Validation of a Finite Element Analysis (FEA) Model of a Nuclear Transportation Package under Impact Conditions

Chris Berry
Lead Engineering Analyst

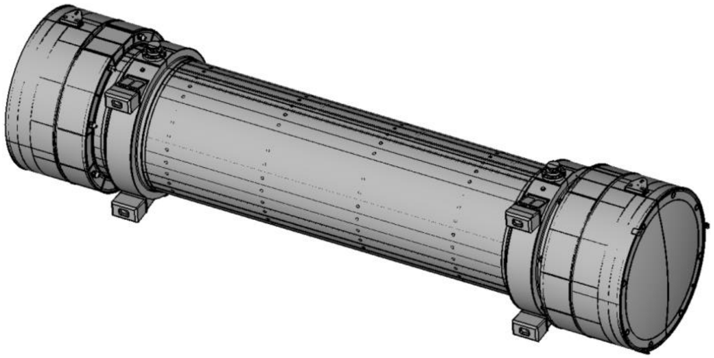
11th October 2016

Outline of presentation

- Background
- Concepts of Validation Process
- Approach to FEA Model
- Results – Test vs FEA
- Discussion – What about Uncertainties?
- Summary and Conclusions

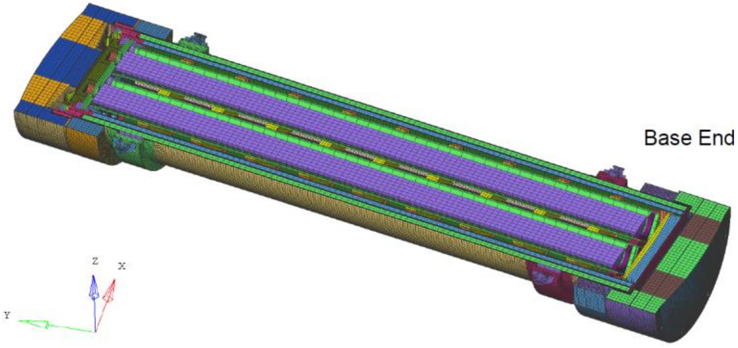
Background - Purpose of Validating FE Model

- Validation of model of M4/12 Transport Package was carried out over 10 years ago
- New model built using latest techniques and utility of significant advances in the LS-Dyna solver
- FE model can be used in future assessments involving impact conditions



