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Efficient energy use in a slaughter and meat processing plant—opportunities for process integration

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Abstract

In this paper, process integration methods are used to investigate the potential to decrease the energy usage in the slaughtering and meat processing industry. Above ambient temperatures, heating of water with different target temperatures is a large heat demand in a plant, while at subambient temperatures the refrigeration plant needs almost all of the shaftwork used at the site. Interaction between, on one hand, energy demands above ambient temperature and, on the other, cooling needs below ambient temperature can take place with freezing compressors or heat pumps. By using process integration methods above and below ambient temperatures, potentials for saving both shaftwork and external heat demand in food plants can be identified. A case study at a modern plant illustrates that even though many energy-saving measures have been taken there is still a technical potential for saving 30% of the external heat demand and more than 10% of the shaftwork used in the plant. The economic potential for the savings is dependent on the conditions at the plant.

Keywords: Process integration; Ready-made meals; Pinch analysis; Energy savings; Food processing; Slaughterhouse; Meat processing; Shaftwork; Refrigeration; Heat pump

1. Introduction

A number of trends in the food industry will make energy-related issues more important in food processing plants in the future. Firstly, increasing sales of ready-made meals increase the degree of processing in the food industry. This leads to larger energy use in the plant, while the energy usage in households is changed and to some degree transferred to the processing industry (Sonesson, Mattson, Nybrant, & Ohlsson, 2004). Secondly, there is also an increasing demand for greater flexibility in the food processing plants. Consumers want a greater range of different products. This, in turn, increases energy use in the plant e.g. through increased warm water usage. These changes in customer behavior, together with raised energy prices, hardened price competition, and policy instruments such as carbon dioxide trading and taxation, should heighten the interest in saving energy in the food industry.

The food processing plants in Sweden used approximately 5.75 TWh fuel and electricity (Statistics Sweden, 2002) out of the approximately 160 TWh used by all industry in 2000 (EUROSTAT, 2005). However, 20% of the total energy use in Swedish society can be attributed to the food supply system (SEPA, 1997). The overall energy use in Swedish food processing plants consists on average of 45% electricity and 55% purchased fuels, not including fuel for transports. Within the food industry, the dairy and cheese and the slaughtering and meat

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Nomenclature

CAHP	compression/absorption heat pump	t	temperature [°C]
COP	coefficient of performance	T_a	ambient temperature, 293.15 K
GCC	grand composite curve	ΔT_{min}	smallest accepted temperature difference
EGCC	exergy grand composite curve	UC	utility curve
SMP	slaughter and meat processing	Q	heat/cooling load [kW]
T	temperature [K]		

processing industries are particularly electricity-demanding. The sugar industry and drink production plants are particularly fuel-demanding.

Process integration is the common term for system-oriented methods that can be used when designing and retrofitting industrial processes to obtain a complete plant with optimal use of resources, such as energy, raw materials and process equipment. The focus of the methods has traditionally been on efficient energy use, but recently other parameters have been studied.

There are several scientific papers describing case studies using heat pinch analysis in the food industry. Most of them, however, describe industries that are similar to the chemical process industry where the pinch technology was developed such as sugar refineries, dairies and breweries. Relatively few studies have been published in the part of the food industry studied in this paper, represented by the meat industry, where the production is mainly batch-wise and related to the manufacturing industry rather than processing industry. One of these studies was made by Chadderton (1995) describing a pinch analysis in a meat plant in New Zealand. Another study by Fritzson and Vamling (2004) describes an energy analysis using pinch tools in a Swedish slaughter and meat processing plant. The experience in this type of food industry in the consulting sector includes studies in slaughterhouses and ready-made meal plants. Most of these are not available to the public.

The aim of this study is to find the potential to decrease energy use, both external heat demand and electricity use in the refrigeration system, in a modern food processing plant. The Swedish slaughterhouse and meat processing plant (SMP) studied is especially interesting since a modern extensive heat recovery system has been integrated with the plant. In the study, two process integration methods are used to find the potential for saving electricity and fuel demand in the plant. To identify fuel savings, heat pinch analysis is used. To lower the electricity use in the refrigeration plant in the SMP, a shaftwork-targeting methodology based on pinch analysis methodology is used together with process simulation in HYSYS®, an integrated simulation program for continuous processing industries.

2. Method

2.1. Process integration – heat pinch analysis

For the benefit of engineers inexperienced with process integration methods, these techniques are briefly explained in this article. The more practiced engineer is advised to skip this section and proceed to the case study.

Heat pinch analysis is the single most important process integration concept and the one that originally gave birth to the field (Gundersen, 2002). The methodology is based on thermodynamic principles. Using pinch analysis, it is possible to identify appropriate changes in the core process conditions that can have an impact on energy savings. Some questions that can be answered by heat pinch analysis are: What are the minimal external heating and cooling demands for a particular process? What is the maximum heat that can be recovered through internal heat exchangers? How should a heat exchanger network be designed so that internal heat-exchanging is optimized?

The concept of heat pinch analysis was developed into an industrial technology by Bodo Linnhoff and his group at UMIST in Manchester in the 1980s (Linnhoff et al., 1994). To read more about the most basic aspects of process integration methods as well as some of the recent and advanced elements of these methods, see Gundersen (2002).

A heat pinch analysis starts with the heat and material balances for a process. In the analysis, streams that need to be heated (cold streams) or cooled (hot streams) are identified. With these in mind, graphical representations of the energy flows of a process can be produced. Some examples of these graphs are the composite curves (CC) and the grand composite curve (GCC). The GCC shows the energy demands at various process temperatures, the net external heating and cooling demands, as well as the pinch temperature. In this way, targets for energy saving can be set prior to the design of the heat exchanger network.

The pinch divides the process into two separate parts, one part above, and one part below the pinch temperature. In the part that is above the pinch temperature