THE EVOLUTION OF SURFACE DAMAGE ON NiAl-BRONZE DUE TO CAVITATION OF REPEATED SINGLE LASER-INDUCED BUBBLES

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KEYWORDS

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ABSTRACT

Cavitation is the formation and collapse of bubbles in liquids caused by pressure changes. Damage of technical surfaces caused by cavitation, due to the bubble collapse occurring close to a solid surface, is an important engineering issue. However, difficulties are encountered to date in modelling and predicting such material damage. When a bubble forms close to a solid surface, its collapse will occur as a complex sequence of liquid-jet formation, movement of the bubble, repeated collapse and re-expansion, partitioning into several bubbles, and the formation of vortices and high-shear flows. Typical studies of cavitation-induced material damage and wear utilize ultrasonic vibration, creating bubble clouds with thousands of collapses per second. Alternatively, for fundamental investigations of cavitation, single bubbles can be created and studied by focusing a short, high-power laser pulse in water. When the material is soft, the bubble's collapse can indent a nearby solid surface in a single event. For most technical alloys, however, repeated impacts are needed to produce detectable damage.

The goal of this study is to correlate the increasing number of collapsing bubbles with the evolving damage on the surface during the incubation phase of cavitation erosion. To this end, single bubbles of 3 mm diameter are repeatedly created in water using a Q-switched Nd:YAG laser focused at a defined distance from the polished surface of samples from NiAl-bronze. The bubble shapes during cavitation events are recorded with a high-speed camera. The resulting damage on the surfaces is quantified using white-light confocal microscopy. The dynamics of "typical" bubbles, as well as those showing an asymmetric collapse behavior are analyzed and correlated with the observed damage patterns.

The results show that until 70,000 bubbles no obvious material removal takes place, and the depth of indentations formed via plastic deformation does not increase, indicating that the material is still in the incubation phase. The soft solid-solution α-phase is indented preferentially, displaying slip lines, and cracks form along the phase boundaries with harder precipitates. When the bubble collapse takes place asymmetrically, the observed damage tends to be deeper, indicating that asymmetric collapse leads to higher shear stresses, causing heavier deformation. Also, frequently two damaged areas appear, because bubbles drift over the surface during repeated expansion and collapse. Therefore, a single bubble can cause several indentations and, if occurring repeatedly, result in more than one damaged region.

The results of this study reveal the wide range of non-uniformity that must be expected in fluid-flow induced cavitation in technical applications, indicating one reason for the difficulties encountered in reliably predicting cavitation erosion.

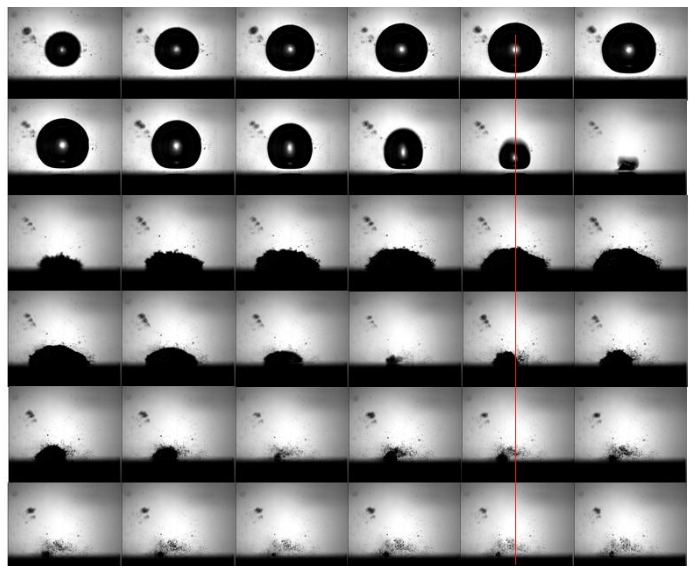

Fig.1 Single cavitation bubble drifting towards the left during repeated expansion and collapse.