicated air composition is categorized into two groups: nitrogen-like slow particles and oxygen-like fast particles by molecular kinetic diameter. Furthermore, membrane properties, selectivity and permeability, are limited by 2008 Robeson's upper bound and a hollow fiber membrane module is taken into account to develop high membrane area. Based on those setting, the hybrid process between the membrane and cryogenic unit is first studied by performing sensitivity test on air feed composition to find out the influence on total energy. Subsequently, the potential air composition result able to save energy is set as fixed variables at membrane's permeate and change membrane geometric parameters and operation condition such as length, fiber diameter, thickness or pressure to meet the experimental upper bound limit. After all reasonable parameters are determined in membrance unit, the economic analysis is applied for membrane and compressors to find out the most optimal combination to reduce the overall total annual cost in the cryogenic unit.

Keywords: Synthesis; Design; Operation; Hybrid membrane process; Aspen custom modeler, oxygen-selective membrane, cryogenic air separation unit