NUMERICAL SIMULATION & EXPERIMENTAL TESTING OF BRIT LEAD CASK(BLC)

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OBJECTIVES OF THE WORK

- Design of BLC to transport sealed radioactive **s**ources from Hot Cell to Gamma Irradiators.
- Optimization of the cask design by numerical analysis and effect of inclined fins.
- Finding the worst orientation from a number of possible orientations by numerical simulation.
- Design validation by experimental testing.
- Compliance of the cask under 9m drop test followed by 1m punch test & 800^{o} C fire test. (Structural integrity)
- To carry out radiometry to ascertain the shielding integrity.

Photo of the BLC

Specification of the Package

Cask Overall Dimensions	940mm x 940 mmx1050mm(H)
Weight of Package	4500Kg. (Approx)
Weight of Lead in Package	3500Kg. (Approx)
Size of cavity of source	ϕ163 mm x 480 (H) mm.
Cobalt-60 content	100 kCi (3700 TBq)

Design Requirement Type B (U)

Shielding Requirement:

- 2mSv/hr at the surface of the cask
- 10mSv/hr at 1m from the surface after accident conditions

Structural Requirement:

Normal Conditions of Transport:

- Water spray test
- Free drop test
- Staking test for a period of 24 hr
- Penetration test

Accident Conditions of transport:

- Mechanical Tests
  - 9m drop test on unyielding target
  - 1m punch test
- Thermal Test
  - 800C Fire Test for 30 minutes
    - 15m Water Immersion Test for 8hrs

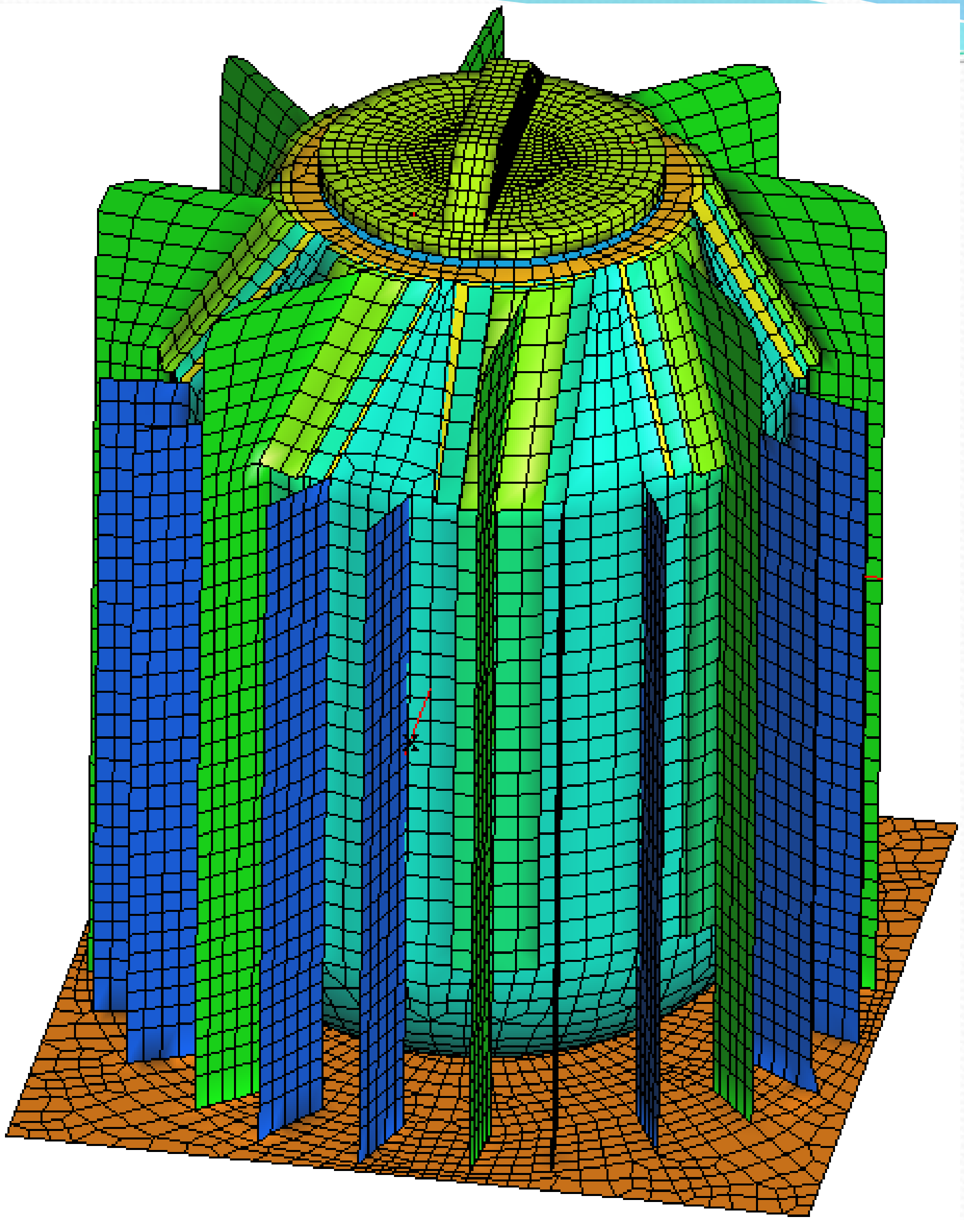
Finite Element Analysis:
Software Package used: A non linear FE code PAM-CRASH

