Simulating High-shear mixer using CFD

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Thesis: “Predict Flow Field and Mixing Time for High-Shear Mixers Using CFD”

Food processing is a cornerstone of today's society. Almost all products on the store shelves are created from some sort of processing line. In these lines, high-shear mixers are often used for combining the different ingredients. To understand how this machinery works and make the process more efficient, the flow field inside the mixer is analyzed. Preferably, Computational Fluid Dynamics (CFD) is used to simulate the flow instead of costly physical experiments. However, due to the complex geometry of this mixer these simulations are very time-consuming. The goal of this thesis is therefore to create a CFD-methodology which is both time effective and yields realistic results.

The food processing industry is evolving everyday and with it comes the need to improve the methods used. Many products are in the need of a mixing tank in their processing lines. One type of mixing tank that is often used, for example when powders should be mixed with liquids, is the high-shear mixer. High-shear mixers are driven by a rotor-stator structure. From a CFD perspective, there are rather few articles and theory about the high-shear mixer due to its complex geometry. However, with the rapid improvement of computational fluid dynamics in the last decades has the possibility to study high-shear mixers arised.

It is possible with the use of CFD to simulate the flow inside the high-shear mixer for greater understanding. However, to achieve a realistic flow in the simulation one has to simulate very small time steps. This has made the simulations non-viable to be used for industrial purposes, but with the improved methodologies in this thesis can the high-shear mixer be simulated within reasonable time.

There are two main properties of the high-shear mixer that this master thesis has been focused on: the flow field and the mixing time prediction. Knowledge of the mixing time is extremely important for the purpose of ensuring that the whole tank is well-mixed. Besides the method used to measure the mixing time, it is equally important that the simulated flow field captures the features most important for mixing. Without these features, a viable mixing time prediction is impossible.

The methodology that was deemed the best for high-shear mixers is called “separation of time-scales". After some time, the flow inside the vessel reaches a stable state, but different sections will stabilize quicker than others. The flow around the rotor-stator, i.e. the most complex section, will reach this state quicker than the rest of the vessel. Once this stable state has been reached, the flow around the rotor-stator can be approximated by profiles. With this, the highly complex rotor-stator can be removed from the simulation and an increased time step can be utilized, saving computational time.

To measure the mixing time, different methodologies were tested. The one deemed the best was the one called the “homogeneity method”. This method is conducted by introducing tracer material to the vessel via a short impuls. Then one measures how long different parts of the vessel take to reach a desired degree of homogeneity. The longest time necessary to reach this degree is then seen as the mixing time.

To determine how viable the methods are, the results have been compared to physical experiments. They have only been tested for one type of fluid, one tip speed and one geometry, so for future studies it is important to test the methodologies for different scenarios. However, it is important to mention that the methodologies gave good results for both the flow field and mixing time. Therefore, it is possible that these methodologies will be the start of a new way of simulating high-shear mixers and facilitate new mixing technology to arise in the near future.