Full 3D CAD model of M4/12 package

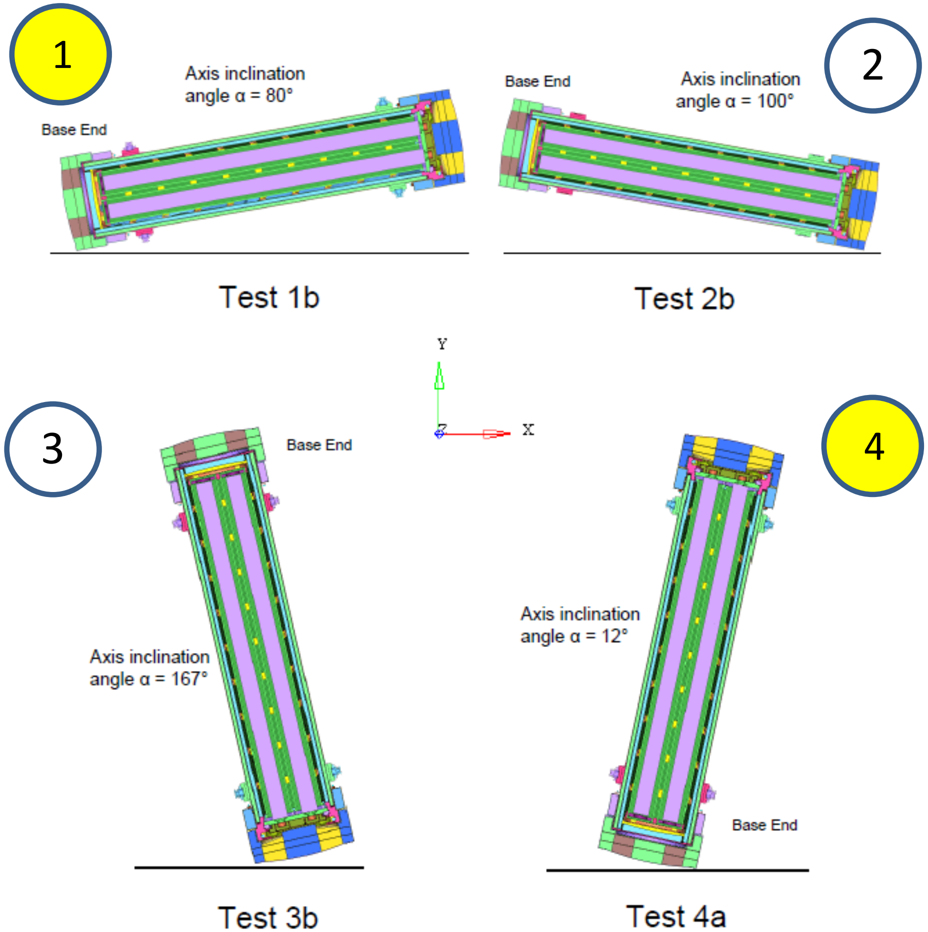
M4/12 Transport Package



FE model utilises half symmetry of M4/12 package

Background - Drop orientations performed in tests

- Four drop test orientations used for validation
- All drops from 9m height
- Primary and secondary impacts included (Test 1b)
- Drop tests 1b & 4a presented
- All analyses performed using LS-Dyna explicit tool



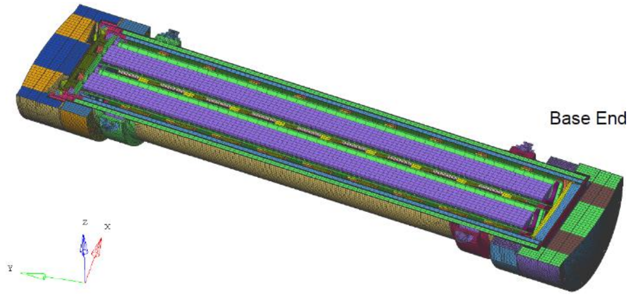
Drop orientations in impact analysis with varying angles for base and lid end impacts

Concepts of Validation Process

- What is Validation?
  - A process by which the predictive capabilities of a simulation are tested against physical test data
  - Successful validation of model based on how well it compares with test data
  - What is acceptance criteria for successful validation of FE Model? 10%, 20% ?
  - FE model should be verified before embarking on validation process
- Verification prerequisites to Validation
  - Representation of geometry based on drawings used from manufacture of package
  - Material usage checks
  - Sensitivity studies
  - Contact behaviour of component interfaces
  - Boundary conditions and loading

Approach to FEA Model

- Origin of Geometry
  - M4/12 package contains many components
  - FE model build based on 3D CAD geometry -> all components checks to manufacturing drawings



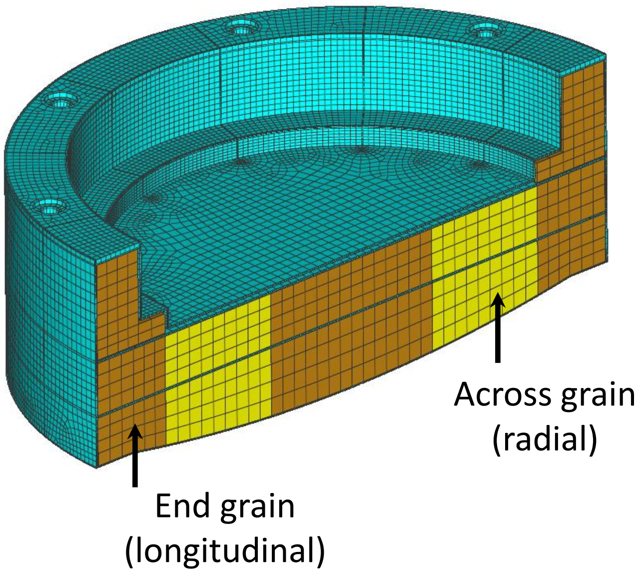
- Contact/ Friction
  - What is the correct friction value to be used in FEA?
  - *CONTACT_AUTOMATIC_SINGLE_SURFACE, assuming friction = 0.3
  - Target surface: using *RIGID_WALL_PLANAR and default friction = 0.0
  - Sensitivity study to understand how varying friction of target surface performed -> results negligible

