MAT162 EXAMPLE 4
LOCAL-GLOBAL MAT162-MAT054 IMPACT ON ELLIPTICAL PRESSURE VESSELS WITH INTERNAL PRESSURE

PROBLEM DESCRIPTION

Background

Impact on composite pressure vessels for space applications such as Z-2 Space Suit composite components (Fig. 5, Ref. [1]) require the use of progressive composite damage modeling for impact critical designs. A local-global MAT162-MAT054 (solid-shell) impact analysis methodology had been used to capture the energy dissipating damage modes under the impactor using MAT162 and solid elements. For space applications, the pressure vessel is internally pressurized thus all impact simulations shall have internal pressure load applied first followed by the impact event. In this example, the local-global modeling and analysis methodology is presented.
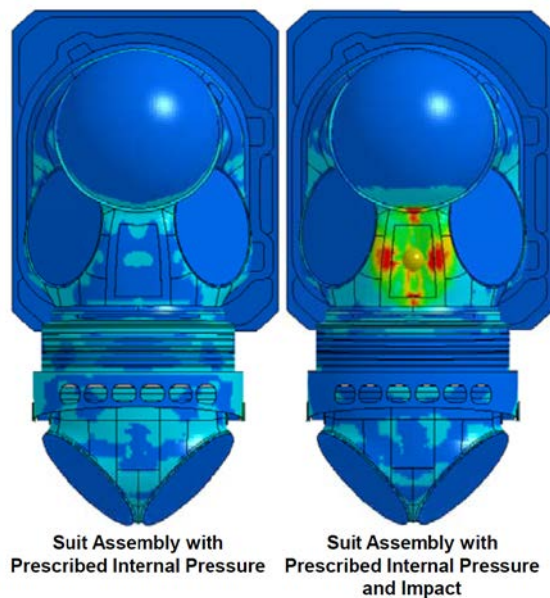

Figure 4.1: Arbitrary Stress Contours of the Space Suit Assembly with Prescribed Internal Pressure and Impact Loading Conditions (Fig. 5, [1]).

Finite Element Modeling

The complex curvature of the Z-2 space suit is modeled as a cylinder with elliptical cross-section. Figure 4.2 shows the finite element model where two solid metal rings are used at the two ends, the central impact zone is modeled with 3D solid elements while the cylinder ends are modeled using 2D shell elements. A solid sphere is modeled as the impactor. The impactor can be parametrically placed at any angle on the mid-section of the cylinder, and the impacts can be defined as normal or oblique to the cylinder surface. In this example four through-thickness solid parts have been used to define three T-T delamination planes. Note that the transverse

deformation and damage cannot be modeled accurately without modeling T-T delamination. The intersection of solid and shell elements are node merged, however, additional constraints can be applied as well. *MAT_162 is used for the solid elements, and *MAT_054 is used for the shell elements. Material properties for unidirectional (UD) T650/5250-5 Carbon/Epoxy composites provided by Materials Sciences Corporation (MSC) has been used in the simulations.
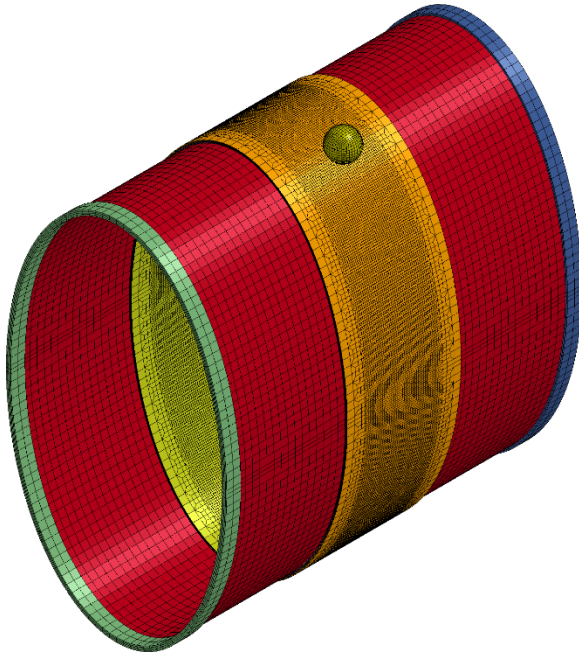

Figure 4.2: Local-Global Solid-Shell (MAT162-MAT054) Finite Element Model of the Elliptic Cylinder subjected to Internal Pressure and Transverse Impact.

Example 4 Movie 1   Example 4 Movie 2

Pressure Loading Conditions
A ramp pressure load is applied on the internal surfaces of the elliptical cylinder and then hold constant during the impact duration. Equivalent tensile loads are applied on the solid metal rings to mimic axial expansion of the elliptic-cylinder. Figure 4.3 shows the pressure loading and beginning of impact as a function of time.
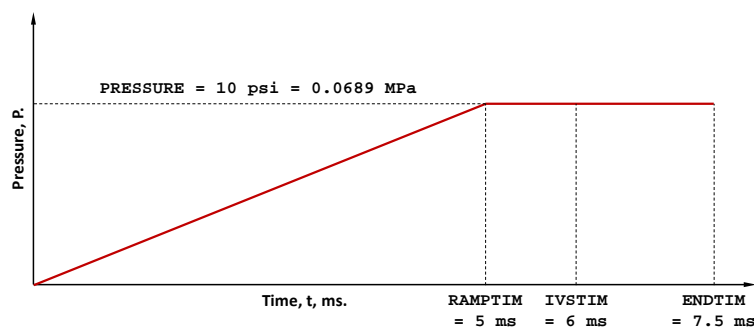
Figure 4.3: Pressure Loading Contitions. Impact Starts at 6 ms and Solution Terminates at 7.5 ms.

