Contents lists available at ScienceDirect

Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

Numerical simulation of dividing wall column with vapor recompression located at side product stage

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ARTICLE INFO

Article history:
Received 22 October 2016
Received in revised form 5 February 2017
Accepted 9 February 2017

Keywords:
Dividing wall column
Vapor recompression
CGCC

ABSTRACT

The energy efficiency of dividing wall column (DWC) can be further improved by the vapor recompression (VRC), but large temperature difference between overhead and bottom of the DWC hindered their combination. Meanwhile, it is difficult to choose suitable side heat exchanger position in the DWC. In this paper, we provided a direct method to design the configurations that the VRC assisted DWC at the side product stage. The Column Grand Composite Curve (CGCC) profiles were used to determine the type of phase withdrawn from the side product stage. In the CGCC profiles, if the side product stage was located in the side reboiler region, the vapor should be withdrawn from the side product stage, the SCVRC-DWC and IR-SRVRC-DWC configurations can be achieved. If the side product stage was located in the side condenser region, the liquid should be withdrawn from the side product stage, the SRVRC-DWC and the IC-SRVRC-DWC configuration can be achieved. Three separation cases with different ESI values were simulated and the results inferred that the proposed configurations had high energy efficiency when enough vapor or liquid flow can be withdrawn from the side product stage.

1. Introduction

Distillation is the most widely applied separation unit in chemical industries, but it has low thermodynamic efficiency and large energy consumption. Therefore, the development of highly energy saving column configuration would bring great benefits to overall chemical industries.

As an intensified thermally coupled system, dividing wall column (DWC) had high energy efficiency and low equipment cost (Asprion and Kaibel, 2010; Dejanovic et al., 2010; Yildirim et al., 2011). The optimization design and controllability of DWC had been researched intensively (Kiss and Rewagad, 2011; Long and Lee, 2012, 2013; Long et al., 2016; Luo et al., 2015; Luyben, 2015). In a typical DWC configuration, all heat was input at the bottom reboiler and removed from the top condenser. So the reboiler and condenser duties were always larger than the single conventional column (Agrawal and Fidkowski, 1998; Halvorsen and Skogestad, 2003; Suphanit et al., 2007). It meant that significant waste heat of DWC could be recovered. Vapor recompression (VRC) was considered as the simplest external heat integrated technology for distillation. Some studies (Felbab et al., 2013; Ferre et al., 1985; Harwardt and Marquardt, 2012; Kumar et al., 2013) found that the VRC was most beneficial for separating close boiling mixture with high heat loads and small column pressure drops.

The VRC assisted DWC configurations had been researched recently, Chew et al. (2014) investigated the configurations that the VRC installed between the overhead and bottom of DWC (named as VRC-DWC), and found that VRC have significant energy efficiency with small temperature difference between the overhead and bottom of DWC. But this temperature difference was always larger than the conventional column especially for separating the wide boiling mixtures. Long et al. (2015) provided the side VRC assisted DWC schemes in which VRC system was located in rectifying section or stripping section. Although the

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http://dx.doi.org/10.1016/j.cherd.2017.02.007

