Design and Development of a Hybrid Model for Impact Analysis on Underwater Vehicles

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1. INTRODUCTION & OBJECTIVE

1.1 INTRODUCTION

Underwater vehicles (e.g. autonomous underwater vehicles, autonomous underwater gliders, submarines, submersibles, and torpedoes, etc.) are subjected to impact loads in both defense and attack operations. This article aims to design and develop a hybrid model for impact analysis and presents the preliminary results showing the effect of material properties on crack development and distribution of stresses and strains after explosion/impact, etc.

Proposed hybrid approach has two components, i.e. Analytical model and numerical model. The analytical model is based upon the classical theories (i.e. Griffith and classical mechanics theories) and the numerical model is built upon the large deformation finite element analysis. Presented results examine the role of different materials (i.e. mild steel, Aluminum 7178-T651, Titanium Ti-6AI-4V, Glass, AISiC metal matrix composite and Epoxy etc.) under the uniform pressure load. Based upon the results and their analyses suitable design guidelines are derived.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

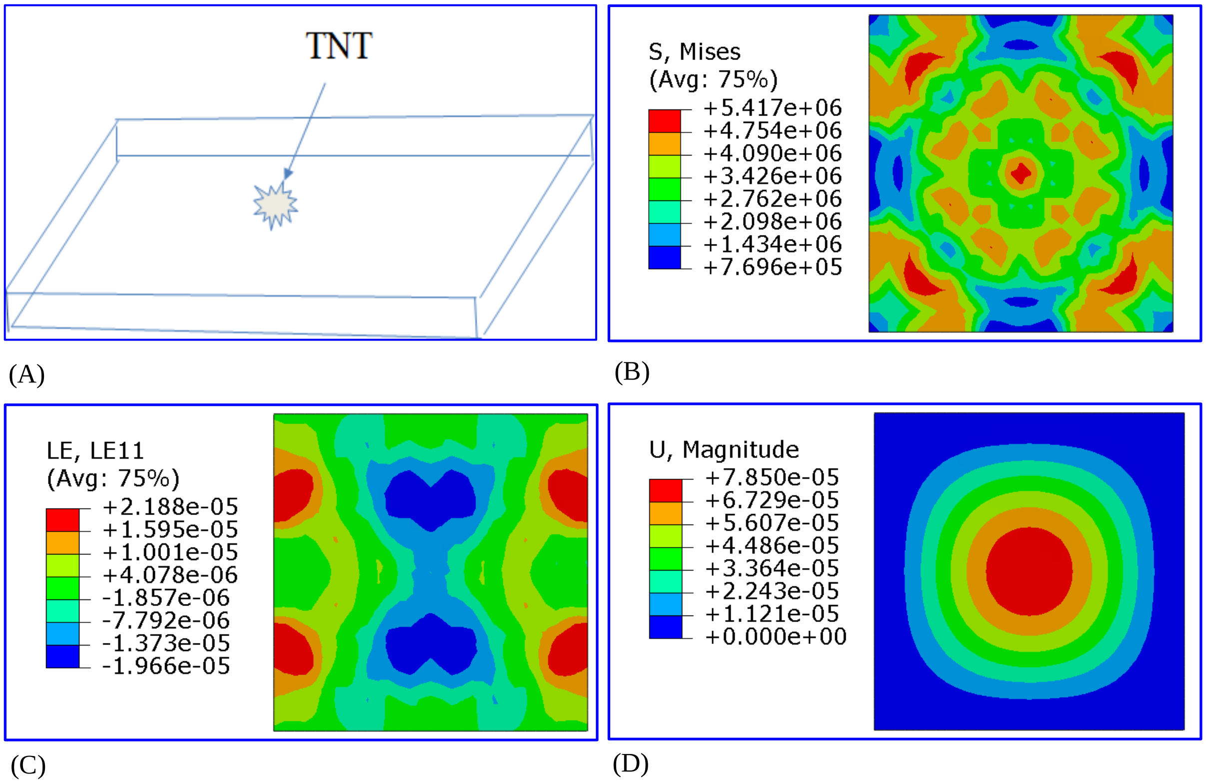
2.1 RESULTS

Table 1 lists the computed bending moment stress (BMS) and shear force stress (SFS) at various cross sections for the cantilever beam.

Table 1: Computed bending moment stress (BMS) and shear force stress (SFS) at various cross sections for the cantilever beam using the classical theories (Sharma (2019)) for the mild steel material.

Span length	X = 0	X = 0.25 l	X = 0.5 l	X = 0.75 l	X = 1
BMS $\left(\frac{N}{m^2}\right)$	-167.59$\times 10^6$	-94.27$\times 10^6$	-41.90$\times 10^6$	-10.47$\times 10^6$	0
SFS $\left(\frac{N}{m^2}\right)$	16.75$\times 10^6$	12.56$\times 10^6$	8.37$\times 10^6$	4.19$\times 10^6$	0

In the numerical model (large deformation driven finite element model, Sharma (2019), Thije et al. (2007), and Zienkiewicz and Taylor (2013)), we create the formulation and show its implementation through a study on metal plate with square section dimension, with explosive simulation. Then, we compute the stresses and strains and examine extensively the role of different material properties and plates of varying thicknesses. Chosen dimensions of plate are: L = 0.3 m, W = 0.3 m, and T = 0.01 m. An explosive (TNT) is used and then it is exploded at a close height of 10 mm in the Z axis direction. Fig. 1A shows the orientation; and Fig. 1B, 1C and 1D show the computed Mises stresses, strains and displacements in the plate, respectively.



(A) (B) (C) (D)

Figure 1: 1A – Orientation, 1B - computed Mises stresses, 1C – computed strains and 1D – computed displacements in the plate, for the mild steel material.

Based upon the presented studies, we can conclude that the steel and its alloys are ideally suited for deep water application in underwater vehicles, e.g. mild steel. It prevents crack propagation and keeps the stresses/strains/displacements on the lower sides. Additionally, in the crack propagation, the failure stress is maximum for plane strain cases in comparison with the plane stress cases, because of the effect of Poisson ratio. Under the impact loads composite materials show higher energy absorption but they show weak performance in tension, buckling and bending/torsion. Because of these reasons in the application where, all the structural deformations are critical, e.g. in underwater vehicles, composite are useful only in certain specific areas where only impact loads dominate, like the front and tail ends, and not in other areas like middle parts, fins, etc.

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