

Mixing Characteristics of Liquid Phase in an Unbaffled Vessel Agitated by Unsteadily Forward-Reverse Rotating Multiple Impellers

Masanori Yoshida^{1*}, Yoji Taguchi¹, Kazuaki Yamagiwa¹, Akira Ohkawa¹,
Masahiko Abe², Shuichi Tezura³ and Masuo Shimazaki³

¹ Department of Chemistry and Chemical Engineering, Niigata University, 8050, Ikarashi 2, Niigata 950-2181, Japan

² Department of Industrial Chemistry, Science University of Tokyo, 2641, Yamazaki, Noda, Chiba 278-8510, Japan

³ Shimazaki Mixing Equipment Co., Ltd., 24-2, Nishi Nippori 2-chome, Arakawa-ku, Tokyo 116-0013, Japan

*myoshida@eng.niigata-u.ac.jp

Abstract— Mixing characteristics of liquid phase in an unbaffled vessel containing water with a liquid height-to-diameter ratio of 2 agitated by unsteadily forward-reverse rotating multiple impellers, a cross type of impellers with four delta blades (CDs), were experimentally studied in comparison with that in a baffled vessel agitated by steadily unidirectionally rotating disk turbine impellers with six flat blades (DTs). For the forward-reverse as well as unidirectional modes of operation, the mixing time in multiple impeller system was larger than that in single impeller system with a liquid height-to-diameter ratio of 1. The ratio of mixing time in multiple impeller system to that in single impeller system was small for the forward-reverse agitation mode compared with that for the unidirectional agitation mode. The result was discussed in relation to the difference in bulk flow pattern between the unbaffled vessel with forward-reverse rotating CDs and the baffled vessel with unidirectionally rotating DTs.

Keywords— mixing time; unbaffled agitation vessel; unsteadily forward-reverse rotating impeller; multiple impeller system; bulk flow pattern

I. INTRODUCTION

In industrial agitation operations, deep vessels with multiple impellers characterized by a liquid height-to-diameter ratio larger than unity are frequently employed for practical purposes to get high volumetric mixing and to reduce the floor area occupied by the equipment in the factory. For such a system, it is well known the importance of the impeller design and the determination of impeller arrangement (Nishikawa *et al.*, 1976; Hudcova *et al.*, 1989; Armenante and Chang, 1998; Armenante *et al.*, 1999). For conventional baffled vessels having steadily unidirectionally rotating multiple impellers, the impellers have been arranged on the shaft with the clearance and number determined on the basis of the data on their power consumption. However, whether or not design of the multiple impeller vessel is reasonable in view of operational characteristics is uncertain.

A primary way to investigate the feasibility of design for the multiple impeller vessel is to evaluate the

mixing time of liquid phase which is a fundamental parameter needed not only for homogenization operation of liquid phase but also for mass transfer operation treating dispersions such as gas-liquid mixtures and solid-liquid mixtures. It seems that the results of few studies on the mixing time in baffled vessels having unidirectionally rotating multiple impellers (Komori and Murakami, 1988; Cronin *et al.*, 1994; Jahoda and Machon, 1994; Vasconcelos *et al.*, 1995) have been used as data for design and operation.

Previously, we proposed an unbaffled vessel having unsteadily forward-reverse rotating multiple impellers, a cross type of impellers with four delta blades (CDs), whose rotation reverses its direction periodically, and this type of agitator was named “AJITER” (Yoshida *et al.*, 1996). For CDs in AJITER, the effect of clearance on the power consumption of impellers was elucidated, which is basic for design of the multiple impeller vessel (Yoshida *et al.*, 2002). In order to provide a more sound and generalized basis for design and operation of AJITER, in addition to clarification of the power characteristics of impellers, further study on the mixing characteristics of liquid phase in a vessel is necessary. In this work, the way of arrangement of CDs in multiple fashion was first established, based on the dependence of power consumption on the clearance of forward-reverse rotating multiple CDs in an unbaffled vessel. For the vessel constructed, the effect of the number of impellers on the mixing time was then evaluated experimentally in comparison to that for a baffled vessel having unidirectionally rotating disk turbine impellers (DTs).

II. METHODS

As the forward-reverse rotating impeller, a cross type impellers with four delta blades (CDs), 120-240 mm in diameter (D_i), were employed for an unbaffled vessel. A conventional impeller consisting of a disk turbine impeller with six flat blades (DT), was adopted as the unidirectionally rotating impeller. DTs, 90-150 mm in D_i , were used under the fully baffled condition (four baffles, 0.1-fold inner diameter of vessel in width). A schematic diagram of the experimental set-up