Study of flow fields in mixing tanks with particles using CFD

Human desires when consuming food are nowadays shifting towards more healthy, and natural food. Products with food particles are commonly well perceived by consumers. Among them, one can find yoghurt with fruit pieces or cereals. To process these products, and satisfy the user expectations, some challenging conditions must be faced. Some of these, are explored in this Master Thesis.

The demand for food products with particles has increased remarkably in the last decades. These evoke to a natural, less-processed product that us, as a consumer, perceive as good. It is always better to have real fruits in your yoghurt, than some other unknown ingredients. Food processing companies are interested then in offering a wide selection of these products.

These are however really challenging to process when compared with other liquid products. As the reader can imagine, normally this type of food is processed in processing lines. Multiple operations are performed to the original set of food products until the last and desired one is obtained. Among these operations, one is simply storing the mixture. Particles and fluid coexisting within the walls of a tank. When the particles are denser than the fluid, the inevitable outcome of this stage is sinking and sedimentation. This locates all the particles at the tank bottom, and the final product quality when the tank is emptied is thus compromised. Some packages can end up having only fruits, or only yoghurt. This is of course an undesired result both for the consumer and the companies.

The solution to this problem is to use stirred tanks. These incorporate a stirrer, an element that creates agitation. The stirrers can be seen as fluid shakers. This agitation provides movement to the fluid, that carries and transports the food particles. If the movement of the fluid is correctly designed, the distribution of particles is correct i.e. uniform. Generally, a good fluid movement presents good bottom-to-top motion. Designing this agitation is however a difficult task. Engineers commonly combine experimental testing and computer simulations to create good fluid motions. With these studies, the geometry of the tanks and stirrers, the stirrer rotational speed, and other parameters can be assesed and selected.

The use of computer simulations reduces the need for experiments and thus, the overall cost of the research projects. When a fluid is involved, Computational Fluid Dynamics (CFD) are used. This tools model the reality, i.e. the tank properties, and solve mathematical equations to predict the flow behavior. In the same way, CFD has evolved to allow particle inclusion, being then possible to model the reality completely. This allows the engineers to understand, sometimes with parameters otherwise impossible to be measured, what is happening inside the tank. This leads inevitably to better and most substantiated conclusions.

However, CFD techniques are not completely accurate. Resolving the complex equations in the modeled reality is sometimes impossible, and when it is possible, high computational time is needed. Normally, equations are simplified using a series of assumptions that reduce the complexity of reality. A trade-off between accurate results and time consumption is thus established. Research is conducted to develop methodologies that predict the reality correctly enough, without using years of computational time. This is however a complicated task.

This Master Thesis researches different methodologies to model the fluid behavior, and the particle distribution in production scaled tanks. These tanks are the same shape and size as the ones used in the mentioned production lines. The methodology is validated against experimental data. Later, it is used to analyze two different tank-stirrer geometries. These stirrers present unique characteristics that make them interesting to research. Finally, the stirrer performance is assessed, obtaining valuable data for their future development.

This Master Thesis offers then, a step forward towards a correct modeling of reality. At the same time, it is able to offer information about two different stirrer geometries that may lead to future promising use.