Finite Element Model

Model: FEMAP v-8.0
Plates: 3D, 4 noded bilinear shell element
Lead: 8 noded 3D brick element
Bolts: One dimensional beam element

The Cask model consists of

64812 nodes
24092 shell elements
35948 solid elements
24 beam elements



FE Model of the cask with Inclined Fins

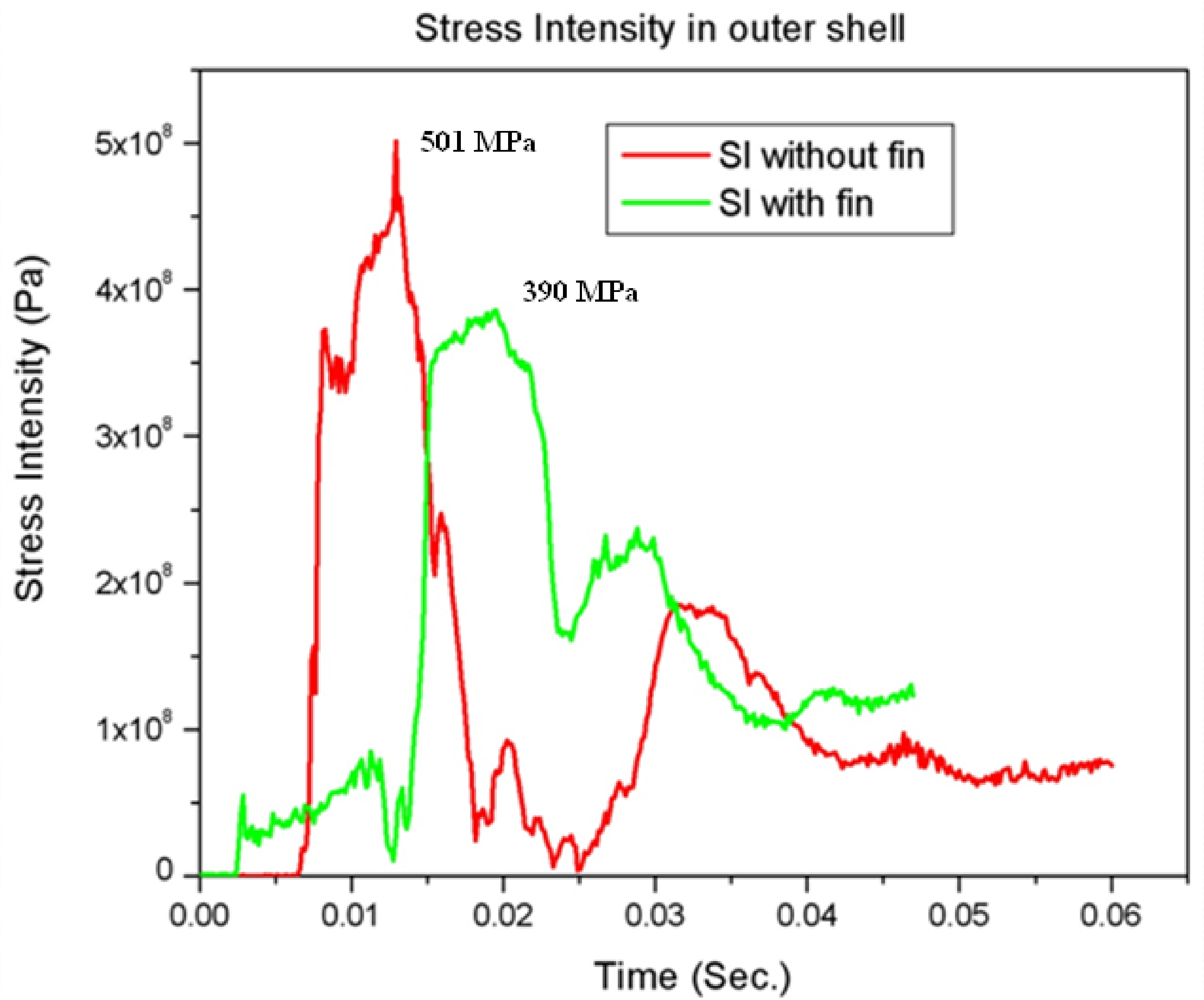
Material properties used for analysis

Sr. No.	Properties	Steel (SS 304L)	Lead	Bolt SA 540 Gr B24
1	Material law	Bilinear Elastic-Plastic	Bilinear Elastic-Plastic	Bilinear Elastic-Plastic with1%plastic strain
2	Density	7800 kg/m^3	11350 kg/m^3	7800 kg/m^3
3	Young's modulus	200E9 N/m^2	Not Used	200E9 N/m^2
4	Poisson's ratio	0.3	Not Used	0.3
5	Yield stress	170 E6 N/m^2	3.2 E6 N/m^2	1035E6 N/m^2
7	Ultimate stress	485 E6 N/m^2	Not Used	1140E6N/m^2

