# Mixing Performances of Unsteady Speed Impeller

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## Introduction

It is well known that the non-mixing regions like a doughnut are generated above and below the steady speed turbine impeller in a vessel at low Reynolds number. In this study, the unsteady speed mixing was adopted to remove the doughnut rings efficiently instead of improving the impellers.

The unsteady speed is generated by using the combination of three non-circle cams in motor. In unsteady speed mixing with planetary motion, the axis with the impeller revolves around the center. The mixing performances of the unsteady speed impeller were compared with those of a conventional impeller with steady speed.

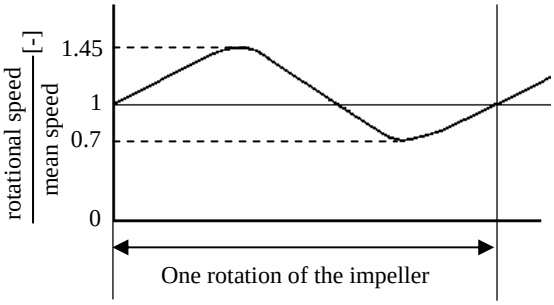
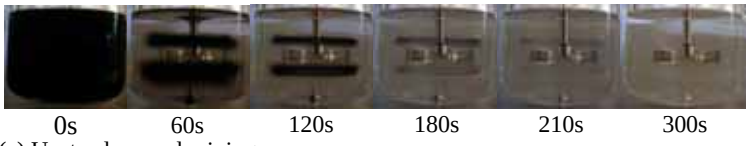



**Fig.1 Unsteady speed motion**

## Experimental Result




(a) Unsteady speed mixing


(b) Unsteady speed mixing with planetary motion


(c) Steady speed mixing

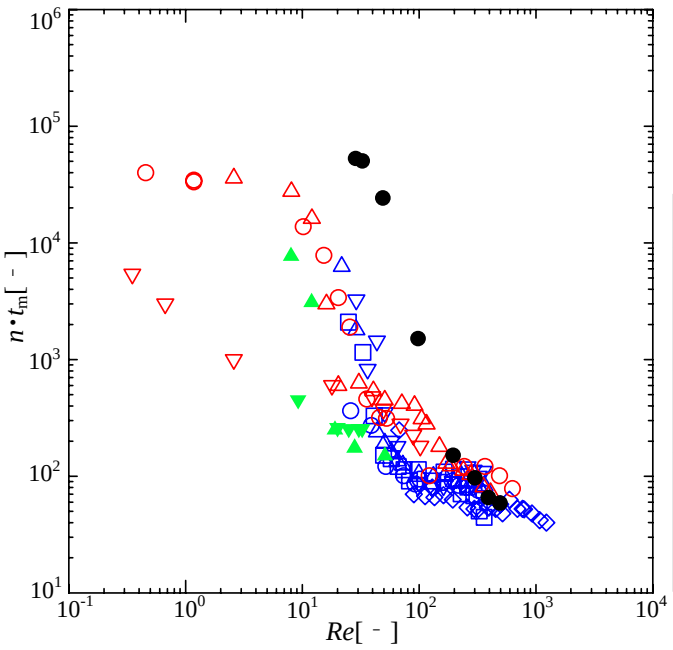
**Fig.2 Mixing process and mixing time using the turbine impeller with the decolorization method at *n*=120rpm, *Re*=30-40**

### (1) Visualization of Mixing Process

Because the center of the vortices above and below the impeller was moved by the unsteady motion, the doughnut rings disappeared soon in unsteady speed mixing. In unsteady speed mixing with planetary motion, the doughnut rings were not generated and the mixing time decreased. The mixing performances were improved by using the unsteady speed impeller and by using that with the planetary motion.

### (2) Effect of unsteady speed on mixing time

The dimensionless mixing time of the unsteady speed mixing was two-order smaller than that of the steady speed mixing for *Re*<100. It was found that the co-reverse periodic rotation and the time-periodic fluctuation of rotational speed was a little more effective than the unsteady speed mixing for *Re*<40. Therefore, the mixing time was hardly influenced of the kind of the methods with unsteady speed for *Re*>40. The dimensionless mixing time of the unsteady speed mixing was the same as that of the steady speed mixing for *Re*>400.




| method | impeller | key |
|---|---|---|
| Steady speed mixing | Turbine | ● |
| Unsteady speed mixing | Turbine | ○ |
| | Pitched–blade paddle(down pumping) | ▽ |
| | Pitched–blade paddle(up pumping) | △ |
| | Four–blade paddle | □ |
| | Maxblend® | ◇ |
| Unsteady speed mixing with planetary motion | Turbine | ○ |
| | Pitched–blade paddle(down pumping) | ▽ |
| | Pitched–blade paddle(up pumping) | △ |
| Co–reverse periodic rotation (Yao *et al.*,1998) | Turbine | ▲ |
| Time–periodic fluctuation of rotational speed (Yao *et al.*, 1998) | Turbine | ▼ |

**Fig.3 The relationship between dimensionless mixing time and Reynolds number**