CHEMICAL ENGINEERING TRANSACTIONS Volume 18, 2009
Editor Jiří Klemeš
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DOI: 10.3303/CET0918136

Process Integration and Conceptual Design with a Process Simulator

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Process Integration is a systematic design concept which has been widely used in conceptual process design in practice. Recent trend in process system engineering community has been to employ various mathematical optimisation techniques, to incorporate Process Integration concepts into optimisation frameworks, and to solve complex and large-size design problems. Significant benefits from using these automated design tools had been demonstrated, which had then led to the development of various process design software. (Smith, 2005)
However, the industrial uptake of optimisation-based procedure has been often limited for some areas; for example, available software is not readily applicable to the process to be studied, or the modelling (or design) framework of the software does not fit well to the characteristics of design problems to be solved. Therefore, process industries heavily rely on the use of process simulators for engineering activities.
When process simulators are used for the conceptual process design, it is not straightforward to apply Process Integration concepts. This often results in a very marginal improvement from the final design. The effective use of simulators is very important to ensure the cost-effectiveness of design and minimise engineers' computational efforts.
This presentation will, therefore, brief difficulties associated with the use of a simulator in Process Integration study, address how the process simulator can be effectively used, and discuss the simultaneous use of a simulator and Process Integration software. Industrial case studies will be given to illustrate design issues and concepts outlined in this presentation, and to demonstrate that the simulator, as a means of pseudo-optimisation tool, can play an important role for conceptual process design.

1. Conceptual Process Design with Simulation

Conceptual understanding of design problem can be obtained through the systematic application of process integration techniques and the strategic use of a simulator. Figure 1 shows the procedure to conduct conceptual process design study using simulation. In order to improve the system performance, both structural change and operating conditions can be considered. With available simulation tools, simultaneous

Please cite this article as: Kim J.K., (2009), Process integration and conceptual design with process simulators, Chemical Engineering Transactions, 18, 833-838 DOI: 10.3303/CET0918136

investigation of structural options and change of operating conditions is not straightforward. The development of optimisation framework and its application would be ideal. However, it may not be realistic, due to various technical or non-technical constraints (e.g. time, resources, etc). Also, readily-applicable software tools for fulfilling the tailor-made optimisation are often not available. The suggested procedure for semi-optimisation study (Figure 1) is based on series of engineering decisions with the aid of conceptual insights and understanding from the problem. The decision-making to find most promising solutions can be supported by not only simulation, but also Process Integration techniques (e.g. Heat Integration). First step in the analysis is to screen potential design variables and to select key variables, which can be judged from engineering experiences and/or relevant literature. Sensitivity analysis is performed with the aid of simulation, to identify the impacts related to specific design variables. Further, various process integration method (e.g. energy targeting, site profile targeting, refrigeration targeting, etc; Linnhoff, 1982; Smith, 2005; Kemp 2007) can be strategically used, based on study objectives. A large number of simulation run is inevitable, but, sensitivity analysis and the use of process integration techniques can significantly reduce the computational efforts, because of better understanding in design problem. It is not an easy task to couple structural changes with operating conditions, and a sensible way is to re-iterate a sensitivity analysis followed by the application of process integration methods, according to the structural options selected. From iterative procedure, it is anticipated to obtain a set of promising solutions, These solutions may not be optimal solutions, but still are very valuable if the cost-effectiveness and/or performance of processes is significant improved.

2. Case Study

An absorption process used in process industries is considered for a case study (as shown in Figure 2). First, the base case is simulated, and 5 key design variables including one option for structural change are identified. A series of simulation is made to check the sensitivity of design variables, and its sensitivity to objective function (in this case, minimisation of energy cost) for each variable is given in Figure 3.

Process integration technique is used to check the importance of utility level targeting as shown in Figure 4, and the information obtained from this targeting is then incorporated in decision-making of optimal setting of those operating variables, aiming to get near-optimal solutions. Table 1 shows the comparison between base case and one of identified solutions. Overall 26.2 % of energy cost savings can be achieved with the use of simulation, although mathematical optimisation techniques have not been applied.