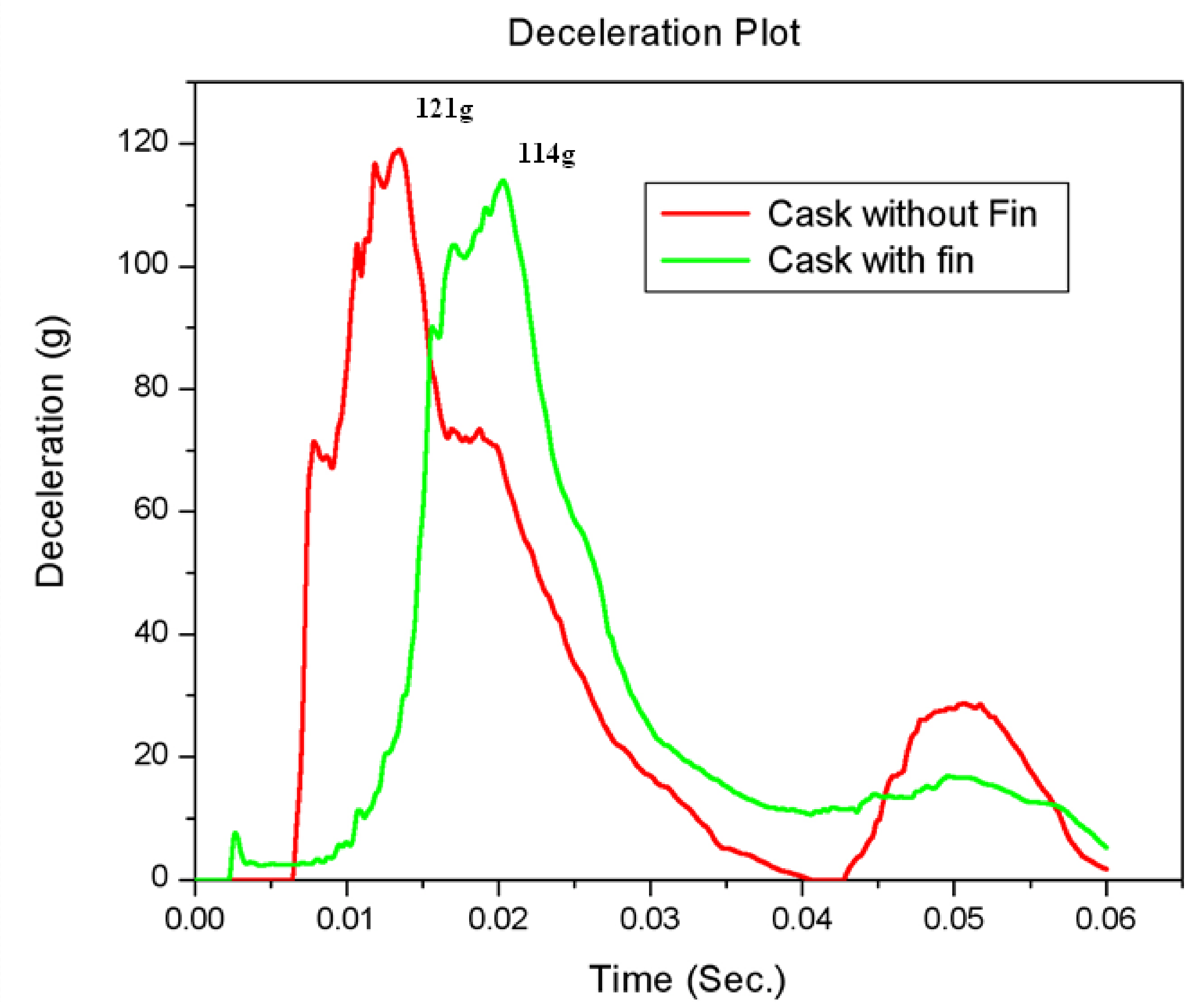
Approximations/ Assumptions made in the FEM Model

- For all the simulations, material properties are considered at room temperature.
- The target is assumed to be a perfectly rigid wall without friction.
- The interfaces such as steel-lead, steel-steel etc. are assumed to be frictionless.
- The structural welds are not considered in the model and uniform base material is modeled across any structural joints.
- The bolt response is assumed to be elastic and 1% plastic.
- All the simulations are carried out for first impact; the second impact on rebound is ignored.
- The elastic-plastic material properties are assumed to be bilinear

Plot of Stress Intensity in the Outer Shell for the Cask with and without fins



Deceleration plot for cask with and without fin



Maximum stress intensities observed in various parts of the cask with fin and without fin

Components	Stress Limit (MPa)	Observed Maximum Stress Intensity (MPa)	
		Corner Drop without fin	Corner Drop with fin
Outer shell of cask	485	501	390
Inner shell of cask	485	387	386
Steel casing of lid plug	485	426	383
Top plate	485	693	476

