A review of sheet cavitation inception mechanisms

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Long Abstract

1. Introduction

Sheet cavitation inception does not necessarily occur on foils and propellers when the local pressure decreases below the vapour pressure. The condition of inception is also dependent on the characteristics of the fluid, the solid surface and the flow. Engineering measures have been developed in model scale facilities to limit the resulting scale effects on cavitation inception. However, the physical mechanisms of sheet cavitation inception are not fully understood [1] and the limits in the applied methods are not clear. In practice, this results often in isolated patches and streaks instead of a continuous sheet cavity.

On the other hand, since the last comprehensive review on cavitation inception mechanisms 25 years ago [1], valuable physical insights into surface nucleation have been obtained by carefully designed and conducted micro-scale experiments. The objectives of this review are to place these findings in the context of two distinct sheet cavitation inception processes and to define the areas for further research. In the following sections, first the various stages of these two surface nucleation processes are outlined. Then, the effects of a number of environment characteristics on surface nucleation is reviewed. Finally, this knowledge is combined in a detailed evaluation of sheet cavitation inception mechanisms.

2. Cavitation inception stages

Next to a pressure below the vapour pressure, a nucleus is needed for sheet cavitation inception. Two types of nuclei can be discerned dependent on their origin, surface-bound nuclei and free stream nuclei [2]. In this section a general outline of the inception process of each type of nucleus is given.

The inception process of a surface nucleus is divided in three stages. In the initial stage the gas nucleus resides in a stable condition on the surface. In the nucleation stage it expands significantly beyond its original boundaries. In the cavity stage a stable sheet cavity results which remains attached to the solid surface.

The inception process of a free stream nucleus follows a similar pattern but with an additional stage. In the initial stage the nucleus is advected with the flow. In the entrainment stage, the trajectory of the nucleus will deviate from its initial streamline and gets entrained into the sub-boundary layer. In the nucleation stage a cavity starts to grow on the solid surface and in the cavity stage again a stable sheet cavity is established which remains attached to the solid surface. If a free stream gas nucleus shows unstable growth without attachment to the solid surface it is characterized as bubble cavitation.

3. Environment characteristics

The environment characteristics are all the features of the fluid, the solid surface and the flow that have an influence on the cavitation inception process.

Relevant characteristics of the fluid are the spectra (size and concentration) of the gas nuclei and micro particles and the concentration of dissolved gas. Experiments in a cavitation tunnel have shown that both micro particles and micro bubbles can act as nuclei for cavitation inception [3]. Filtering and degassing the water had a detrimental effect on the occurrence of cavitation. Micro-scale observations of a foil with leading edge roughness show that indeed free-stream solid micro particles can induce sheet cavitation inception [4]. The nucleation of bubbles by contact between solid surfaces is studied in more detail in [5], but the initial formation mechanism is not fully understood.

A surface characteristic that has shown significant positive effect on sheet cavitation inception is leading edge roughness, applied by distributed sand grains [6]. If applied in a 50% coverage ratio this roughness may also provide crevices in which surface nuclei can be stabilized. In an experimental study with one of the same propellers as used in [6], the successful combination of free-stream nuclei and leading edge roughness is shown [7]. The initial cavitation extents found without seeding may be explained by the presence of surface nuclei. A more detailed study of the effects of surface nuclei on cavitation inception is presented in [8]. Further, roughness can induce the pinning of contact lines which supports the formation of a stable sheet cavity [9].

Turbulence is one of the main flow characteristics that has been investigated in relation with cavitation inception. Although several studies show a significant effect [10], the working mechanism is not fully understood.

4. Inception mechanisms

Various hypotheses will be evaluated in this section and recommendations for further research will be made.

5. References

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