World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:10, No:08, 2016

A Simplified Method to Assess the Damage of an Immersed Cylinder Subjected to Underwater Explosion

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Abstract : The design of a submarine's hull is crucial for its operability and crew's safety, but also complex. Indeed, engineers need to balance lightness, acoustic discretion and resistance to both immersion pressure and environmental attacks. Submarine explosions represent a first-rate threat for the integrity of the hull, whose behavior needs to be properly analyzed. The presented work is focused on the development of a simplified analytical method to study the structural response of a deeply immersed cylinder submitted to an underwater explosion. This method aims to provide engineers a quick estimation of the resulting damage, allowing them to simulate a large number of explosion scenarios. The present research relies on the so-called plastic string on plastic foundation model. A two-dimensional boundary value problem for a cylindrical shell is converted to an equivalent one-dimensional problem of a plastic string resting on a non-linear plastic foundation. For this purpose, equivalence parameters are defined and evaluated by making assumptions on the shape of the displacement and velocity field in the cross-sectional plane of the cylinder. Closed-form solutions for the deformation and velocity profile of the shell are obtained for explosive loading, and compare well with numerical and experimental results. However, the plastic-string model has not yet been adapted for a cylinder in immersion subjected to an explosive loading. In fact, the effects of fluid-structure interaction have to be taken into account. Moreover, when an underwater explosion occurs, several pressure waves are emitted by the gas bubble pulsations, called secondary waves. The corresponding loads, which may produce significant damages to the cylinder, must also be accounted for. The analytical developments carried out to solve the above problem of a shock wave impacting a cylinder, considering fluid-structure interaction will be presented for an unstiffened cylinder. The resulting deformations are compared to experimental and numerical results for different shock factors and different standoff distances.

Keywords : immersed cylinder, rigid plastic material, shock loading, underwater explosion
Conference Title : ICIE 2016 : International Conference on Impact Engineering
Conference Location : Paris, France
Conference Dates : August 22-23, 2016