Tutorial 10

Impact of a Composite Disc using Multilayered Shell Elements



Problem description

Outline	The transverse impact analysis of a simply supported composite disc is performed using a single layer of multi-layered shell elements.
Analysis type(s):	Explicit
Element type(s):	Multilayered composite shell
Materials law(s):	Composite using the Global ply damage and failure law
Model options:	Boundary conditions, contact, initial velocities, rigid body
Key results:	Stress distributions and damage with failure prediction, impact force time history
Prepared by: Date: Version:	Anthony Pickett, ESI GmbH/Institute for Aircraft Design, Stuttgart July 2007 V5 (updated November 2012 for Visual-Crash PAM V8.0)

Background information

Pre-processor, Solver and Post-processor used:

- **Visual-Mesh:** For generation of the geometry and meshes.
- **Visual-Crash PAM:** To assign control, material data, loadings, constraints and time history (control) data.
- Analysis (PAM-CRASH Explicit): To perform an explicit Finite Element analysis.
- Visual-Viewer: Evaluating the results for contour plots, time histories, etc.

Prior knowledge for the exercise

It is assumed that Tutorials 1,2 and 3,4 have been worked through. In order to avoid unnecessary repetition some explanations on use of Visual for creation of entities will be kept rather brief, whereas some new options will be explained in more detail.

Problem Data

Unit System:	mm, kg, ms	
Dimensions:	Disc Φ 120mm, thickness 4.2mm	
	Rigid punch Φ 50mm	
	Support Φ 110mm inner, Φ 130mm outer	
Loading:	Imposed velocity (10mm/msec max.)	
Composite:	Biaxial NCF with Epoxy resin,	
	Lay-up [90/0/45/-45/-45/45/0/90]s	x x x

Supplied datasets

The finite element mesh (in PAM-CRASH format) is supplied for this problem. Copy the mesh file to a model file which will be used to build the analysis model using **Visual-Crash PAM**.

Copy :

Composite_SingleMultiLayerShell_Mesh.pc

to Composite_SingleMultiLayerShell_Model.pc

This will allow the work to be repeated if the model definition phase goes wrong.

Using VCP to make the analysis model

Start Visual-Crash PAM (VCP) and read in the mesh:

Select **File > Open** and open the file

Composite_SingleMultiLayerShell_Model.pc

Specify the model units system

Set the model units system by selecting **Crash** > **Optional Controls** > **Units** to open the adjacent panel, Set the units to **mm**, **kg**, **ms** and **Kelvin**.



Finish with Apply and Close.

Positioning and viewing options:

Important options are available in the main (top) panel to position, center, zoom (in and out) and gererally vary viewing of the model.

- Click the axis tab and with the 'left' mouse key to open options to position the model in the x,y,z or perspective (isometric) frame.
- Click the viewing tab with the 'left' mouse key to open options to zoom in/out and generally position the model.



Defining some basic model data

For the PAM- controls set the following parameters

INPUT-	Set the PAM-CRASH version being used (e.g.
VERSION	2012)
RUNEND	Termination time for the analysis (=2.0 msec)
SOLVER	Use CRASH for a PAM-CRASH analysis
OCTRL	• THPOUTPUT – output interval for graphical (x,y)
	time history information (e.g. use POINTS =
	1000 for one thousand points)
	• DSYOUTPUT - output interval for deformed
	states (e.g. use STATE = 50 for fifty pictures)
	• Parameter ERFOUTPUT - for a .erfh5 results file
	specify type 3 without compression
	(ICOMPRES=0)
ANALYSIS	Use EXPLICIT for a dynamic analysis



Further composites specific output:

In the control option **OCTRL** (already defined above for output intervals) are additional options for other specific outputs to the results files (SOLPLOT, NODPLOT, etc..; respectively for solid elements, nodes, etc.,...). In this case,

- For SHLPLOT (shell elements outputs), the following options for specific output are available.
- Check DFLT is activated (done by default) which gives basic forces, moments, etc., for shell elements. It also includes DMG for output of composites damage.
- Available outputs are defined in VCP and the manuals.

Defining Parts and Materials for the Support and Punch

For each Material (Punch and Support)

- Open the Material Editor
- Select Shell and Element type 101 as the material type (= elastic shell material)
- Set the material parameters as shown,
 - Material ID number and a suitable title
 - 1. Use e.g. ID 1 for support (title = Support)
 - 2. Use e.g. ID 2 for punch (title = Punch)
 - Material density = 7.8e-006 kg/mm³

دg/mm³

- Modulus = 70.0 kN/mm^2 and Poisson's ratio = 0.3
- The other numbers are hourglass and element default parameters (assign or leave blank)
- Click on **Apply** and **Close**

Then for each Part (Punch and Support)

Define a new Part for the Punch and then for the Support. In each case give,

- \circ An appropriate ID number
- $\circ~$ Link the part to the corresponding Punch or Support material (parameter IDMAT)
- Assign a thickness of 1mm



Defining the composite laminate

For a laminate the following 3 entities must be defined and linked:

- 1. The Ply data Mechanical/damage data
- 2. The Material data Lay-up/output
- 3. The Part data Thickness and vector for reference fibre direction

<u>1. Ply data</u>

In the object explorer click on **Ply** (or use **Crash>Materials>Composites>Ply**) to open a new ply panel,

- Select a ply ID number (e.g. IDPLY = 1, or use the given default)
- Select ITYP=1 for Global Ply UD composite
- Specify the mechanical and damage parameters shown adjacent and give a suitable title (perhaps include the composite material type in this title)
- Finish with **Apply** and **Close**.



