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Recommendations for rationalizing cleaning-in-place in the dairy industry: Case study of an ultra-high temperature heat exchanger

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ABSTRACT

The objective of this work was to propose a new strategy, based on objective and rational arguments and calculations, that can be implemented by plant designers and operators in the dairy industry to reduce operating time and the volume and load of effluents. The strategy is based on the on-line and off-line use of sensors and tracers, the accuracy, relevance, and robustness of which were evaluated for each phase of the sequence used for cleaning an industrial sterilizer. The efficient duration of each phase of the cleaning sequence (management of the end of operation) and the sorting of the fluids (management of mixtures and destination of fluids) were determined in real time. As a result, significant reduction in total overall duration of the cleaning sequence, wastewater volume (waste volume was reduced by half), and detergent volume (caustic soda and acid was reduced by up to a few tens of kilograms per cleaning) was achievable.
Key words: cleaning-in-place, management, sensor, effluent

INTRODUCTION

Cleaning-in-place (**CIP**) systems are commonly used in the food industry for ensuring hygienic safety of foods and for recovering plant performance. In the dairy industry, the time of nonproduction dedicated to CIP is excessive and ranges from 4 to 6 h per day. Moreover, the cleaning operation leads to 50 to 95% of the waste volume sent to the purification station, representing from 0.5 to 5 L of water per liter of processed milk regardless of the type and size of the plant or equipment (Marty, 2001; Sage, 2005). These effluents represent nonaccidental losses of matter and DM ranging from 0.1 to 6.0 g of equivalent milk per liter of processed milk. With such characteristics, these effluents contain a matter amount equivalent to 200,000 t of milk and represent approximately 1% of the 22.5×10^6 t of milk produced each year in France (Räsänen et al., 2002).

At present, the industrial CIP procedure mainly lies on practical experience imposed with excessive safety margins in terms of duration and chemical consumption. For the past 20 yr, dairy industry operators and CIP designers have not taken advantage of knowledge acquired about mechanisms, kinetics, and sensors adapted to fouling, rinsing, or cleaning operations (International Dairy Federation, 1995, 1997; Alvarez, 2003). Some efforts could therefore be made to help the dairy industry reduce both the overall duration of the cleaning operation and the volume and load of the resulting waste. This could be done by reducing the duration of each sequence phase or by using adequate fluid sorting procedures, which would lead to reuse and increased value of the food matter while always maintaining the quality of hygiene of the equipment.

The objective of this work was to propose a new strategy, based on objective and rational arguments and calculations, that can be implemented in the dairy industry to reduce overall operating time and the volume and load of effluents. The strategy is based both on the critical analysis of the literature and on the on-line and off-line use of sensors and tracers, the accuracy, relevance, and robustness of which were evaluated for each phase of the cleaning sequence to allow the on-line determination of the end of each phase and the adequate time needed for fluid sorting. More generally, this study aimed to propose a decision making tool that consists of objective and relevant methods to help CIP designers and food industry operators manage daily cleaning operations more efficiently. To illustrate the proposed strategy, the industrial case of a UHT heat exchanger treating high-fouling dessert cream was studied. The critical analysis of the existing equipment, the proposition of a revised procedure, and the experimental validation of the suggested improvements were performed.

