Investigation of Supercritical Water Processing of Biomass: Study of High Pressure Separation

By: Reza Espanani

Advisor: Dr. William Jacoby

ABSTRACT

This dissertation includes two sections. In the first section, a thermodynamic model is presented for vapor-liquid equilibrium calculation of low boiling point components. In the second section, separation of N_2/CO_2 mixture is investigated by a high-pressure, density-driven separator.

Vapor-liquid equilibrium (VLE) of low boiling point components occurs at low-temperature and usually at high pressure. A proper method for computing the fugacity coefficient is to use a cubic equation of state with mixing rules. However, empirical mixing rules include one adjustable parameter and cannot predict VLE of some mixtures accurately. An alternative that could be used for non-ideal mixtures is the Wong-Sandler mixing rule, which is derived based on the excess Gibbs free energy (G^{ex}). In this research, VLE of light gaseous mixtures was calculated using the Peng-Robinson equation of state (PR EOS), the Wong-Sandler mixing rule, and the NRTL equation as a G^{ex} model. Assuming the adjustable parameters as a function of temperature, the results show that this thermodynamic model is an appropriate method to predict VLE of low boiling point materials at wide range of temperatures.

A mixture of 85% nitrogen and 15% carbon dioxide (N_2/CO_2) is separable at ambient temperature on a continuous basis. A high-pressure, density-driven separator (HDS) was designed and fabricated to explore the process. The effect of the fluid variables, including pressure and mixture flow rate, was assessed on a separation efficiency metric. An important design parameter, the length of the HDS, was also evaluated in the experimental design. Separation efficiency is correlated with two dimensionless groups. The first is the Archimedes number. It is a ratio of buoyant force to viscous force. The second dimensionless group is defined in this work. The Espanani number is the ratio of the pressure force to the viscous force. Excellent correlation between separation efficiency and the product of the Archimedes number and the Espanani number is observed.