The Response of a Floating Structure Due to Underwater Explosion with Cavitation Effect

Xiaobin Li\textsuperscript{1,2}, Xing Wei\textsuperscript{1}, Peng Zheng\textsuperscript{1}, Wei-guo Wu\textsuperscript{1,2}
\textsuperscript{1} School of Transportation, Wuhan University of Technology
\textsuperscript{2} Key Lab of High Speed Ship Engineering, Wuhan University of Technology
Wuhan, Hubei, China

ABSTRACT

For surface vessels, the effect of cavitation can be significant when considering its response due to underwater explosion. A numerical study on the response of a floating mass-spring system due to underwater explosion with cavitation effect is performed using ABAQUS/Explicit software. The underwater shock wave is treated as a one-dimensional step-exponential pressure wave which propagates through the water that simulated using acoustic fluid element in ABAQUS/Explicit. The cavitation effect can be captured using the pressure criteria. The results obtained are compared with those obtained by Sprague and Geers (2001) with Cavitating Acoustic Finite Element (CAFE) models. The significance of cavitation effect is illuminated by comparing the floating mass-spring system response with and without cavitation.

KEY WORDS: underwater explosion; cavitation effect; shock response; fluid-structure couple; ABAQUS/Explicit.

INTRODUCTION

For designing military vessels, the performance of impact can be significant when considering its response due to underwater explosion. The analysis of impact resistance of anti-ships includes many aspects, such as: the initial shock wave, the attenuation of the initial shock wave, partial cavitation due to shock wave by water reflection or structure reflection, fluid-structure couple, contraction of partial cavitation, structural response and so on. For surface vessels, the effect of surface is very important. In Fig. 1, $p_i$, $R_i$ denotes shock wave and the distance between explosion point and the vessel respectively. Since water can not afford large stretch (10-100Pa), and withstand time is very short, so cavitation occurs when the total pressure is less than the maximum tensile stress. Cavitation pressure is gasification pressure of water (7°C for 1Pa, usually taken as 0). The difference of internal and external water pressure will drive the expansion of cavitation. At this time when the water is separated from the surface vessel, and the load of shock waves disappear at the same time which is so-called "cut off effect". Until the ambient pressure becomes positive, cavitation begins to shrink. Secondary loading on the structure will be produced when contraction of cavitation until the water and the surface of vessels re-contact. The difference between the secondary load and the initial shock load in nature is that the secondary load is a slamming load, whose magnitude depends on the relative velocity between fluid particles and structure.

Fig.1 Surface effect of surface vessels due to underwater explosion

Research of Cavitation was first done by Taylor (1941). He analyzed the response of an infinite plate under the effect of underwater explosions and the cavitation effect produced meantime by using a theoretical method, and the displacement-time and velocity-time history curves of the plate and water were obtained. Although the plate theory explains its main physical processes very clearly. However, for the complex actual structures, they are difficult to be solved by using theoretical methods. So researchers turn to numerical method to study cavitation and its impact on the vessels structure. Mindlin and Bleich (Mindlin R.D.,and Bleich, H.H, 1953) first put forward a plane-wave approximation (PWA) method to calculate the responses approximately in 1953. Later, Geers (1974) predicted the responses of surface vessels and submarines due to underwater explosions by applying this method proposed by Mindlin and Bleich in 1974. For surface vessels, cavitation effect is obvious usually by displacement criteria (DiMaggio F.L.,