Approach to FEA Model

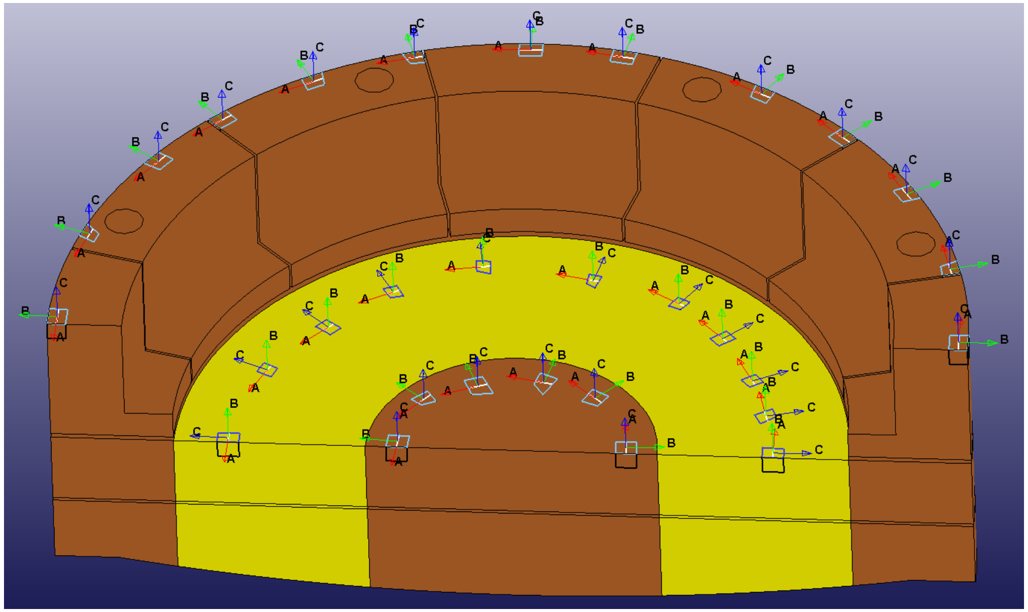
- Weight comparison
  - Weight of test specimen = 13.3t, weight of FE model = 12.772t
  - Difference in weight is 4%
- Material usage
  - All materials assigned, checked and recorded
  - Shock absorbers use wood as main energy absorbing material
  - How do we check the anisotropy of wood is modelled accurately?

Approach to FEA Model – Wood material directions check

- Vector plots aids visual checking in LS-PrePost
- Correct alignment of material directions of wood grain across elements
- Wood modelled using keyword *MAT_MODIFIED_HONEYCOMB
- AOPT = 4.0: locally orthotropic in cylindrical system



Assembly of wood within Base End Shock Absorber



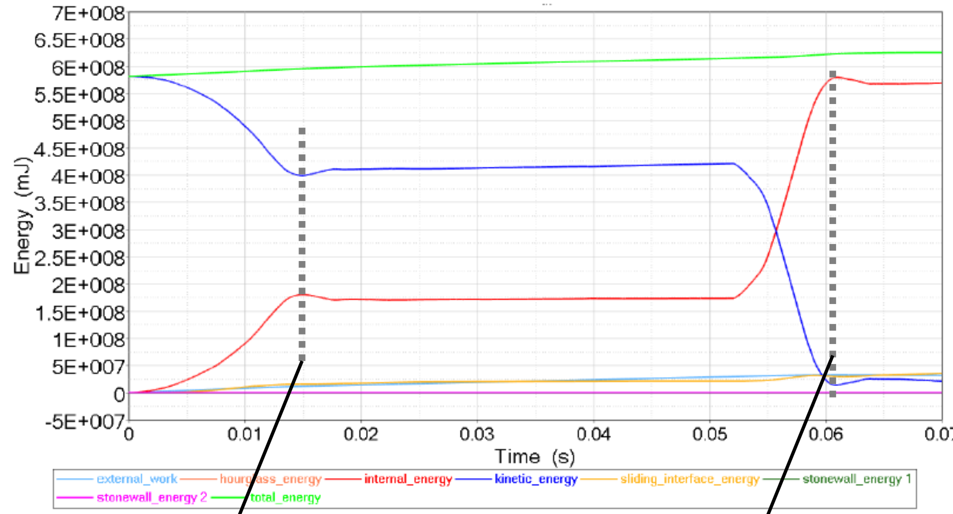
Material directions of wood in Shock Absorber: LCC along grain direction

