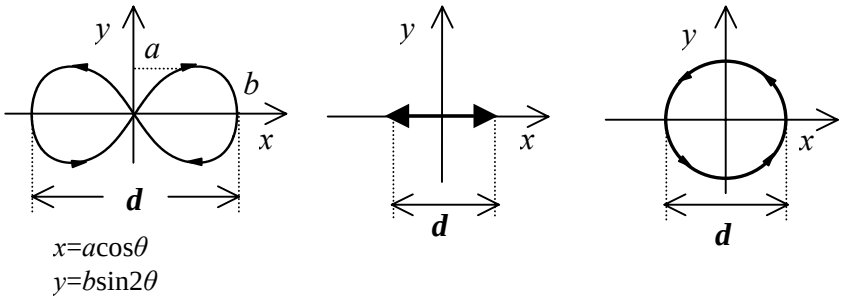
# Mixing Efficiency of Shaking Vessel with Various Motion

Y. Kato[1], S. Hiraoka[1], S. Watanabe[1], Y. Tada[1], Y. Nagatsu[1] and J. Büchs[2]

([1]Nagoya Institute of Technology, JAPAN, [2]RWTH Aachen University, GERMANY)

## Introduction

Shaking flasks are widely used as the screening and the pre-fermentation in biochemical process. There are many shaking methods for liquid mixing in flasks, e.g. rotary, reciprocal, figure-eight and up-down motions. Although shaking vessels were widely used in laboratories and factories, they were operated with the experience. The purpose of this study is to find the optimum operating condition of the figure-eight shaking, and to find the better shaking method by comparison with the reciprocal shaking and the rotary shaking.




**(a)Figure-eight motion** **(b)Reciprocal motion** **(c)Rotary motion**

**Fig.1 Three motions of shaking vessel**

## Experimental Result

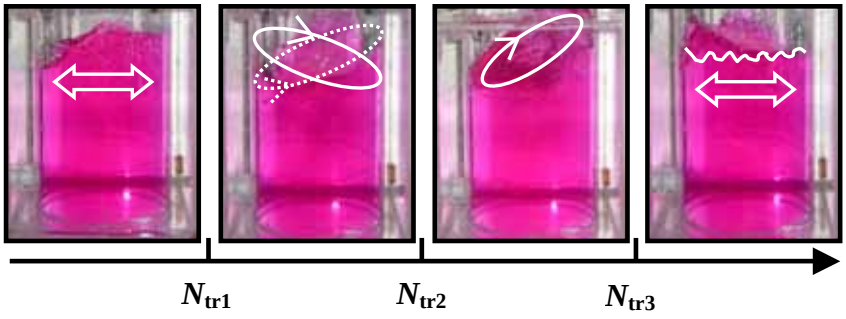



**Fig.2 Flow patterns of the figure-eight shaking**

**(1) Flow pattern**

The change in the flow patterns of the figure-eight shaking was the same as that of the reciprocal shaking. When the shaking frequency was lower than $N_{tr1}$, the flow pattern took the progressive wave type. As the shaking frequency increased, a chaotic flow pattern was generated to change the flow direction. When the shaking frequency was larger than $N_{tr2}$, the steady rotational flow was generated. Finally, when the frequency was larger than $N_{tr3}$, the rotational flow disappeared.

**(2)Solid-Liquid Mass transfer coefficient**

$k_L$ of the rotary shaking increased with increasing the rotational frequency, while $k_L$ of the reciprocal shaking and the figure-eight shaking did not increase simply with increasing the shaking frequency.

**(3)Gas-Liquid Mass transfer coefficient**

$K_La$ of the rotary shaking monotonously increased with increasing in the shaking frequency, while $K_La$ of the reciprocal shaking and the figure-eight shaking did not increase with increasing the shaking frequency, because the power consumption did not monotonously increase with increasing the shaking frequency.

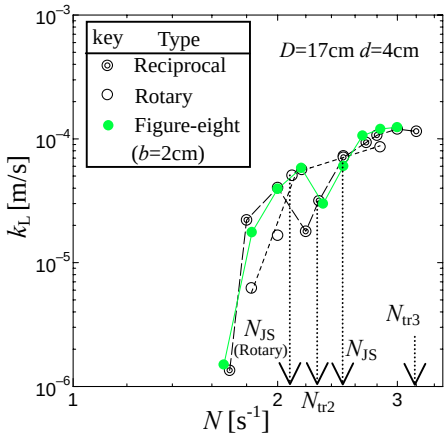



**Fig.3 Solid-liquid mass transfer**

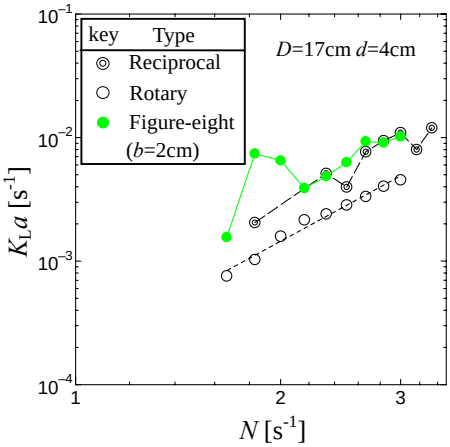



**Fig.4 Gas-liquid mass transfer**