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Distillation technology and need of simultaneous design and control: A review

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ABSTRACT

During the whole of history, distillation has been the most extensive separation method. Regardless of its flexibility and simplicity, distillation technology is highly energy consuming. Modernistic distillation technologies based on intensification process has more ascendency than its conventional, not in terms of less energy consumption but it reduces the capital investment cost and improved efficiency. In order to meet the demands of modern society, a drastic development in the field of separation is required. Here this article first pointing towards the overview of latest trends in distillation technology with process intensification principles. In order to meet the control of modern chemical process, simultaneous design and control is proposed over the conventional design and control methods. Second, the article is pointing to various optimisation techniques used for simultaneous design and control of chemical processes. Significant development in the area of simultaneous design and control is categorised into two. 1) Controllability indicator based foundation 2) optimisation based foundation. In the simultaneous design and control of chemical process, first discussion started with the motivation and significance of simultaneous design and control based optimisation technique, then pointing towards the existing methodologies with theoretical algorithms and its merits and demerits.

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1. Introduction

A physical separation of liquid mixtures with difference in boiling point or volatility of the essential components is called Distillation. It is a widely used separation process in the current era and its history starts from a beverage factory in China (800 BCE) [1]. It is a batch wise process by heating a liquid mixture in a pot and condensing the vapour with the help of a condenser. The process of distillation taking place continuously (Fig. 1) in vertical empty columns linked with piping, heat exchangers, vessels, pumps and supporting structures [2–5]. By considering the feed stream and product, distillation requires a decrease in entropy so it is not spontaneous in nature. For making the process thermodynamically possible additional heat is required. Due to the irreversible losses with respect to the pressure drop, mass transfer and heat transfer, the efficiency of distillation is very low [6–9].

Development in the chemical process industry transformed towards the high energy efficient separation technologies. By the development of process intensification (PI) the overall cost is reduced and improves the sustainability of industrial process. PI is a process design methodology, which improves the process flexibility, quality of the product and inherent safety [10]. The main principle of PI is clearly defined in [11] as: 1. Maximising the intra and inter molecular event effectiveness 2. Give equal processing experience to each and every molecule 3. Maximise the synergistic effects 4. Maximise the surface area to which force apply and optimise the driving force.

Chemical processes are nonlinear system continuously affected by external disturbances and process uncertainty which leads to process variability. Even though algorithms can be used to reduce process variability and design, also have a huge impact on closed loop behaviour of the system. Conventional chemical plant design is fully based on steady state calculations and synthesis investigation by considering controllability only after the process design variables have been determined. Thus independent consideration of controllability and flexibility is taking place. This sequential approach is inadequate to handle large variations in controllability and flexibility.

Based on the above, it has been proposed to optimise the chemical process design simultaneously. Thus the closed loop performance of the system dynamics are analysed together with system design and control. Design and control related degrees of freedom is used to determine the optimal operating state and unit capacity of the system. The problem is addressing trade-off

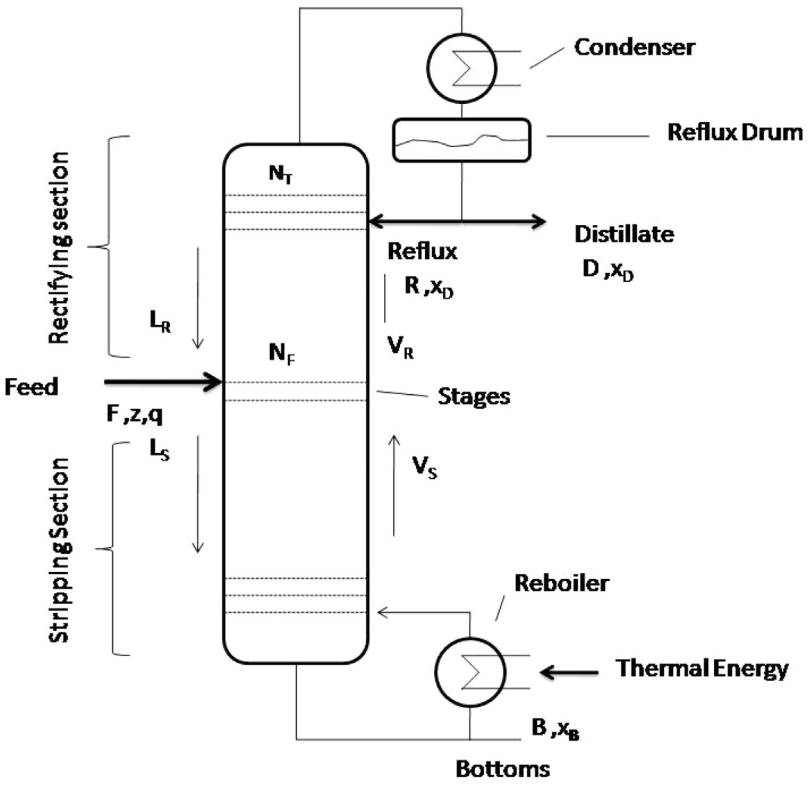

Fig. 1. Schematic diagram showing continuous distillation column.