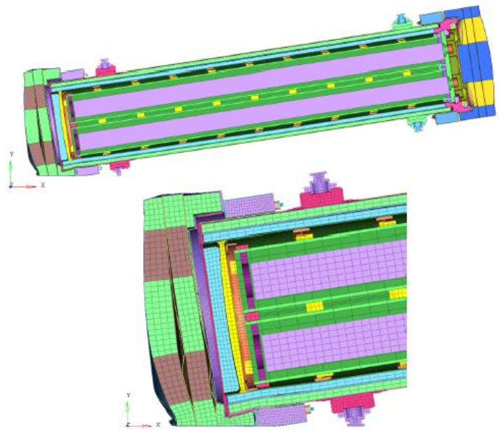
INTERNATIONAL NUCLEAR SERVICES

Results – Impact Analysis of Drop Test 1b

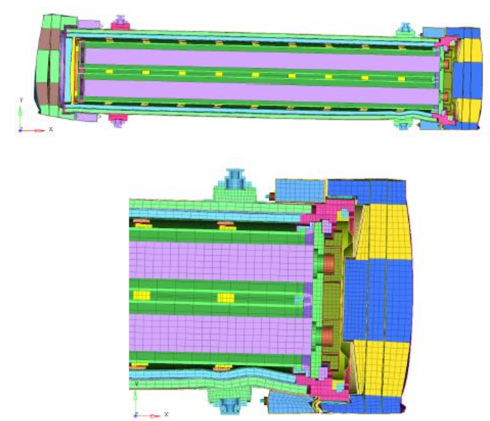
- Energy curve identifying time at primary and secondary impact occur
- Termination time = 70ms
- Energy results as expected
- How do the analytical impact deformations compare with those from test?

