Isogeometric Analysis for Large-amplitude Sloshing

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Abstract. The large-amplitude sloshing of propellant is a widely concerned problem in aerospace engineering. Computational fluid dynamics methods have been proposed to simulate large-amplitude liquid sloshing for decades, with several meshed or meshless methods. This paper proposes an isogeometric analysis method for sloshing simulation. The main challenges are tracking liquid free surface and time step convergence. Level Set method is combined with IGA with fixed grids to track free surface moving, also can be used to track liquid separateness which is quite common in large-amplitude sloshing. As IGA can provide numerically accurate solution at any location in computational domain, the mesh of Level Set can be different with IGA mesh without losing accuracy. Characteristic-Based Split (CBS) method is used to control divergence of each time step. The comparison between the numerical results and analytical, the numerical results and experimental results shows good agreement.

Introduction

With the rapid development of space engineering, modern spacecraft has become an important tool for scientific research and daily life. Spacecraft usually carry a large amount of liquid propellant to complete complex space missions[1]. In the process of launch, orbit change, rendezvous, docking, and large angle attitude maneuver, liquid fuel in spacecraft is easy to slosh violently, which has a significant impact on the attitude stability and control accuracy of spacecraft. Therefore, it is of great academic value and engineering significance to study the liquid sloshing in spacecraft.

With the rapid development of computer technology, increasing attention has been paid to numerical research methods for liquid sloshing. The numerical methods to study liquid sloshing include finite difference method, finite volume method, boundary element method, finite element method and particle method, etc. The study of liquid sloshing by isogeometric method is also very popular recent years. Akkerman [2] applied the isogeometric analysis to the free surface flow, combined with the level set method to track the free surface of liquid. Yan [3] combined the isogeometric method and the level set method to study the rising bubble in liquid. Wang [4] studied liquid sloshing in a horizontal cylindrical cavity by combining the isogeometric method with the scaled boundary finite element method.

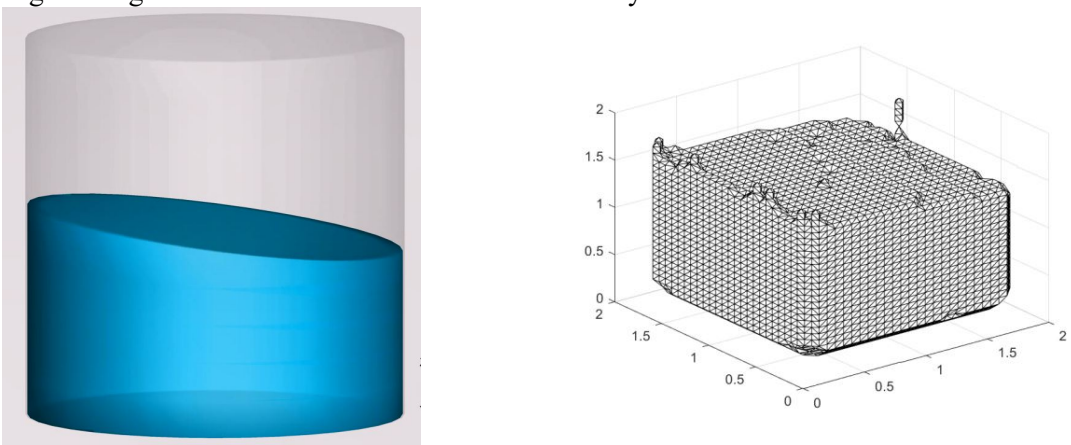

Figure 1: Liquid sloshing in cylindrical container (left) and cubic tank (right)

Results and discusstion

In this paper, it is the first time to combine isogeometric analysis and level set method to study liquid sloshing problem, and using characteristic-based split method to overcome the numerical instabilities arising from the convection term in the fluid governing equations. Furthermore, the mesh of level set method is independent with isogeometric analysis, which makes the numerical simulation accuracy and efficiency more flexible. Numerical results shows good sloshing results and liquid separation can be observed.

References

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