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Judicious generation of alternative water network designs with manual evolution strategy

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ABSTRACT

This study is aimed to judiciously generate the desired alternative configurations of a given single-contaminant water-using system under the constraints of minimum freshwater usage, minimum match number and minimum total throughput. A generalized source-shift procedure is proposed for this purpose, which can be applied manually by evolution from a preliminary network which requires minimum freshwater usage. Systematic implementation guidelines are also provided to perform the evolution steps. In addition, the minimum interconnection number can be estimated in advance and the total number of promising alternative solutions can also be determined *a priori*. Six examples are presented in this paper to demonstrate the effectiveness and benefits of applying our method.

Keywords: Process design; Optimization; Network synthesis; Water network; Manual evolution; Generalized source shift

1. Introduction

Industrial water network synthesis (Jezowski, 2010; Mann and Liu, 1999) has been an active research area in process systems engineering for more than a decade. The available design methods can be classified into two general types, i.e., the pinch based and the mathematical programming based approaches. A full review on the former approach is given by Foo (2009), while Faria and Bagajewicz (2010a) presented a thorough survey of the latter.

To take into account of the recent shift in setting priority among conflicting criteria for water network design, it becomes necessary to place emphasis on water conservation from the outset and then address other critical issues, e.g., capital cost, safety and operability, etc., at later stages. For any water-using process, it is usually possible to identify more than one network structure that features minimum freshwater usage, minimum match number and minimum total throughput simultaneously. In order to select the most appropriate design, these initial candidates should obviously be identified as many as possible in cases when some of the "promising" solutions may have infeasible layouts or are difficult to be implemented in reality. Two distinct approaches have been taken to accomplish this task after a preliminary network configuration is obtained. One is to partially or totally redesign the network, while the other is basically evolutionary in nature. In the former case, two distinct strategies have been proposed:

- If the pinch-based design procedure (Dunn and Wenzel, 2001; Prakash and Shenoy, 2005a; Savelski and Bagajewicz, 2001; Wang and Smith, 1994) is adopted to synthesize a preliminary optimal network, it was suggested to go back to an intermediate step and consider the other branch options.
- If the mathematical programming method is used for generating the basic optimal solution, the common practice is to rerun the same model with
  - a different initial guess and/or an alternative solver (Bagajewicz and Savelski, 2001; Li and Chang, 2007),
  - additional cutting conditions (Ahmetovic and Grossmann, 2011; Faria and Bagajewicz, 2010b; Poplewski et al., 2010), or
  - the "solution pool" technique (Li and Chang, 2011b).

In practical applications, it is usually time consuming to implement the pinch-based procedure for the purpose

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