Energy Graph





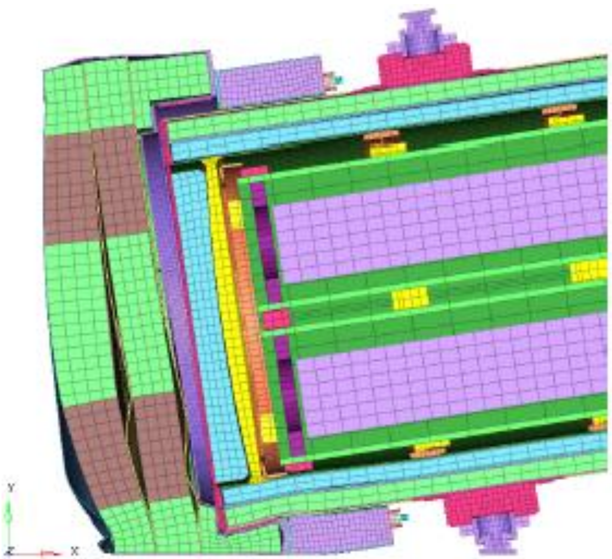
Primary Impact, t = 15ms



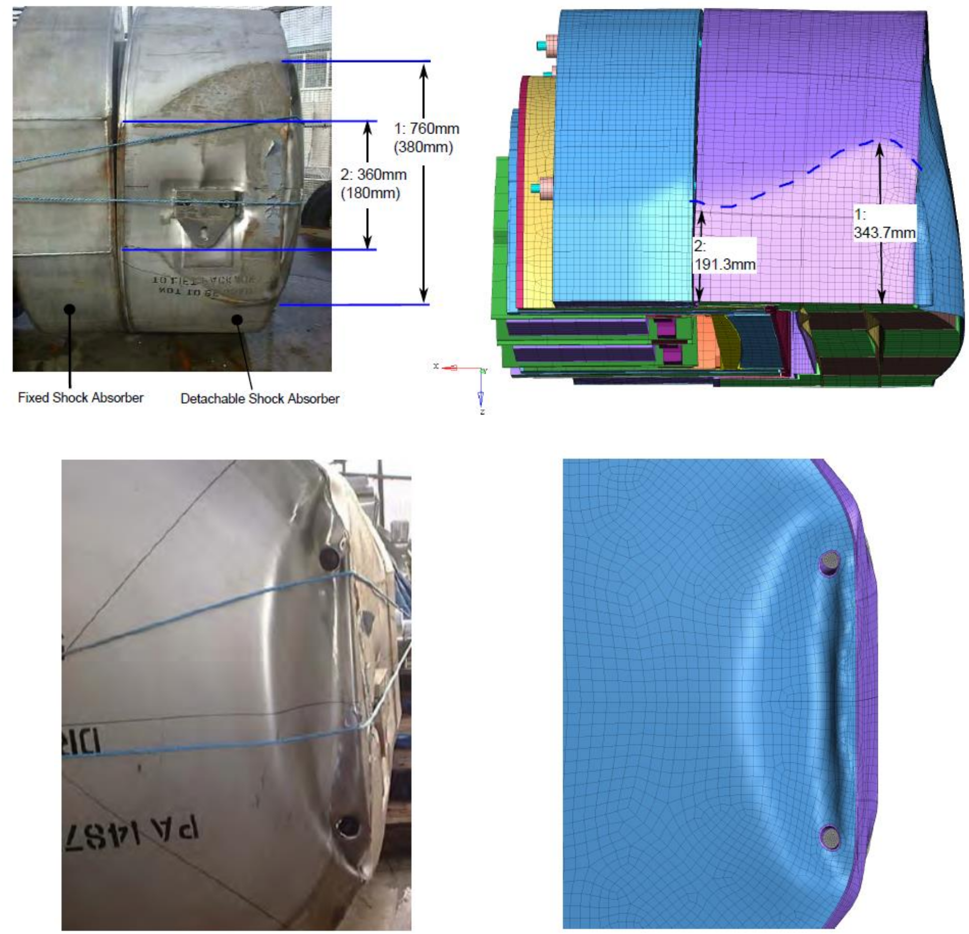
Secondary Impact, t = 61ms

Results – Comparison of Test vs FEA - Test 1b (1 of 2)

- Primary impact: deformation to Base End Shock Absorber



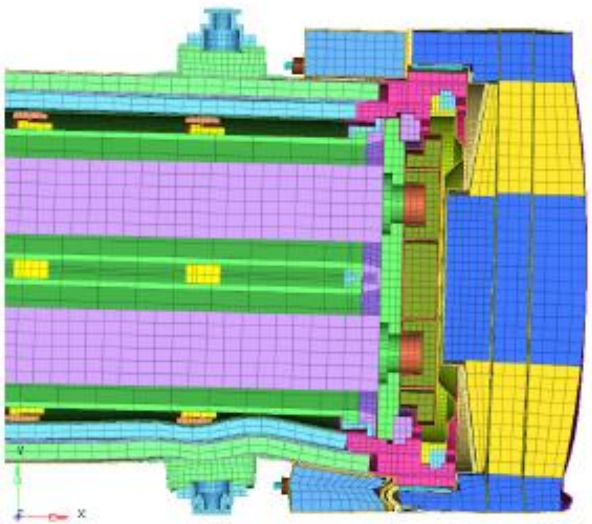
Impact at Base End of Package



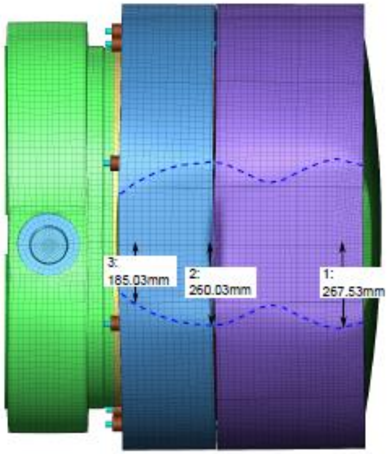
Test vs FEA – Measure of Impact deformations

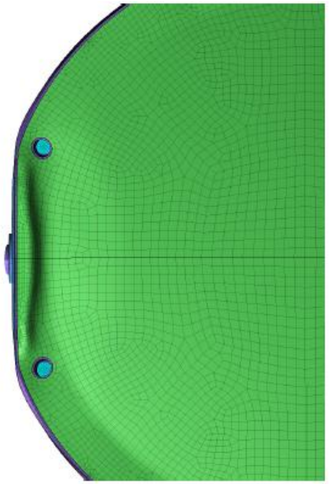
Results – Comparison of Test vs FEA - Test 1b (2 of 2)