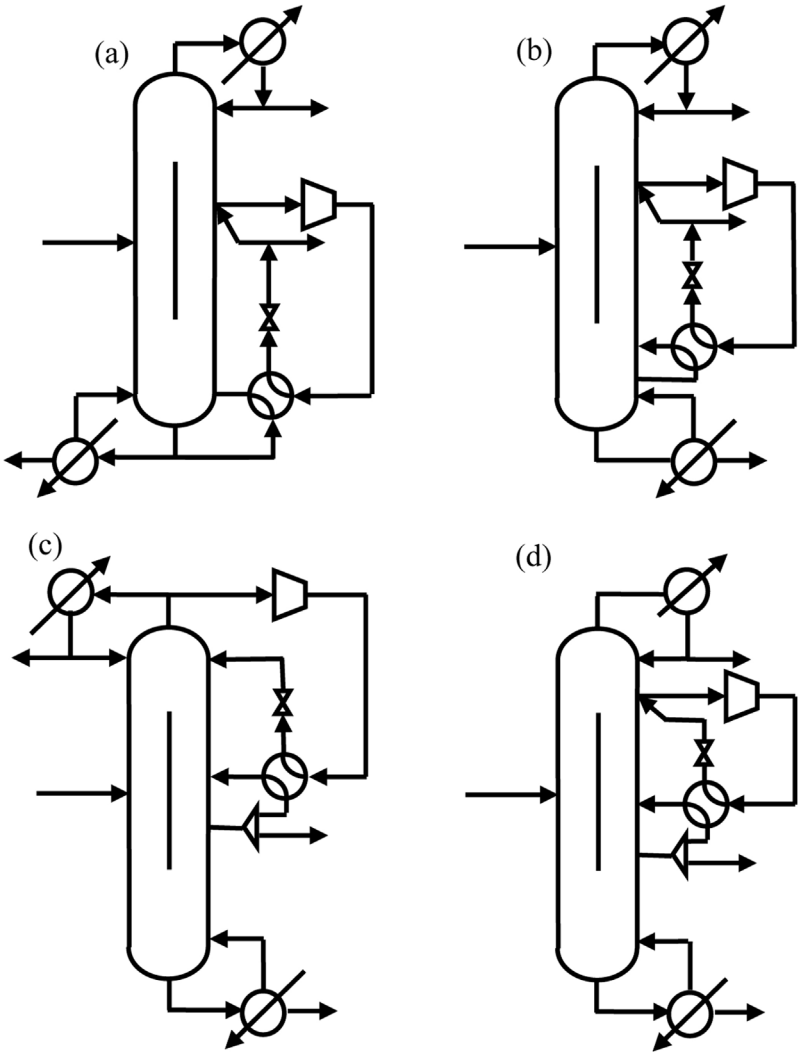

Fig. 1 – Schematic diagram of the (a) SCVRC-DWC, (b) IR-SCVRC-DWC, (c) SRVRC-DWC and (d) IC-SRVRC-DWC.

temperature difference between two withdrawn streams is reduced, but the driving force of mass transfer in the VRC added stage will be decreased (Chen et al., 2013; Yu et al., 2015).

We focus our research on the configurations that the VRC was installed at the side product stage of the DWC. Compared with other side VRC assisted DWC configurations, this kind of configuration had two outstanding advantages. One was that the addition of VRC can not generate large influence to the separation because the stream withdrawn from the side product stage was purer than other side stream. Another one was that the temperature of the stream withdrawn from side product stage will not be changed largely after exchanged heat, which was very beneficial to the heat transfer.

It was necessary to develop more direct method to design the DWC with VRC located at the side product stage. For the DWC, either side reboiler or side condenser could be installed at the side product stage, because it was the connection of the stripping and rectifying sections of the DWC. But only one type of side exchanger can improve its energy efficiency. Navarro-Amoros et al. (2013) found that excess vapor or liquid will be arose at the side product stage when the DWC was considered as three columns model, so the VRC or the reverse vapor recompression (RVRC) could be installed at the side product stage. But the excess vapor or liquid was just achieved in optimal three columns model, the RVRC system was not commonly used in industry.

In this article, we provided a new method to design the DWC with VRC located at the side product stage. In the method, the Column Grand Composite Curve (CGCC) profiles were used to determine the type of phase withdrawn from the side product stage. With the aid of CGCC profiles, four kinds of VRC assisted DWC configurations were proposed.

2. Dividing wall column with VRC located at the side product stage

If the vapor was withdrawn from the side product stage, two kinds of VRC assisted DWC configurations could be achieved, Fig. 1(a) shows that the VRC was between the side product stage and the bottom reboiler, which was equivalent to the VRC assisted DWC with a side condenser. So this type of configuration can be named as SCVRC-DWC. To further reduce the temperature difference between two withdrawn streams, the liquid stream could be withdrawn from the stripping section. So the SCVRC-DWC with an intermediate reboiler (IR) configuration could be achieved and named as IR-SCVRC-DWC shown in Fig. 1(b)

If the liquid was withdrawn from the side product stage, two kinds of VRC assisted DWC configurations could be achieved. Fig. 1(c) shows the configuration that the VRC was between the overhead and the side product stage, which was equivalent to the VRC assisted DWC with a side reboiler and can be named as SRVRC-DWC. To further reduce the temperature difference between two withdrawn streams, the vapor stream can be withdrawn from the rectifying section. So the