Reference
1. Z-2 Prototype Space Suit Development. Amy Ross, Richard Rhodes, David Graziosi, Bobby Jones, Ryan Lee, Bazle Z. (Gama) Haque, and John W. Gillespie Jr. 44th International Conference on Environmental Systems, 13-17 July 2014, Tuscon, Arizona. <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140003571.pdf>.

RESULTS

Four layers of UD T650/5250-5 Carbon/Epoxy of total thickness 3.125 mm with stacking sequence [0/+45/-45/90] has been used in this model. A normal impact velocity of 100 mps is used at an obliquity angle $\theta = 15°$ from the vertical axis. Figure 4.4a shows the out-of-plane deformation of the elliptic-cylinder under impact, while Fig. 4.4b shows different impact damage modes of the [-45] layer. Figure 4.5 shows all components and resultant of the impact contact force, which shows that the impact contact starts at time t = 6 ms.
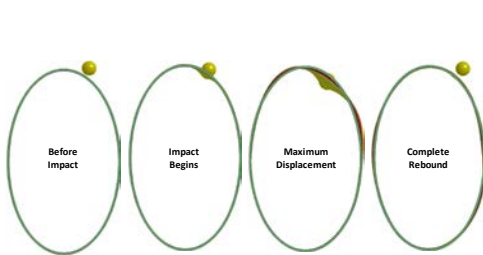

Figure 4.4a: Deformation of the Elliptic-Cylinder under Impact

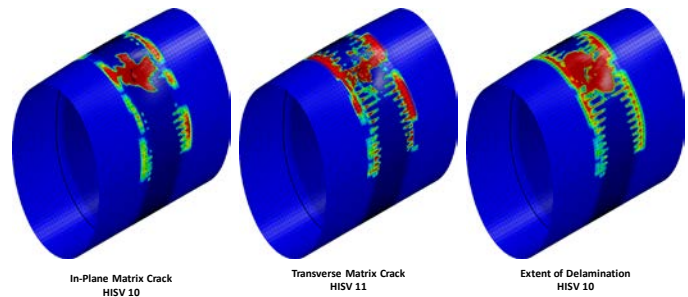
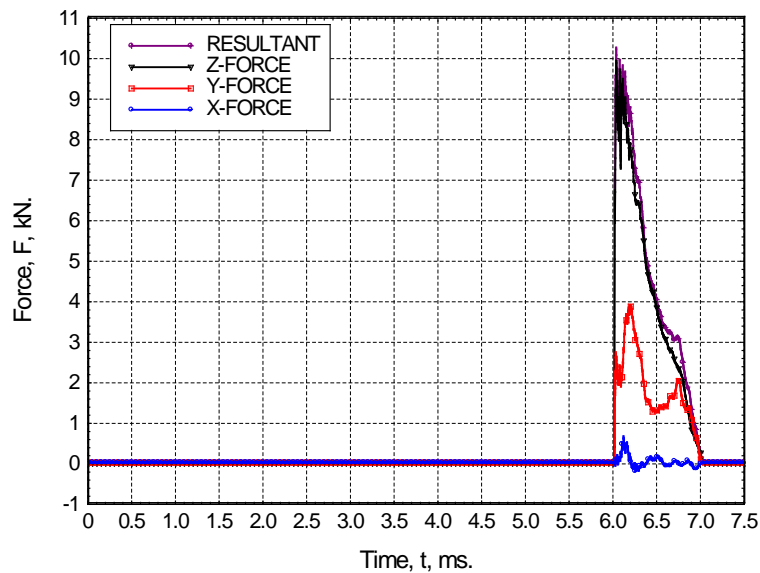Figure 4.4b: Impact Damage Modes of the [-45] layer at Maximum Deformation.

Figure 4.5: X-, Y-, and Z- Components and the Resultant of Impact Contact Force.

DOWNLOAD
This example problem can be downloaded from UD-CCM MAT162 website:

EXAMPLE 4: Elliptic-Cylinder-SHELL-SOLID-MODEL.zip
This zip folder contains the following KEWORD files. Run the first file.
001-mmts-Ellipical-Cylinder-SHELL-SOLID.key
002-CONTROL.key
002-README-Elliptical-Cylinder-SHELL-SOLID.key
003-SHELL-SOLID-Elliptical-Cylinder-FEM.key
004-700-Sphere-FEM.key
005-PARTS.key
005-MAT54-Cards-for-T650-5250-5-UD-151-to-154.key
005-MAT162-Cards-for-T650-5250-5-UD-161-to-164.key
006-CONTACT-ERODING-SINGLE-SURFACE-SMP.key
006-CONTACT-ERODING-SINGLE-SURFACE-MPP.key
007-DATABASE.key
007-DATABASE-CROSS-SECTION-PLANE.key
008-BOUNDARY-CONDITIONS.key
009-LOADING-CONDITIONS.key
010-INITIAL-CONDITIONS.key