- Secondary impact: deformation to Lid End Shock Absorber



Impact at Lid End of Package



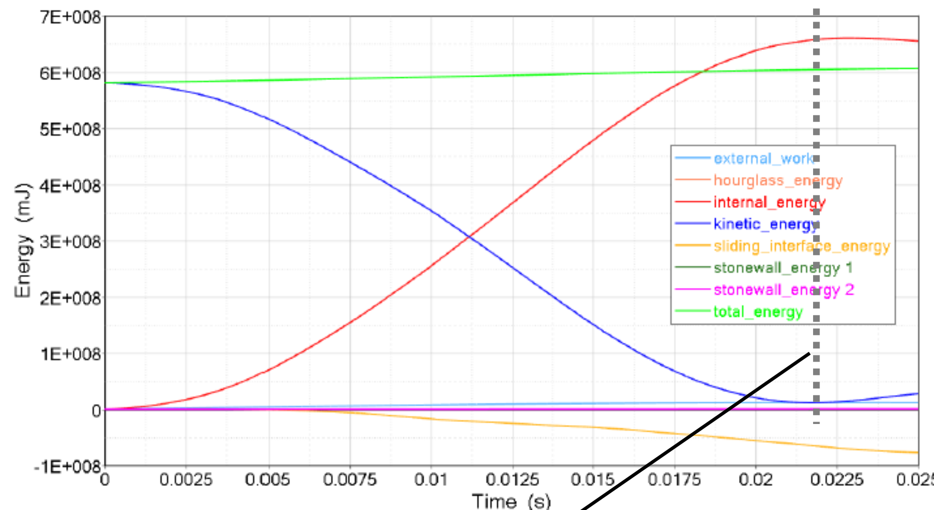


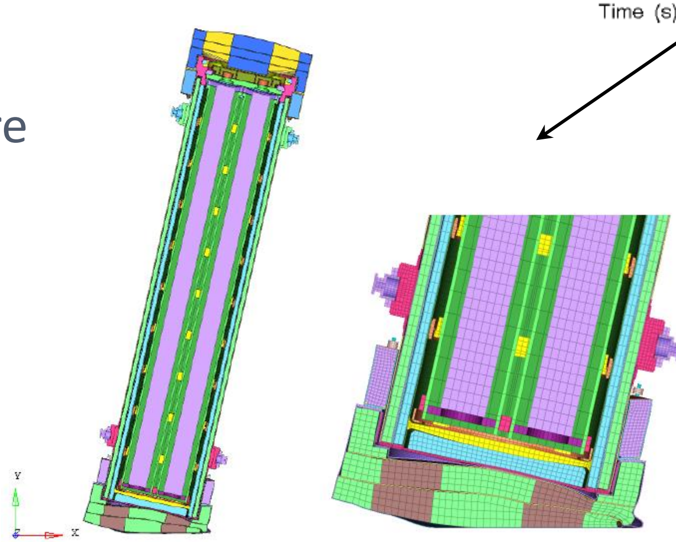
Test vs FEA – Measure of Impact deformations

Results – Impact Analysis of Drop Test 4a

- Energy curve identifying time at primary impact at time = 22ms
- Negative Sliding interface energy – remote from point of impact
- Again, how do the analytical impact deformations compare with test?

