Active Vapor Split Control for Fully Coupled Columns: Experimental Studies

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Abstract

The idea of a 4-product fully coupled distillation column has existed in literature but has not been adopted in industry for the reasons of complex design and operation. A sole exception is an installation by BASF (Dejanovic, Matijasevic et al. 2010). The potential energy saving in 4-product fully coupled columns like 4-product extended Petlyuk arrangement can be about ~50% and ~30% in a Kaibel arrangement (Halvorsen and Skogestad 2003). In previous works, a 4 point temperature control structure for the regulatory layer has been recommended (Strandberg 2006) and was experimentally demonstrated (Dwivedi, Halvorsen et al. 2011) using a pilot plant.

The full realization of energy saving potential of thermally coupled columns may require on-line adjustment of the vapor split in order to handle expected feed property variations and still maintain minimum energy operation. In particular for cases where the optimal operating window with a fixed vapor split is narrow, like in a 4-product Kaibel column, and also in some 3-product DWCs where high purity is required in the side product. Ability to adjust the vapor split also adds to the operational flexibility, which is important since limitation in flexibility has been seen as a disadvantage in commercialization of thermally coupled columns. Although some experimental work for 3- product fully coupled columns have been reported (Mutalib, Zeglam et al. 1998; Niggemann, Hiller et al. 2010), the use of an active vapor split valve for control as an during has not been shown due interest or discouraged in the fully coupled columns (Agrawal and Fidkowski 1998).

This paper demonstrates the use of a vapor split valve in a 4 point temperature regulatory layer of a four product experimental Kaibel column. The excess degree of freedom that is, the liquid split valve that divides liquid reflux between the prefractionator and the main column can be used as a degree of freedom for economic objectives such as, for minimization the energy consumption for a given purity specification or, for maximizing product purity for fixed boil up.

Additional advantage of using the vapor split in the regulatory layer is that, it is very fast input, which make set point tracking much faster. Also in a multivariable system like a four product Kaibel column, the interaction effects between the loops can be checked, as the vapor split valve operates in a much faster time scale.

The design of the vapor split valve used, is rather rudimentary. However, even with such a simple valve design, we can ensure a stable column operation. The work emphasizes that with a simple temperature feedback action, in spite of the input uncertainty i.e., here, uncertainty in vapor split between prefractionator and the main column, the column can still be operated and stabilized. As there were some limitations of the used prototype, more innovations are required and can be a focus of interest for valve experts for developing an effective and robust vapor split valves that can be operated for such applications which allow low pressure drops.

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