2. Defining the composite materials

- Open a new material in the explorer panel, or via Crash > Materials > Structural
- Select type **131-Multilayered_Orth...** as the material type (= multi-layered orthotropic shell)
- Set the material parameters as below (see also next page),
 - Give a suitable title for the composite (e.g. type and layup)
 - Materials density = 1.8e-006 kg/mm³
 - \circ Number of plies (set NOPER= 16 with ILAY=0). This opens 16 ply cards to be defined,
 - 1. Set all thicknesses = 0.2625mm
 - 2. Orientations = $[90/0/-45/45/45/-45/0/90]_s$ (NB the `s' means symmetry giving [90/0/-45/45/45/-45/0/90/90/0/-45......./0/90]
 - 3. Link all plies to the required ply cards (parameter IDPLY)
 - The other numbers are hourglass and other element default parameters (leave blank)
 - Below the layup data is PLYNUM and AUXVAR data which allows specify shell element information (strains, damage, etc.,...) to be output for post processing. As required specify,
 - PLYNUMx = ply number for the required output,
 - AUXVARx = corresponding auxiliary variable (see next page for definitions)

Finish with **Apply** and **Close.**

3. The composite Part

Define a new Part for the laminate and specify,

- An appropriate ID number.
- $_{\odot}$ Link the part to the composite material (parameter IDMAT).
- \circ Set the laminate thickness H=4.0.
- Specify a reference vector for the fibres which is used together with angles on the material cards layup. Use IORT=0 for global frame and a vector 1,0,0.

Finish with Apply and Close.

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PAM-CRASH materials cards:

Finishing the model

1. Entities for the Punch

For convenience the stiff punch is defined as an 'approximate' rigid body. A simple and CPU fast method is to fix all nodes in the x-y plane and specify a <u>fixed velocity</u> in the vertical direction. Note this loading is not the same as a punch with <u>initial velocity</u> that slows down during impact as kinetic energy is converted into plate deformation energy.

- 1. Use **Crash > Loads > Displacement BC** and fix all nodes in the punch to have displacement boundary conditions 110111.
- 2. Use **Crash > Loads > 3D BC** and then select type VELBC for velocity loading. Define a curve function for IFUN3 (= dir. z) having a constant velocity -10mm/msec over a duration longer than the analysis (e.g. 0→100 msec).

2. Entities for the Support

Fix the support with displacement boundary conditions (all nodes = 111111).

3. Contacts: For the Punch-to-Disc and Disc-to-Support

For the Disc-to-Support:

- 1. Open Crash > Contacts and select contact type 34 (one sided contact).
- 2. Define one side (e.g. the Disc part) as SLAVE and the other contact part (e.g. the Support part) as MASTER.
- 3. Set the contact distance hcont=0.95mm. The actual separation of parts is approximately 1mm and this smaller contact distance will ensure there are no initial penetrations at the start.
- 4. Set the contact friction FRICT = 0.2 and contact damping XDMP1 = 0.1.
- 5. All other default parameters can be used (leave blank).

Repeat the same operations for the Punch-to-Disc contact. For the punch either the complete punch can be selected, or to save some CPU time only obvious nodes on the lower surface of the Punch (that will make contact) can be selected.

4. Save (update) the dataset (Composite_SingleMultiLayerShell_Model.pc) using the Export option.

Running the model and investigating results

The PAM-CRASH dataset is run; then open the results file,

Composite_SingleMultiLayerShell_Model_RESULT.erfh5

in a new Visual Viewer session.

Deformed state results

- Click **Results > Animation Control** to visualise the model and use the adjacent panel to examine deformations (either at a certain time, or as a continuous animation).
- Click **Results > Contour** and under Entity types activate SHELL and type Damage to visualise total damage in the shells. Note that other visualisation options are available. The evolution of contour damage can be seen at specific states (via the **Results > Animation Control**), or animated.









Time history results

Start time history contour plotting using **File > Import and Plot**

3. In the panel that appears activate,

- CONTACT in the Entities
- The required contact: Punch to Disc
- Contact Force Magnitude
- Click PLOT

The red (oscillating) contact force time history curve should appear giving a maximum force of ≈ 15 kN.

This information can be passed through a filter (activate the filter under the tab **Advanced**). E.g. use a filter type CFC1000 to get the smoothed curve shown (green). This takes out all high frequency oscillations above 1000Hz.