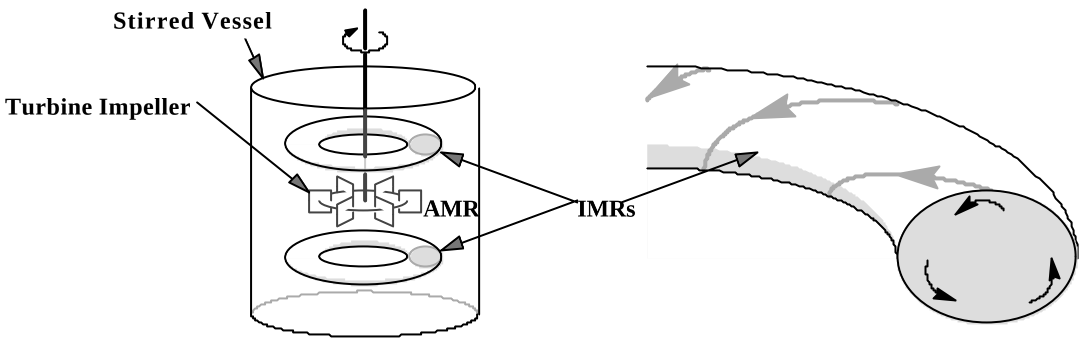
## Paper 21.2

# Laser-Optical Observation of Chaotic Mixing Structure in a Stirred Vessel

by
Tsukasa MAKINO, Takuya KAISE, Naoto OHMURA and Kunio KATAOKA
Kobe University
Department of Chemical Science and Engineering
Rokkodai-cho, Nada-ku, Kobe 657-8501; Japan

## ABSTRACT

The purpose of the present work is to observe the chaotic mixing structure in a stirred vessel with the aid of flow-visualization using a laser induced fluorescent. Under the laminar flow condition in a stirred vessel, two types of mixing regions were observed, i.e. *active mixing region* (AMR) and *isolated mixing region* (IMR), as shown in figure 1. The IMRs took clearly the form of two toroidal vortices respectively above and below the turbine impeller in the range less than Re = 100. These regions did not interchange much fluid material with the AMR and remained visible for a couple of hours. On the other hand, a good mixing state was observed in the AMR. From the cross sectional view, it has been found that the good mixing in the AMR results from the stretching and folding motion of the turnstile-lobe like regions generated by each stroke of turbine blades. This result indicates that mixing properties in the AMR was strongly dependent on both the secondary circulating flow rate and the passing frequency of turbine blades, which corresponds to the perturbation frequency. Under the same rotational condition, a set of three stable filaments surrounding the core torus of an IMR was found in the case of the six-bladed turbine, while a set of four filaments was found in the case of the four-bladed turbine. Hence it can be considered that these structures depend on the periodical perturbations caused by the rotating turbine blades. In order to observe the inside structure of ring-doughnut-shaped core regions, the unsteady rotation procedure was applied. Another set of filaments was observed to exist inside the core. It has been found that the IMRs had complex multi-structures consisting of various KAM tori. The rotating period of an island $P_i$ and the passing period of turbine blade $P_t$ had a rational relation between them. Furthermore, the rational number of the ratio, $P_i/P_t$, corresponded to the number of islands. These results indicate well the structure complicated with stable/unstable manifolds obtained from the Poincaré-Birkhoff theorem. It can be considered that the geometric structure of the IMRs is controllable depending on the number of blades and the rotational speed of impeller.




a) b)

*Fig. 1. Schematic picture of IMR in the stirred vessel*
*a) Schematic picture of AMR and IMRs in the stirred vessel*
*b) Enlarged illustration of IMR*