ACOUSTIC IMPEDANCE ANALYSIS FOR DETERMINING PRESENCE AND CLEANING SUCCESS OF DAIRY FOULING

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ABSTRACT

In the dairy industry, cleaning is essential and often conducted once a day. In the majority of cases fixed Cleaning-In-Place (CIP) cycles are used. These CIP cycles are often designed for the worst case and are overdesigned for slightly fouled heat exchangers. Adapting or shortening cleaning cycles to the actual amount or degree of fouling cannot be achieved easily because up to now no online monitoring system of cleaning success exists. There are several methods to determine fouling or cleanliness, including measuring electric impedance, heat transfer coefficient or pressure drop, examining waste water, swabbing equipment, vibration sensors *etc*. However, most of these methods are either performed offline, are invasive or require existing heat exchangers to be adapted to the method used.

Hence, an online monitoring system has several problems to hurdle: it should be fast, easy to use, inexpensive, non-destructive, and non-invasive. To overcome these problems ultrasound has been used in this work. It is a well-known technique in Non-Destructive-Testing (NDT) and medical applications, as well as in the food industry, and fulfills the afore-mentioned criteria. In the food industry sound velocity measurements are already used to determine flow in pipes, filling in tanks or fermentation progress in beer.

Here, another important acoustic parameter has been employed: the acoustic impedance. This is a measure of the resistance a medium imposes to a sound wave. It depends on sound velocity, density, and material elastic properties like the bulk modulus for liquids, or Young's modulus for solids. A change in material state from liquid to solid and vice versa and therewith changing elastic properties affect the acoustic impedance. It can therefore be used as a measure of the state of a material and, in cleaning, for detecting the presence and absence of fouling. We have developed a new way to calculate acoustic impedance in pulse-echo mode dependent on reflectivity at interfaces. The derived equations can be used for basic as well as for complex setups.

To evaluate the method, preliminary experiments and simulations with SPICE have been conducted. The acoustic impedance of milk fouling type A under static conditions has been measured in a basic set-up. The presence of fouling has thereby been detected unambiguously and cleaning success (corresponding to absence of fouling) can be monitored. Our preliminary result for milk fouling type A yields an acoustic impedance of 2.95834 MRayl which, when compared with 1.48623 MRayl for water or 1.55832 MRayl for milk, indicates that fouling layers can be easily distinguished. Also, simulations with LTSPICE have been performed to prove the derived equation. Preliminary results show the right trend.