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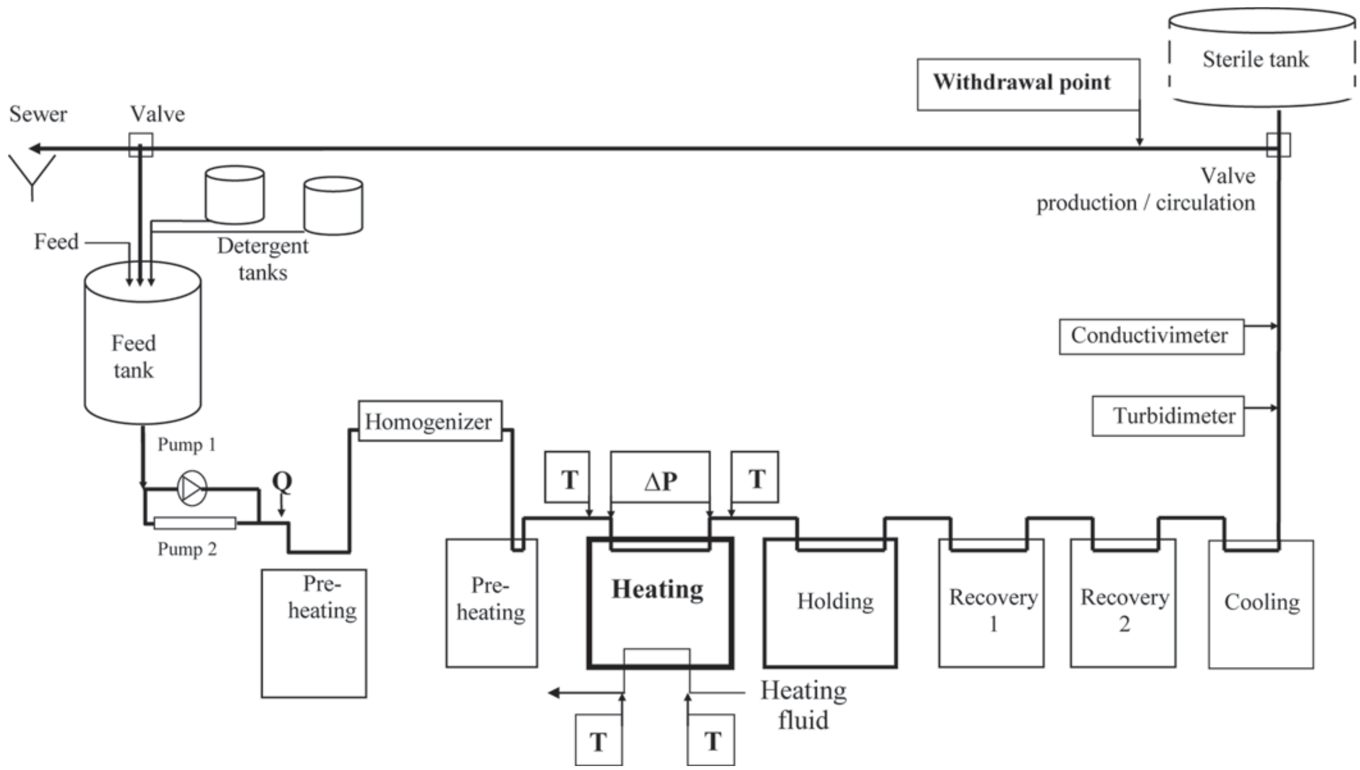

Figure 1. Schematic representation of the industrial UHT heat exchanger (ΔP = differential pressure sensor; Q = flow-rate sensor; T = temperature sensor).

MATERIALS AND METHODS

UHT Heat Exchanger

The industrial equipment studied was a tubular UHT heat exchanger (Invensys APV, Evreux, France) with 316 stainless steel tubes, each of them of 6.0 m long and consisting of 7 channels that were 14.0 mm in diameter. The sterilizer was composed of 5 zones (preheating, heating, recovery 1, recovery 2, and cooling; Figure 1). The study focused on the heating zone (inlet = 80°C; outlet = 128°C), which was the limiting zone because of its sharp fouling increase.

Several sensors were installed in the equipment (Figure 1). The flow-rate of the milk-based product (**Q**; 2.0 m^3/h) was measured with an electromagnetic flow meter (±0.5%; Magflo 6000, Danfoss, Trappes, France). A differential pressure sensor (2010 TD, 0–18 bar, ABB, Minden, Germany) was installed in the heating zone (accuracy = ±0.2% of the global scale of 10×10^5 Pa). Four 100-Ω platinum temperature sensors (±0.4°C) were installed at the entrance and outlet of the heating zone, 2 in the heating fluid and 2 in the dairy fluid compartments. A conductimeter (LMIT 08, 0–200 mS/cm, Henkel Ecolab, Nanterre, France) with an integrated 100-Ω platinum temperature sensor and a turbidimeter (Optec M, TTS Technologies, Saint Sébastien sur Loire, France) was installed at the outlet of the cooling section. The calibration of the conductimeter was realized from physicochemical analyses performed on samples withdrawn from the equipment.

The industrial equipment allowed real time data registering and storing by a computer. All the data were collected every 20 s during the production step and every 5 s during the launching and cleaning sequence. Data were collected with the monitor PL7 Pro software (Schneider Automation, Brest, France) transferred to Access (Microsoft, Redmond, WA) and treated with Excel (Microsoft).

Operating Mode of the UHT Heat Exchanger

The sterilization was performed in 2 steps: the launching phase, during which dessert cream flushed water out from the equipment, and the production phase. At the end of the production phase, the cleaning sequence started using a decentralized CIP system. Cleaning solutions and water used during rinses were systematically discharged to the purification station after each use (i.e., it was a single-use system).

We studied the cleaning sequence that was the most time consuming and generated the most effluents. The first phase of this sequence was the flushing– first water