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Effect of Impeller Clearance on Power Consumption of Unsteadily Forward-Reverse Rotating Multiple Impellers in an Unbaffled Agitation Vessel

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Abstract

Power consumption of unsteadily forward-reverse rotating multiple impellers, a new cross type of impellers with four delta blades (CDs), was experimentally studied in an unbaffled agitation vessel containing water with a liquid height-to-diameter ratio of 2. The effect of clearance on the power number of forward-reverse rotating double and triple CDs was compared with that of unidirectionally rotating disk turbine impellers with six flat blades (DTs) in the baffled vessel. The result was discussed in relation to the difference in bulk flow pattern between the unbaffled vessel with CDs and the baffled vessel with DTs. The study also revealed that the value of power consumption for the forward-reverse rotating multiple CDs in the unbaffled vessel can be evaluated as the value for the single CD system multiplied by the number of impeller stages over a wide range of impeller clearances.

1. Introduction

Power consumption of impeller in agitation vessels is an important parameter not only required in selecting and designing the drive unit but also needed in characterizing the difference in transport phenomena within the vessel. For example, the volumetric mass transfer coefficient, a significant measure for scale-up of aerated agitation vessels, is closely related to the power consumption per unit volume or mass of liquid, i.e., the specific power input (Van't Riet, 1979). In other words, when an improvement in the volumetric coefficient is planned by varying operation conditions including the way of attachment of impellers in multi-stage configuration system, the magnitude of the intended volumetric coefficient is predicted through estimation of changes in the specific power input. In industrial agitation operations, deep vessels which have multiple impellers characterized by a liquid height-to-diameter ratio considerably larger than unity are frequently employed. For such a system, the importance is well known of the selection of impeller design and the determination of impeller arrangement. A number of studies have already been carried out on the relationship between the power consumption of steadily (=unidirectionally) rotating multiple impellers and their clearance in conventional vessels with baffles attached to avoid the formation of a purely rotational flow (Takeda *et al.*, 1968b; Taguchi and Kimura, 1970; Nishikawa *et al.*, 1976; Hudcova *et al.*, 1989; Armenante and Chang, 1998). These results can successfully be applied to design and operation of baffled vessels having steadily rotating multiple impellers.

On the other hand, there has recently been a growing interest in using the method that gives unsteady agitation action to fluid either by changing the direction or speed of impeller rotation, i.e., that allows the impeller to rotate unsteadily in liquid. In fact, some papers have been reported the operational characteristics of this kind of agitation vessel having unsteadily rotating impeller in relation to the specific power input (Lamberto *et al.*, 1996; Ogawa *et al.*, 1996; Nomura *et al.*, 1997; Yao *et al.*, 1998). As has been pointed out, improvement in performance (operational characteristics) of the agitation vessel is achievable under low power consumption by using unsteadily rotating impeller. However, these works dealt with the vessels having only unsteadily rotating single impeller and the results were not developed into the vessel having multiple impellers, which is likely to be more important from the viewpoint of industrial (=practical) application. In other words, this suggests that the previous works can hardly give knowledge on the power characteristics necessary as the basic data for design and operation of the vessel having unsteadily rotating multiple impellers, or more

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