

# NUMERICAL VALIDATION OF A CALIBRATED SHIP STEEL MATERIAL MODEL USING BLAST PANEL TESTS

J. Verreault, O.J. Coppejans

*TNO, Naval and Offshore Structures, Molengraaffsingel 8, 2629 JD, Delft, The Netherlands*

**Key words:** Blast panel, Apollo, ship steel

## ABSTRACT

Reliable numerical simulations of Close-Proximity UNDER-water EXplosions (CP-UNDEX) nearby a ship structure is an important capability for designing and operating Naval ships. However the key challenge is for the simulation to be reliable which implies the validation of several aspects involved in the simulation (explosion load, fluid-structure interaction, ship response, etc.). One of the several aspects involved in a CP-UNDEX scenario is the severe plastic deformation of the ship hull and possible plate failure. A blast panel setup is used for the validation of the material model. This study replicates these blast panel tests using the Apollo software for the close-in blast loading and LS-DYNA for the plate response, which is 5 mm thick with a side length of 1 m. The chosen material model is the so-called Shear Modified Rice and Tracy, which is calibrated using tensile tests and punch tests for plasticity and failure. Test specimen for tensile and punch tests were taken from the panels after the blast tests. The blast panel test setup has been modelled in Apollo/ LS-DYNA, the calibrated material model has been implemented and in total seven different blast tests have been simulated, both for unstiffened and stiffened panels. Charge mass for these tests ranges from 750 g to 1265 g with a stand-off above the plate varying between 67 mm and 118 mm. Simulation results of non-failing panels show an excellent agreement with experiments in terms of permanent plastic deformation across the plate in time. This excellent agreement is observed from the least to the most severe non-failing cases. For the failing panels the failure pattern is very well reproduced by the simulations for both non-stiffened panels (plug formation, cracks initiating from the plug hole followed by petaling) and stiffened panels (rupture along the stiffener weld followed by opening of the plate petals). It is concluded that the level of agreement is well within expectations which provides high confidence in this material model. The material model presented in this work can be used for steel plates subjected to shock loading such as ship hulls subjected to severe UNDEX. It works particularly well for scenarios for plate fields between stiffeners and also well near stiffeners, provided that small elements are used in the order of the plate thickness. For scenarios involving contact or stress concentrators or stiffeners and large shell elements, additional research is required.