Method Employed

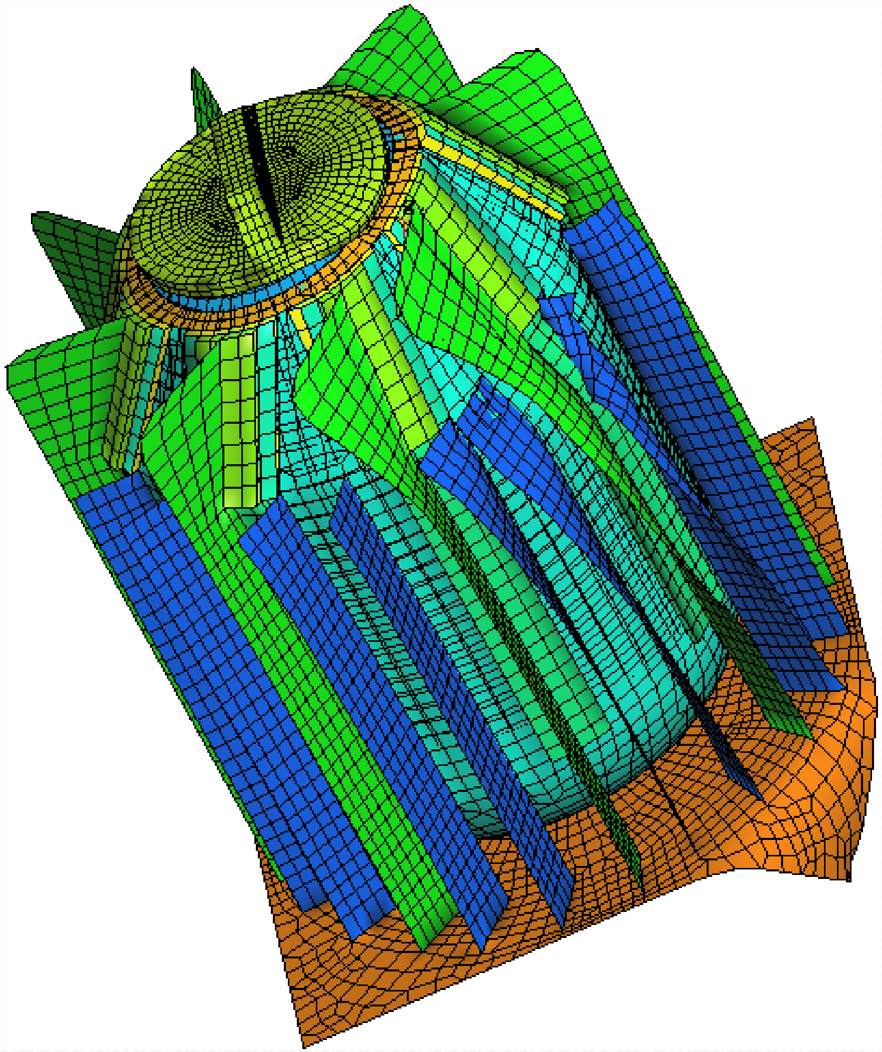
Numerical Simulation

Possible orientations considered