PROCESS INTEGRATION IN PETROLEUM REFINING
A PERSPECTIVE AND FUTURE TRENDS

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Background

Petroleum refining has always been at the forefront of developments in process integration. The crude oil distillation preheat system is a classic heat exchanger network design problem that has presented significant challenges because of its size and complexity. However, the importance of efficient designs for such systems has spurred an ongoing effort to continually improve their performance.

Approaches to the Design of Heat Recovery Systems

Various techniques have been developed for the design of such heat recovery systems. The earliest systematic approaches to be applied were based on pinch analysis [1-4]. Perhaps the most important concept underlying these early tools was the idea of setting energy targets before design. Despite the advances that have taken place in the intervening years, this remains the best known and most compelling part of process integration. However, there is a general lack of understanding of the limitations of such targets and just how achievable they are in practice. Even for new design, the size and complexity of the refinery preheat problem presented challenges for approaches based on pinch analysis. Whilst pinch analysis has proved to be an extremely powerful tool, the majority of the guidance applies in the region of the pinch itself and for large problems, such as the refinery preheat train, there is little guidance away from the pinch region. This situation becomes exaggerated in the case of retrofit, where pinch analysis has proved to have very significant limitations.

Since the early development of thermodynamic approaches to process integration, there has been huge progress in the development of approaches based on optimisation. The basis of many of these approaches is to set up a superstructure for the design that includes all the features that are candidates for the final solution. This is then subjected to optimisation that removes redundant (non-optimal) parts of the design and adjusts the continuous parameters to their optimum settings. Whilst it is very tempting to think of this as being the ultimate solution to the problem, the size and difficulty of the optimisation required remains an obstacle. Different approaches can be adopted for the optimisation based on deterministic or stochastic search optimisation or hybrid deterministic and stochastic search methods. Each has their advantages and disadvantages [5].

The Ongoing Challenge of Network Retrofit

Most of the process integration activity carried out industrially relates to the retrofit of existing processes for reduced energy demand or the retrofit of energy systems for increased process throughput. Whilst the methods for the design of new energy systems have become relatively sophisticated, methods for the retrofit of energy systems are still far less well developed. Indeed, the cost-effective retrofit of heat recovery systems remains one of our biggest challenges. Revamping existing systems can be complex with many difficulties that are hidden at the outset. The cost of new items of equipment is often a minor issue. By contrast, the cost of piping modifications and civil engineering is far more of a problem than the purchase of new items of equipment.

Whilst techniques of pinch analysis can be applied to the network retrofit problem, it is fundamentally unsuited to retrofit. This is rooted in the fact that the approach attempts to turn the network into a new grassroot design in a single step, leading to retrofits that are complex and most often uneconomic. What is needed is an approach that starts with the existing design and evolves in the series of controlled steps towards a new grassroot design (but not necessarily moving all the way to a grassroot design) in such a way that the designer maintains control over the cost and complexity of the retrofit.

A problem that underlies the retrofit of heat recovery systems is the need to add additional area without the costs escalating. One way in which this can be done is the use of heat transfer enhancement for existing heat exchangers. In this way, existing heat exchanger shells can be revamped without the need for expensive piping and civil engineering work. Changes in network structure need to be combined with the effective use of heat transfer enhancement in a systematic approach.

Coupling Heat Exchanger Network and Process Models

The importance of exploiting degrees of freedom within the process for improving energy performance has been a feature of process integration from the earliest days. It was recognised from early applications of process integration that combining process changes with changes to the heat recovery system, leads to far better results compared with changes to the heat recovery system alone. However, in order to obtain the best results, the process models and heat exchanger network models need to be combined. Whilst in principle this is straightforward, there are many difficulties.

Ideally, it would be preferred to couple a rigorous process model with a detailed model of the heat exchanger network for optimisation. However, such models are not robust enough to be included in an optimisation, and would be computationally very demanding. The simulation model of the process needs to be simple and robust enough to be included in an optimisation model with the heat recovery network details. If process models and heat recovery models can be combined effectively, then there are not just opportunities for design and retrofit, but also operational optimisation. Recent experience in petroleum refinery distillation is that significant energy savings can be accomplished by the modelling of the distillation and heat recovery system simultaneously. The use of surrogate models overcomes the problem of the required accuracy and robustness and is computationally very efficient [6-7].

This paper will present a number of industrial case studies illustrating the power of an approach that can couple surrogate models of refinery distillation with models of the heat exchanger network.

References

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