FOULING AND CLEANING OF PLATE HEAT EXCHANGERS: DAIRY APPLICATION

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ABSTRACT

Plate heat exchangers (PHEs) used in milk thermal treatments are subject to rapid fouling, while Cleaning-in-Place (CIP) produces large amounts of wastes. Up to 80% of production costs in the dairy industry have been attributed to the effects of fouling and cleaning.

In spite of decades of research, a detailed model for simulation, monitoring, control and optimisation of full heating and cleaning cycles for PHEs is still not available. Mechanistic simulation models based on differential equations typically address only fouling but not cleaning. More detailed models based on Computational Fluid Dynamics (CFD) are computationally very expensive and impractical to use for optimization, scheduling and control of complete PHEs.

Here, a dynamic 2D model of PHEs is presented that enables optimizing milk thermal treatment operations, taking into account both fouling and cleaning. The model balances predictive accuracy and computational feasibility.

It integrates: i) various mechanisms and kinetics for fouling and cleaning; ii) a detailed moving boundary model of deposit growth that captures its spatial distribution; iii) a dynamic thermo-hydraulic model of mass and heat transfer in a single PHE channel; iv) the flexible assembly of channels into a variety of PHE configurations, and iv) the flexible definition of heating-cleaning cycles.

The fouling model has been validated for two PHE configurations against experimental data, with excellent results. Alternative fouling mechanism have been explored (due to aggregate proteins or denatured proteins, and with/without deposit re-entrainment). Results show that the fouling observed in the two arrangements is best fitted by distinct fouling models, and that the performance of the two PHE arrangements is quite different.

Dynamic cleaning models have been integrated with the deposit moving boundary model and validated. This has enabled for the first time the seamless, detailed simulation of individual and multiple heating-cleaning cycles, where each phase starts from the detailed deposit distribution at the end of the previous phase. The models' detail enables the introduction of sophisticated condition-based logic in the operation each phase and overall cycle. Using such condition-based logic it is shown that cleaning time could potentially be reduced by ~50%. Finally, it is shown that the heating/cleaning cycle can be optimized for maximum productivity, balancing fouling and cleaning trade-offs. This is demonstrated for one of the PHE arrangements.

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