for analysis of cask with fin

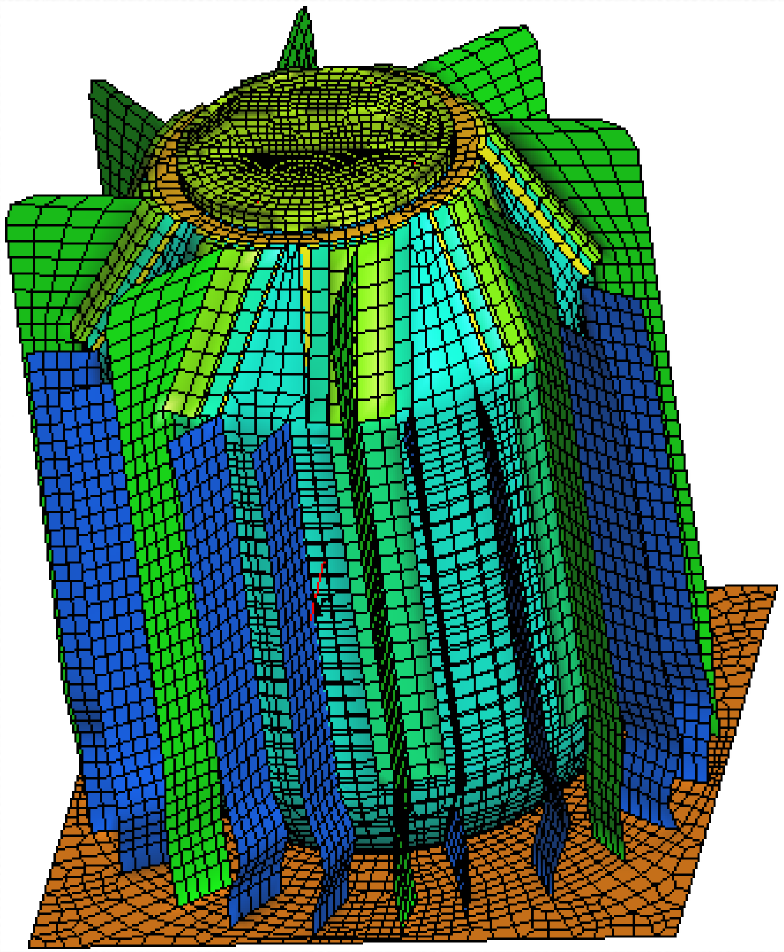
- Corner
- Horizontal
- End
- Inverted End