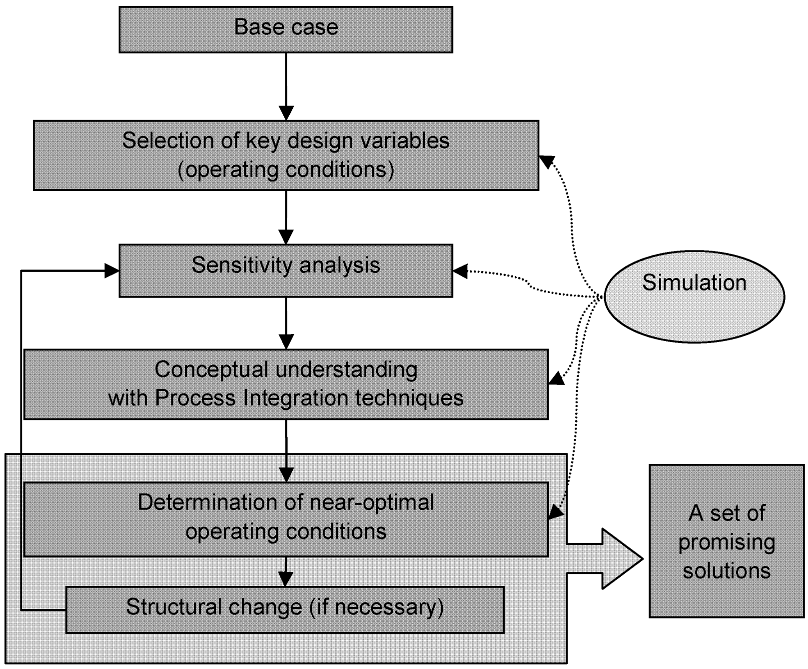

Figure 1 Process design with simulation

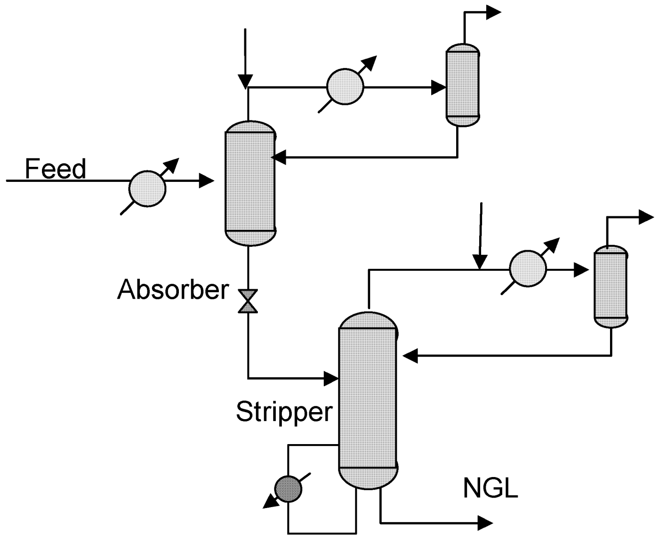

Figure 2 A separation process

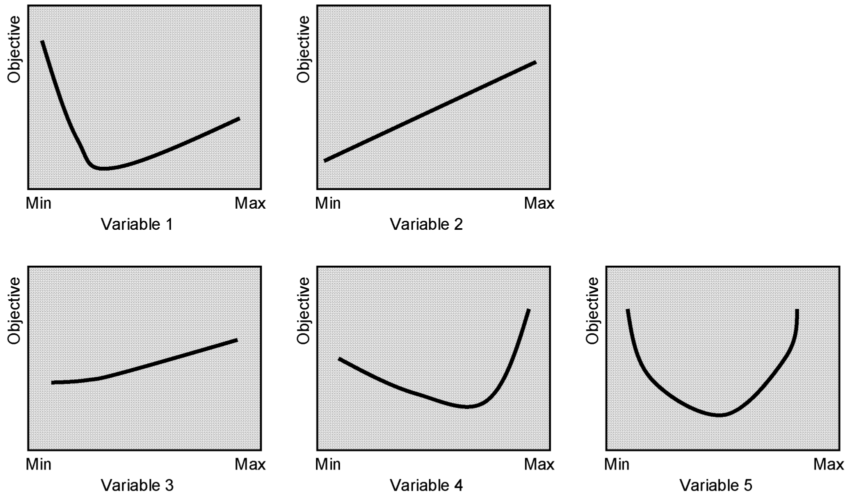

Figure 3 Sensitivity analysis

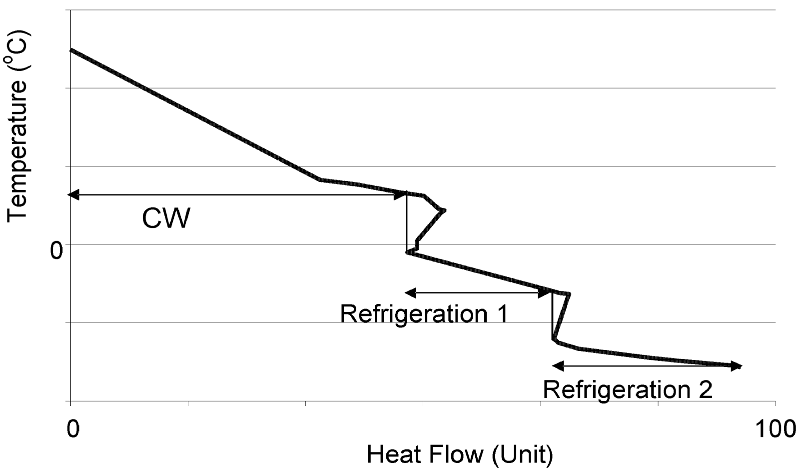

Figure 4 Application of process integration targeting techniques

Table 1 Improved design vs. Base case

Energy cost	Improved design	Base case
Utility A	263.6	520.5
Utility B	409.8	376.2
Utility C	59.2	88.8
Utility D	5.7	14.5
Total energy cost (Unit)	738.2 (26.2 % saving)	1000

3. Summary

Proper and effective use of simulator is able to provide significant improvement (e.g. energy saving) of processes, which is clearly demonstrated in the case study. Conceptual understanding of the design problem is a key to obtain a much improved solutions.

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