Abstract

In most industrial processes, energy is an integral part of the production process; therefore, energy consumption has become an intensified area in chemical engineering research. Extensive work has been done on energy optimisation in continuous operations; unlike in batch operations because it was believed that due to the small scale nature of batch plants, small amounts of energy is consumed. Certain industries such as the brewing and dairy industries have shown to be as energy intensive as continuous processes. It is, therefore, necessary for energy minimisation techniques to be developed specifically for batch processes in which the inherent features of batch operations such as time and scheduling are taken into account accordingly. This can be achieved through process integration techniques where energy consumption can be reduced while economic feasibility is still maintained. Most of the work done on energy minimisation either focuses on direct heat integration, where cold and hot units operating simultaneously are integrated, or indirect heat integration, where units are integrated with heat storage. The schedules used in these models are, in most cases, predetermined which leads to suboptimal results.

This work is aimed at minimising energy consumption in multipurpose batch plants by using direct heat integration together with multiple heat storage vessels through mathematical programming. The proposed approach does not use a predetermined scheduling framework. The focus lies on the heat storage vessels and the optimal number of heat storage vessels together with their design parameters, namely size and the temperature at which the vessels are initially maintained, are determined.

The formulation developed is in the form of a mixed integer non-linear program (MINLP) due to the presence of both continuous and integer variables, as well as non-linear constraints governing the problem. Two illustrative examples are applied to the formulation in which the optimal number of multiple heat storage vessels is not known beforehand. The results rendered from the model show a decrease in the external utilities, in the form of cooling water and steam, compared to the base case where no integration is considered and the case where only one heat storage vessel is used.