Experimental Test

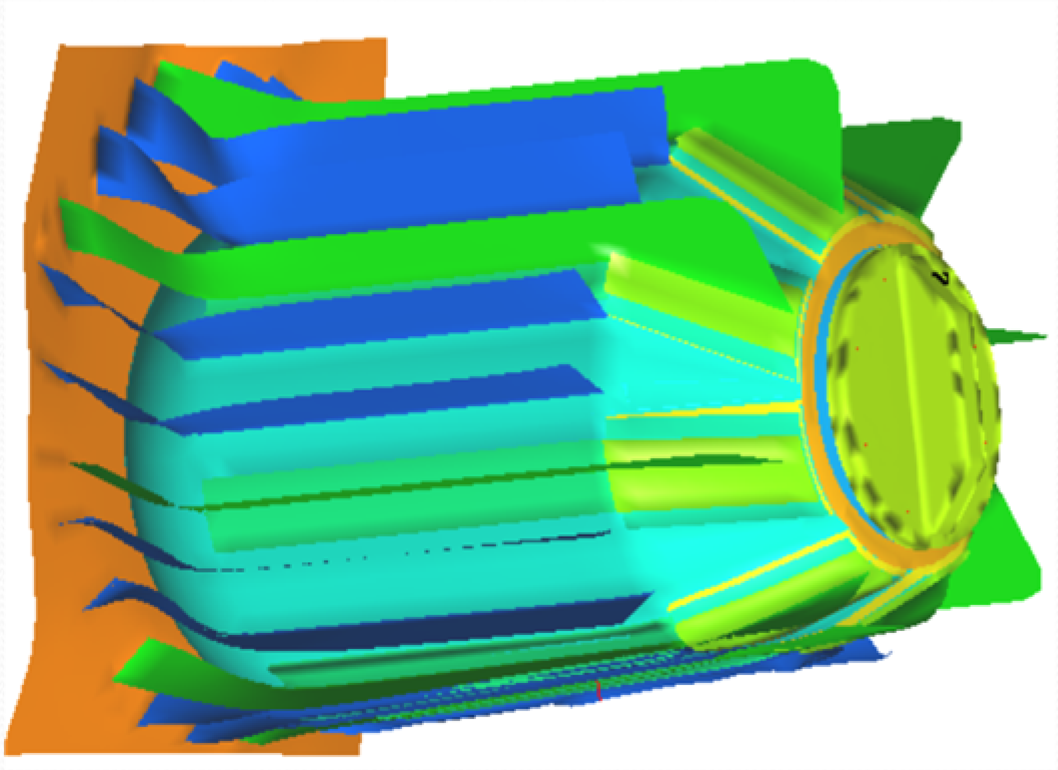
Deformation of the cask under 9m corner drop



