基于光滑粒子动力学（SPH）方法的流固耦合问题模拟研究

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摘要：流固耦合问题广泛存在于自然现象及工程系统中。该问题涉及固体在流场作用下的运动、变形与破坏的各种行为以及固体位形对流体运动的影响，往往具有强非线性、时变性，含有介质大变形以及运动界面。因此采用传统的网格类方法模拟该类问题往往具有很大的挑战性。光滑粒子动力学方法（SPH）是一类拉格朗日型无网格粒子方法，能够自然追踪运动界面，方便处理大变形，为模拟流固耦合问题提供了有益的选择。本文阐述了SPH 方法及其在典型流固耦合问题中的成功应用。方法上介绍了不同的高精度 SPH 格式，提高 SPH 稳定性及效率的改进方法，以及 SPH 与其他方法耦合框架下对于流固耦合界面的处理方式[1-3]。应用上，本文模拟了流体与刚体、弹性体、柔性体、颗粒体耦合作用问题，以及带有极限载荷的流固耦合问题，如爆炸冲击问题[4]。

关键词：流固耦合，光滑粒子动力学方法，计算流体力学，计算固体力学

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Smoothed particle hydrodynamics (SPH) for modeling fluid-structure interactions

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Abstract: Fluid-structure interactions (FSI) are widely involved in many natural phenomena and engineering applications. It is very challenging to numerically simulate FSI problems with conventional grid-based methods due to the nonlinearity and time-dependent nature inherent in FSI together with possible large deformations and moving interfaces. The smoothed particle hydrodynamics (SPH) method is a truly Lagrangian, meshfree and particle method, and it can conveniently treat large deformations and naturally capture the rapidly moving interfaces and free surfaces. In this paper, we introduce the sucessful applications of SPH and its modified versions for solving FSI problems. The methodology of SPH along with the conventional and highly accurate approximation schemes are firstly described [1-3]. Next, the treatments of FSI interfaces using pure SPH method and the hybrid approaches of SPH with other grid-based or particle-based methods are discussed. In applications, we introduce the SPH modeling of FSI problems with rigid, elastic and flexible structures, those with granular materials, and with extremely intensive loadings [4].

Key words: Fluid-structure interaction (FSI), Smoothed particle hydrodynamics (SPH), Computational fluid dynamics (CFD), Computational solid dynamics (CSD).