Introduction to Explicit Dynamics Using ANSYS Workbench

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Contents

• Explicit vs Implicit
• Application areas
• Solver Technology
• Material requirements for explicit analyses
• Which solver is appropriate
• Parameterisation and Simulation Driven Product Development
Why Use Explicit Dynamics?

“Implicit” and “Explicit” refer to two types of time integration methods used to perform dynamic simulations.

Explicit time integration is more accurate and efficient for simulations involving:

- Shock wave propagation
- Large deformations and strains
- Non-linear material behaviour
- Complex contact
- Fragmentation
- Non-linear buckling

Typical applications:

- Drop tests
- Impact and Penetration
Example Applications - Implicit & Explicit

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<th>Nonlinearity</th>
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Creep | Static/Dynamic | Quasi-Static | Drop | Ballistics | Detonation & Blast | Hypervelocity Impact

**Implicit Methods**

**Explicit Methods**
Example Applications
- Hypervelocity Impact

High Energy Physics
- CERN new LHC and Beam Dump

Asteroid Impacts

Space Debris & Micrometeoroid Impacts

Geometry B 3D Load
1/2 symmetry 3D model with axial symmetry plane
Example Applications
- Detonation

Homeland Security – Street Blast

Blast Effects in Masonry Building

Blast Effects on Prestressed Bridge

Blast Effects on Armoured Vehicle
Example Applications - Ballistics

Jet Impact on Concrete

Armor Impacts:
- Lagrange (FE) above
- Euler below
- SPH below right

Tandem Warhead

Bird Strike

Fragmenting Warhead

Experiment (below) courtesy Cranfield University

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Example Applications
- Drop

Prestressed Gas Container Drop

Laptop Drop

Shower Head Drop

Water Container Drop – Using Polyflow Thickness
Example Applications
- Other “Low” Velocity Applications

- Water Jet
- Impact on Welded Barrier
- Golf Bunker Shot
Example Applications - Quasi-static

- Tube Buckling
- Shackle Failure
- Wire Crimping
- Water “Splash”
- Rubber Sealing
- Window Locking Fixture
Technology
- Solvers

• Lagrange – FE
  – 2D & 3D Volume Elements
  – 2D & 3D Shell Elements
  – Beam/Truss Elements

• Lagrange – “Mesh Free”
  – 2D & 3D SPH

• Euler – FV (VOF)
  – 2D & 3D solvers for Solids, Liquids and Gases
    • Multiple materials (MM) with strength
  – 2D & 3D solvers for inviscid gas dynamics (FCT)

• ALE – FV
  – Automatic mesh rezoning in 2D & 3D
Solvers

Lagrange  Euler  ALE  SPH

AUTODYN-2D v4.3 from Century Dynamics
Technology - Connections & Coupling

Lagrange (FE) Solvers (Solids, shells & beams)
Structural Response
Complex Materials

Euler (CFD) Solvers (Multi-material, Blast)
Solid / Gas / Fluid Flow Blast Waves

Solid Impact
FSI (Deforming Structures)
Combined Blast & Impact Loading

Mesh Free Solver
Hypervelocity Impact
Brittle Material Fracture / Fragmentation

ALE Solver
Fluid-Structure Interaction with Strong Structures

Bonding / Contact
Bonding / Contact
Coupling
Coupling
Spatial Discretization

• Geometries (bodies) are meshed into a (large) number of smaller elements.
• Structural elements used in ANSYS Explicit Dynamics have Lagrange formulations:
  – i.e. elements follow the deformation of the bodies.

• ANSYS AUTODYN allows other formulations to be used:
  – Euler (Multi-material, Blast)
  – Mesh free (SPH)
Running Explicit Dynamic problems requires making trade-off between Ease of Use (effort for setup), Accuracy and the time to complete a simulation.