Deformation of the cask under 9m end drop



Deformation of the cask under 9m horizontal drop

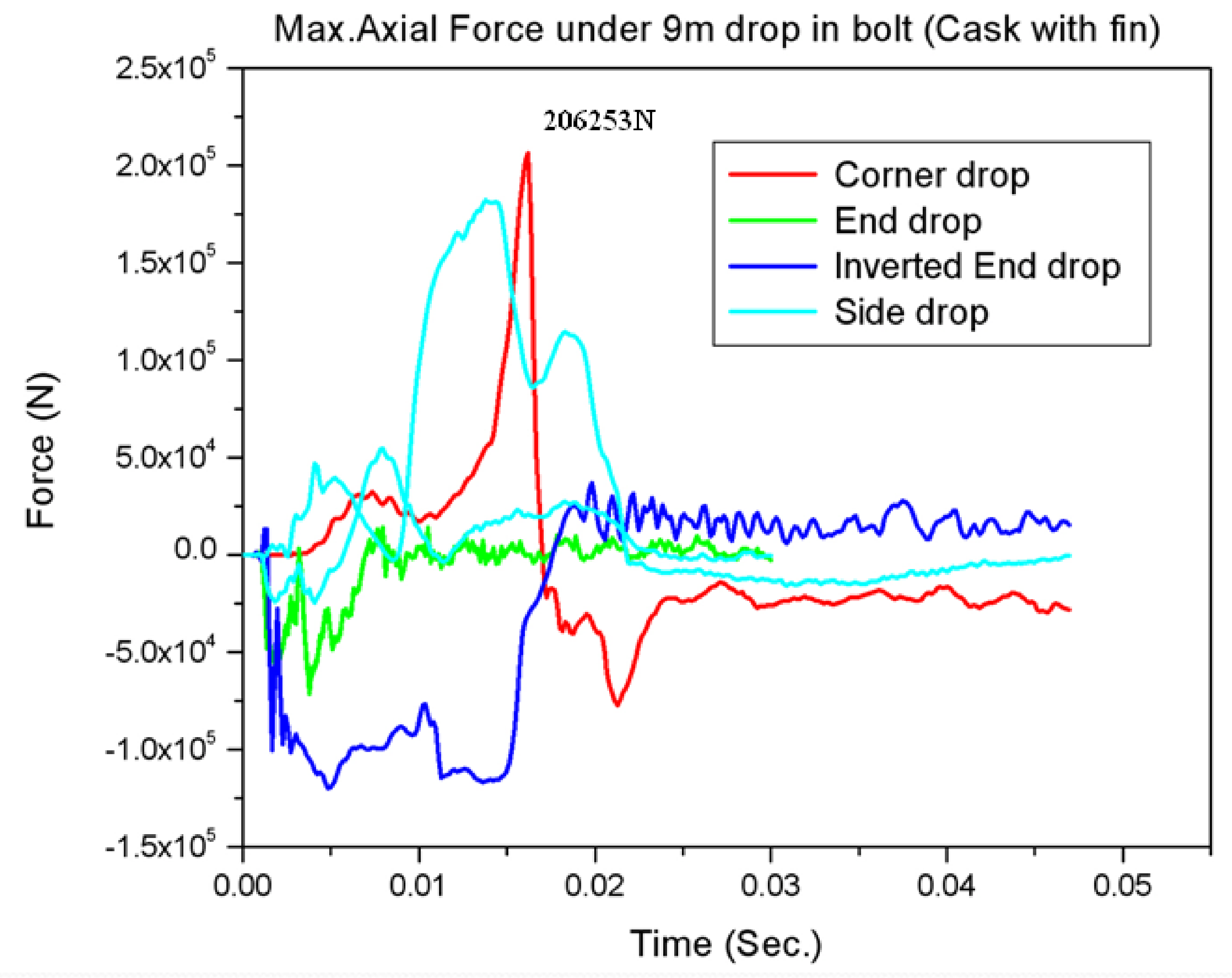


Maximum stress intensities observed in different parts of the cask for various orientations

Component	Stress Limit (MPa)	Observed Maximum S.I. **(MPa)**			
		Corner Drop	Side drop	Inverted end Drop	End Drop
Outer shell of cask	485	390	336	279	398
Inner shell of cask	485	386	363	471	310
Steel casing of lid plug	485	383	431	451	403
Top plate *	485	476	320	471	357

*stresses in the projected part that is used to lift the plug of the top plate are not reported as it is a 50mm thick solid and high stresses in this region will not impair the safety of the cask.