Energy Graph from Run 4a



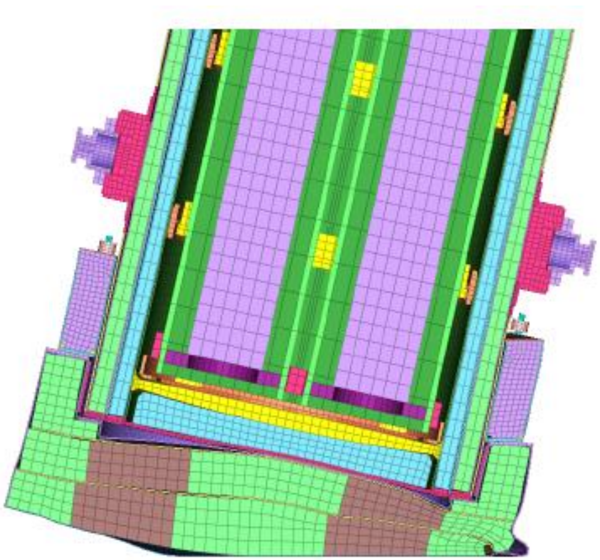


Primary Impact,
t = 22ms

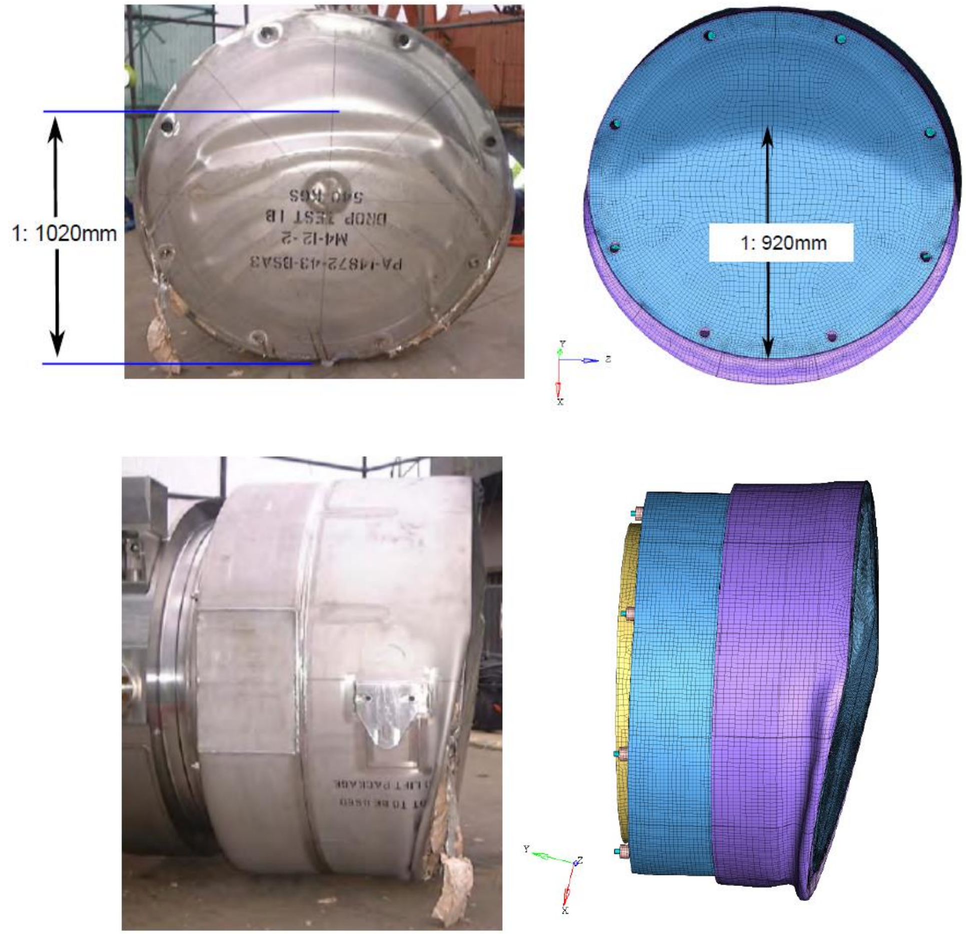
Base End

Results – Comparison of Test vs FEA - Test 4a

- Primary impact: deformation to Base End Shock Absorber



Impact at Base End Shock Absorber



Test vs FEA – Measure of Impact deformations

INTERNATIONAL NUCLEAR SERVICES

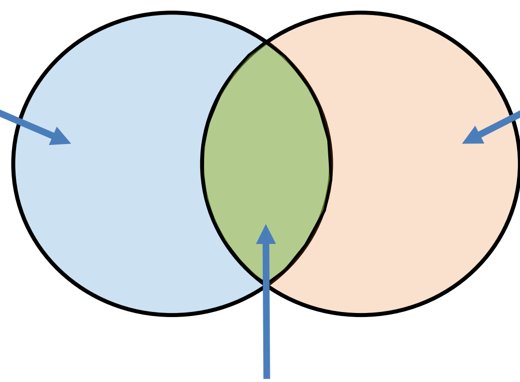
Discussion

- Good agreement between Test vs FEA
- Impact deformation measurements from FEA mostly under-predicts the test
- Deformations are within 12%
- What is acceptable criteria? 10% or 20%

Uncertainties in Test vs FEA

Test

- Manufacturing tolerances
- Repeatability of test
- Accuracy of measurements
- Use of simple measuring devices



Convergence:
Test vs FEA

FEA

- Geometry representation
- Material behaviour
- Contact/Friction values
- Element type usage
- Interpretation of measurements can be subjective

Summary and Conclusions

- Difficulties in measuring deformations in test and simulation
- Good agreement between Test and FEA within 12%
- Validation of model acceptable
- Available techniques for assessing impact test measurements
  - High speed camera integrated with digital image correlation (DIC) technique -> improve the consistency of test results
  - Laser 3D scanning

Any Questions?