力学学报　2005 37 (6): 682-688　ISSN: 0567-7718　CN: 11-2063/O3

非对称槽道中涡旋波的特性研究

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收稿日期　修回日期　网络版发布日期　接受日期

摘要　利用PIV流场显示技术，对振荡流体在非对称槽道中涡旋波的产生、发展和消失的规律进行了实验研究和分析，测得了涡旋波流场的速度矢量图，阐明了涡旋波流场周期性变化的特点．结合涡动力学方程，深入分析并揭示了做周期性运动的流体能在槽道中产生波的特性这一规律，从中发现：流体周期变化的非定常性和不对称的槽道结构是形成涡旋波流动的主要因素．本文对涡旋波流场中各个旋涡的速度分布和涡量进行了测量和计算，分析了涡旋波强化传质的机理，并研究了Re数对涡旋波流动的影响

关键词　振荡流,涡旋波,PIV,Re数,速度矢量图,涡量

分类号　0357.1

The study of the characteristic of vortex wave in an asymmetric channel

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Abstract

It has been received much attention that the dispersion phenomena can be produced by unsteady flows in a channel during the past few decades because of their usages in chemical, biochemical and medical engineering. As the study of fluid mechanics has evolved from steady state investigations towards the reality of unsteady phenomena, it has become increasingly clear that instantaneous whole field non-intrusive flow measurement techniques are required. In the past few years particle image velocimetry (PIV) has developed rapidly as a means for obtaining whole fields of fluid velocities. It has capitalized on recent computer hardware and software developments, to the extent that it now is practicable for determining and mapping fields of unsteady movement, especially at the narrow flow channels. This study makes the use of PIV to capture the vortex wave motion and their structures during oscillatory flows through a two-dimensional asymmetric channel. The vortex wave is a relatively recently discovered fluid structure where a standing wave of vortices can be generated either by an unsteady motion of a channel wall or by unsteady flow through an asymmetric channel expansion. The vortex wave, which evolved at low speed, can enhance the mass transfer of boundary layer in channels and consequently maintain very low wall shear rates for some shear sensitive microorganism or mammalian cells. In this paper, a set of experimental equipment was established for vortex wave flow. Unsteady incompressible flow, flowing at low-Reynolds-number in periodic oscillatory pattern, in a two-dimensional channel with backward sidestep structure was investigated by using PIV. The generation, development and disappear of the vortex wave about oscillatory flow in an asymmetric channel has been analyzed quantificationally. A series of velocity vector figures at different phases have been obtained. The velocity profile and the vorticity of vortex wave have been tested and calculated in this paper in order to analyze the mechanisms of strengthening mass transfer. The results show that the vortex wave flow-field is periodical and the waves will be brought as the fluid periodically flows. It indicates that the main feature of vortex wave is that it is a two-dimensional standing wave formed during the deceleration period and the core flow follows a curving path with a sequence of vortices forming alternately on each wall between the core flow and the walls of the channel. In addition, the relationship between Reynolds number and vortex wave has been investigated. The experimental results corresponded satisfactorily with the analysing results of the vorticity equation. It has showed that the vortex strength enhances but the size of the vortices and the wave is almost changeless as Reynolds number increases.

Key words　oscillatory flow　vortex wave　PIV　Reynolds number　velocity vector　vorticity

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