Axial force generated in the cask with fin for different drop orientation



WORST ORIENTATION

- Overall stresses generated in the corner drop and inverted end drop are more than that of side and end drop
- The axial force in the bolts are higher in corner orientation than that of any other orientation.
- The bolts in the corner drop are also subjected to bending stress.

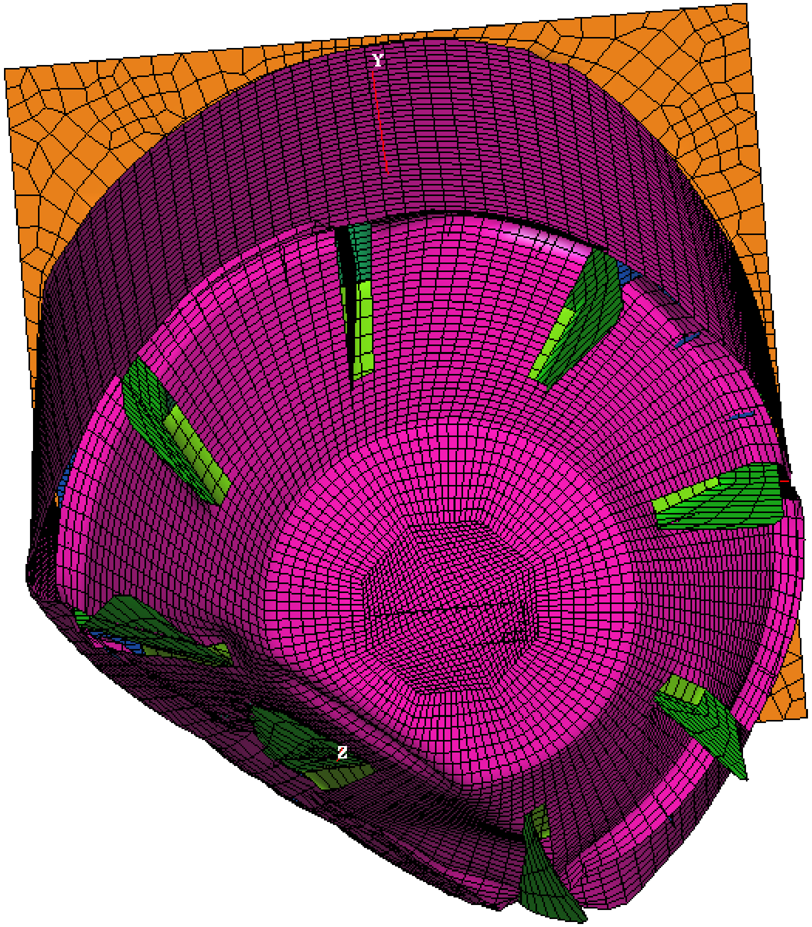
CORNER DROP IS THE WORST ORIENTATION

DROP TEST FACILITY AT ARAI, PUNE

Un-Yielding Target

Orientation of the Cask before 9m drop

9m drop test



Deformation pattern after Numerical analysis

Deformation pattern after Experimental drop test

Orientation of the Cask before 1m drop

Photograph taken just before impact

Photograph taken just before 800° C Fire test

Photograph taken after 800° C Fire test

Radiometry

Source used for Radiometry – (Co-6o)

Radiation levels projected for 3700 TBq / 100kCi

Maximum radiation level	Before Drop		After Drop	
Activity content of the Package: 3700 TBq / 100kCi	Observed mSv/h	Permissible mSv/h	Observed mSv/h	Permissible mSv/h at 1m
At the surface of the package	**0.75**	**2.0**	**1.5**	**10**

Conclusion

- Inclined fins limited the stresses generated in the cask.
- Numerical analysis shows that stresses generated in the cask meet the regulatory requirement for all orientations.
- After experimental test, visual check shows no apparent damage to the cask body. The mode of deformation observed in the inclined fins corresponds tothe pre-computed data obtained from numerical analysis.
- The cask's structural integrity is intact under 9m drop followed by 1m punch test & 800°C fire test.
- Radiometry confirms that after accident conditions radiation levels meet the regulatory requirement and the shielding integrity is maintained.

THANK YOU