Re-entry jet and Shock induced cavity shedding in cloud cavitating flow around an axisymmetric projectile

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Long Abstract

Introduction

Cavitation instability always attracts a lot of attention, which often appears as cavity shedding and sheet to cloud transition. Most previous research works were focused on the shedding mechanism induced by the re-entry jet, which is usually considered as the most important factor on the transition [1]. Besides the re-entry jet, other factors are also regarded as impossible factors. For example, Arndt et al [2] found there are two different Strouhal numbers for the cavitating flows around the hydrofoil in various conditions. The shedding phenomenon for one on them was possibly generated by the shock propagation. This phenomenon and mechanism were found to commonly exist in many researchers' works. Genesh et al [3] developed a high temporal resolution X-ray device and measured the density evolution inside the unsteady cavitating flow around a wedge. They confirmed that with certain caviation number, the shock was generated and its propagation could cause the shedding of the cavity and the transition from sheet to cloud cavity, which attracted lots of attention.

Considering the latest development and Understanding of shock propagation as a cause of cavity shedding, we want to examine some previous results and confirm the mechanism. A fully compressible algorithm is established on the cavitating flow around the axisymmetric projectile. By a joint investigation on experimental and numerical results, different mechanisms of cavity shedding were found in the various flow conditions. The effects of re-entry jet, shock and collapse on the cavitation instability are compared and discussed.

1. Methods

The typical experiments are performed by using a launching device based on the SHPB technology. Detailed of the method can be found in the reference. The typical photographs in the experiment are shown in Figure 1, in which the re-entry jet and the shedding cavity collapse can be seen clearly and there are suspected shock propagations in the second and third cycles.

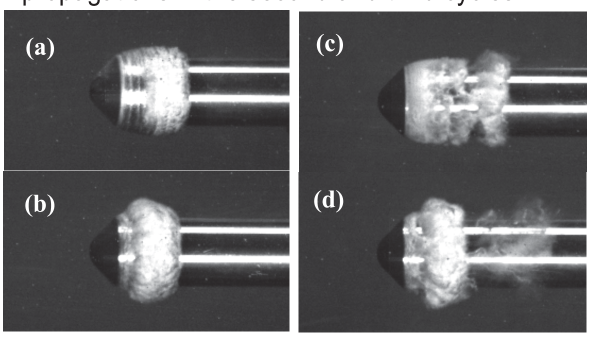

Figure 1. Typical snapshots with different mechanisms of cavity shedding (a, re-entry jet in the first cycle; b, shedding in the first cycle induced by the re-entry jet; c, suspected shock propagation in the second cycle after shedding cavity collapses; d, cavity shedding in the third cycle.)

In order to analyze the shock propagation and its effect in the flow field, a fully compressible algorithm for unsteady cavitating flow is established based on the open source code OpenFOAM. The barotropic equations of state for liquid, gas and the mixture phase are adopted to describe the variations of density and sound speed of the mixture phase under various pressure, which can give more accurate simulation on shock propagation and phase change rather than the commonly used incompressible scheme.

2. Results and discussion

Typical results of shock induced shedding are as shown in Figure 2. Strong shock with high pressure is generated by the cavity collapse, and propagates to the surrounding area (as shown in Figure 2 (a)). Because the resistance inside the cavity is remarkably lower than the liquid water, the shock propagates around the cavity closure and through the liquid water. When the shock intersects with the cavity boundary, very high pressure and strong negative pressure gradient is generated at the cavity closure. So new strong re-entry jet is formed at the same time when the shock arrives at the boundary (as shown in Figure 2 (b)).New strong re-entry jet flows to the leading edge and cuts off the cavity again, which induce the shedding in the new cycle (as shown in Figure 2 (c) and (d)). Because the cavity is foam-like which means it contains large amounts of bubble and liquid water. So the density inside the cavity is significantly larger than that in the first cycle which is a transparent sheet cavity, and the re-entry jet can disturb the pressure field and cavity pattern more remarkably in this cycle (as shown in Fig.1 (d), Figure 2 (c) and (d)).

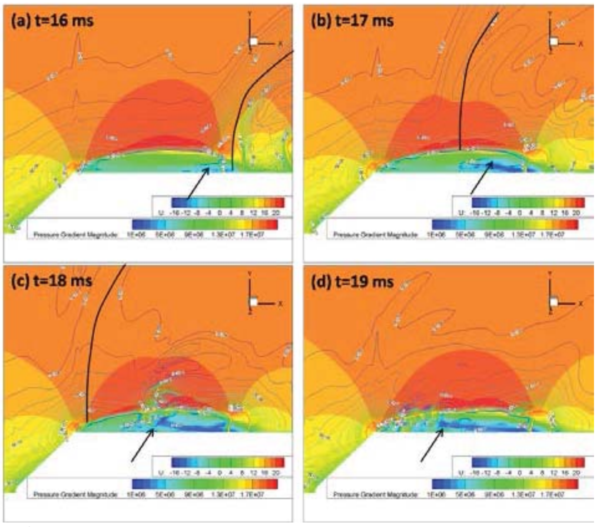

Figure 2 Time sequences of shock propagation and new re-entry jet generation. The shock represents as large pressure gradient region and is shown by the black curve. The front of the re-entry jet is pointed by the black arrow.

From the experimental and numerical results, it is confirmed that there are two different shedding patterns in different cycles in a single condition, which are mainly induced by the re-entry jet and shock, respectively.The strong shock at the cavity closure is generated by the shedding cavity collapse. Its effect on cavity instability is indirect which still needs a strong re-entry jet as the medium media.

References

[1] C. E. Brennen. Cavitation and Bubble Dynamics, USA:Oxford University Press，1995.

[2] Arndt, Song et al. Instability of partial cavitation- A numerical & experimental approach. *Symposium on Naval Hydrodynamics*, 599-615, 2001.

[3] H. Ganesh. Bubbly shock propagation as a cause of sheet to cloud transition of partial cavitation and stationary cavitation bubbles forming on a delta wing vorte. *PhD thesis, University of Michigan,* 2015.