ANSYS Explicit Solutions make it easy and convenient to make the trade-offs required to complete a project in the shortest time with the least amount of labor.
Defeaturing

- In explicit analyses the timestep is proportional to the element size therefore small geometric features can cause extended run times
- Removing these small features (defeaturing) can significantly improve timestep
- This can be done at the geometry level or...
- ANSYS Workbench provides several tools to do this at the analysis level
  - Mesh based defeaturing
  - Virtual topology
- Timestep can also be improved / maintained with numerical methods
  - Mass scaling
  - Element erosion
Material Behaviour Under Dynamic Loading

In general, materials have a complex response to dynamic loading

The following phenomena may need to be modelled

- Non-linear pressure response
- Strain hardening
- Strain rate hardening
- Thermal softening
- Compaction (porous materials)
- Orthotropic behavior (e.g. composites)
- Crushing damage (e.g. ceramics, glass, geological materials, concrete)
- Chemical energy deposition (e.g. explosives)
- Tensile failure
- Phase changes (solid-liquid-gas)

No single material model incorporates all of these effects

Engineering Data offers a selection of models from which you can choose based on the material(s) present in your simulation
Material Deformation

Material deformation can be split into two independent parts

- **Volumetric Response** - changes in volume (pressure)
  - Equation of state (EOS)

- **Deviatoric Response** - changes in shape
  - Strength model

Also, it is often necessary to specify a **Failure model** as materials can only sustain limited amount of stress / deformation before they break / crack / cavitate (fluids).
Plasticity

Effects of Strain Hardening (Johnson-Cook Model) Hypervelocity Impact

- Normal impact of tungsten sphere on thick steel plate at 10 km\(\text{s}^{-1}\)
- Lagrange Parts used with erosion
- Johnson-Cook strength model used to model effects of strain hardening, strain-rate hardening and thermal softening including melting
Brittle / Granular

Johnson-Holmquist Strength

- Use to model brittle materials (glass, ceramics) subjected to large pressures, shear strain and high strain rates
- Combined plasticity and damage model
- Yielding is based on micro-crack growth instead of dislocation movement (metallic plasticity)
- Fully cracked material still retains some strength in compression due to frictional effects in crushed grains
- Yield reduced from intact value to fractured value via a Damage function
- Damage accumulates due to effective plastic strain
Tensile Pressure Failure

- **Example:** Dynamic Spall
Failure

Example: Impact on Ceramic Target

- 1449m/s impact of a 6.35mm diameter steel ball on a ceramic target
- Johnson-Holmquist Strength model used in conjunction with Crack Softening

Simulation

Experiment (Hazell)
Which Solver do I use?

• Having the correct material model is not enough
• It is also important to choose a solver which is suited to the application area you are looking at
• Some solvers are more appropriate for studying certain areas than others
Smooth Particle Hydrodynamics

Ballistics

- Impacts on concrete

Figure 3

Shot #5 Final Deformation, SPH/Euler/Lagrange Simulations

KEP on Concrete

SPH Analysis

Figure 2

Shot #5 Target Damage Observed During Trials
Mixed Solver Methodologies

Ballistics
- Impacts on concrete
- SPH + FE
Failure

Example: Impact on Ceramic Target

- 1449 m/s impact of a 6.35 mm diameter steel ball on a ceramic target
- Johnson-Holmquist Strength model used in conjunction with Crack Softening

Experiment (Hazell)

Simulation
Blast and Fragmentation

Contact, Erosion and Coupling can be used simultaneously in a numerical simulation

- Failure and fragmentation of components
- Venting of fluids / gases through failed / fragmented components
- Combined blast and fragment loading of structures

➤ Resulting in modeling flexibility and generality!
Analysing single fixed designs can lead to valuable insights into their behaviour.

A greater depth of knowledge can be achieved by looking at multiple design points. These may contain variations in the geometry, materials, mesh settings etc etc.

This process (virtual prototyping) can be carried out via the parameter manager within ANSYS Workbench.
What If Study

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Updating the Solution cell in Explicit Dynamics (ANSYS) for design point 8.
Thank you for your time

Questions?