Analytical improvements for underwater explosion shock prediction

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Résumé

The high explosive hydroforming (HEHF) is an old known process to work with metal. Many companies and armies tried to manage the process but finally abandoned in the past. However, this method was investigated, and many experiments performed [1].
In order to predict metal forming in a more efficient way, simulation software is used. Even with high performance computing, the reliability of predictive model strongly depends on time step that is required to be very small due to the underwater explosion (Undex) phenomenon. It remains a compromise between accuracy and computation time.

The Undex phenomenon was described in the literature by different authors such as Cole [2], Hunter & Geers [3]. Their works are focused on the pressure induced by spherical charges in far field (between 10 and 100 radius of the charge) using empirical formulas. Kirkwood & Beth [4] and Barras [5] proposed a more analytical method of pressure calculation in near field (less than 10 radius of the charge) for spherical, cylindrical and planar charges. It is based on the piston principle.

Those last models are the most interesting because they require only physical data of the explosive such as the Chapman-Jouguet state which is well documented in literature for a large variety of explosives. The purpose of this work is to propose an analytical approach that consists in determining an equivalent mechanical loading in near and far field for a variety of charge geometries.

In this work, the Barras model is compared with accurate numerical simulations in explicit scheme with Radioss® and experimental data taken from the open literature to evaluate the exact limitation of the model. The following key parameters are checked: the peak of overpressure versus distance, the shock position and the bubble behavior which leads the shock.

The next step is to extend this model to be valid in the far field case. Currently, the model is still limitated in far field and few hypotheses are responsible for it. For instance, the gas equation of state describing the gaseous detonation products that expends into the water could be better defined by using a more relevant equation of state such as Jones-Wilkins-Lee [6].

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The validity of the proposed model is compared with experimental results from the literature.

The improvements in the proposed model lead to a more accurate description of the early stage of the bubble formation and thus for the shock loading, but still not reaching the limit of the Cole far field. The benefits permit to limit the Undex modelling during numerical simulations which is a huge saving in CPU time.

RINEHART J.S and PEARSON, John, Explosive Working of Metals, *Pergamon Press*, 1963. New York.

COLE, Robert Hugh. *Underwater explosions.* Dover Publications, 1965.

HUNTER, Kendall S. et GEERS, Thomas L. Pressure and velocity fields produced by an underwater explosion. *The Journal of the Acoustical Society of America*, 2004, vol. 115, no 4, p. 1483-1496.

KIRKWOOD, J. G. and BETHE, H. (1942). The pressure wave produced by an underwater explosion I. (OSRD no. 588). *Shock and detonation Waves* pages 1-34.

BARRAS, Guillaume. *Interaction fluide-structure: Application aux explosions sous-marines en champ proche.* 2012. Thèse de doctorat. Lille 1.

LEE, E., FINGER, M., et COLLINS, W*. JWL equation of state coefficients for high explosives. Lawrence Livermore National Lab.(LLNL)*, Livermore, CA (United States), 1973.

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