Form 2

Dissertation Abstract

Report no.	(Course-based) No.1144	Name	Md. Tauhedul Azam
Dissertation title	**Experimental and Computational Investigations of Fluid Mixing Process in Rotating Jet Flow** （回転噴流における流体混合過程の実験的および数値的研究）		

Abstract

※ The abstract should be in keeping with the structure of the dissertation (objective, statement of problem, investigation, conclusion) and should convey the substance of the dissertation.

Mixing processes has been accepted as a considerable discipline of academic research because of their significance in process industries. The success of many process industries including chemical, pharmaceutical, food, paint, etc. depends on the effective mixing operation. Consequently, various kinds of mixer have been developed in order to solve these multi-faceted mixing problems.

In this research, the fluid mixing process in a stirred tank with a newly designed conduit-type mixer are investigated. This is a blade-free mixer and constructed with a set of L-shaped channel. The rotating conduit-type mixer stirs the fluid by generating rotating jet flow from its channels due to the centrifugal force. The mixing process of this mixer is identically different from the conventional blade-type mixer. The fluid mixing process in the rotating jet flow produced by the conduit-type mixer are compared with the fluid mixing process by the conventional fin-type mixer (flat-blade mixer).

In this thesis, the investigation results are analyzed in three parts. First, the flow pattern of the conduit-type mixer are visualized by a flow visualization with particle tracer method. In the second part, the local concentration behavior and the mixing time in a stirred tank are analyzed by a concentration measurement method. In the final section, the mechanism of wider circulatory flow pattern are investigated using particle image velocimetry (PIV) and large eddy simulation (LES).

According to the flow visualization experiment, the fin-type mixer generated a pair of closed circulation loop around the mixer and mixing at the bottom corner was poor. Consequently, large sedimentation was observed at the bottom corner of the tank. On the other hand, the conduit-type mixer generated a wider circulatory flow pattern and stirred the fluid over a vast area of the tank. This was caused by the rotating jet flow which can stir the fluid from the long-distance of the tank. As a result, the sedimentation at the bottom corner was small. Thus, flow visualization results suggest that the conduit-type mixer has advantages to mix the fluid uniformly in space.

The concentration measurement showed that the mixing time of the conduit-type

mixer is slightly longer than that of the fin-type mixer. This is because to produce the wider circulatory flow pattern required the longer initial time.

The flow pattern obtained from visualization experiment was confirmed by the flow pattern obtained from the large eddy simulation (LES). It showed that the vortices generated by the rotating jet (or blade) dominated the flow fields in the radial direction from the mixer. The particle image velocimetry (PIV) and large eddy simulation (LES) results were validated by comparison with phase-averaged velocities for each other.

The fin-type mixer generates counter-rotating trailing vortex pair behind the blade tip. The trailing vortices issued by the blade tip has moved outward from the mixer by inducing radial velocity between them. In a short distance, they form a circular vortical structure by reconnecting with the co-rotating vortices from the different blades. This circular vortex becomes unstable and breakdown, in a short time. The radial flow degenerates due to this quick dissipation of the vortices, resulting in a closed circulation loop around the mixer and a circular flow near the tank wall was observed. The closed circulation loop around the mixer and the circular flow near the tank wall are the reasons for poor mixing, which was also observed in the flow visualization experiment. Furthermore, the quick dissipation of the circular vortical structure provides a high turbulent kinetic energy (tke) near the fin-type mixer, however, in the far field the tke is low for the fin-type mixer. In other words, for the fin-type mixer, the mixing or exchange rate of fluid is high near the mixer, but in the far field, mixing is not very effective.

In case of the conduit-type mixer, the rotating jet generates a counter-rotating vortex pair at the vicinity of each nozzle outlet. The generated co-rotating vortices from the different nozzles continuously merging together to form a spiral-shaped vortex tube. In a meridional section of the spiral-shaped vortex tubes, the reverse von Kármán vortex street was observed. The counter-rotating vortices of reverse von Kármán vortex street migrates in the outward direction with self-induced velocity and induces outward velocity between them. In this process, the spiral-shaped vortex tube pair migrates the jet flow in the outward direction for which the jet flow sustained in a long-distance and generates a wider circulation. Compared with the fin-type mixer, the conduit-type mixer generates larger mean kinetic energy (mke) and smaller turbulent kinetic energy (tke) near the mixer. The merging of the co-rotating vortices produced by the different nozzles of the conduit-type mixer continuously provides the tke to a long distance. As a result, the decreasing rate of the tke is very low for the conduit-type mixer. Moreover, the convection of the tke is high because of the high mke of the conduit-type mixer. For this reason, in the far field, the tke generated by the conduit-type mixer is larger than by the fin-type mixer. This means that mixing in the far field is effective by the conduit-type mixer. Therefore, the mixing by the conduit-type mixer is favorable for the uniform mixing process.