STANDALONE SIMULATIONS OF SIAD AEROELASTIC RESPONSE USING LS-DYNA

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and

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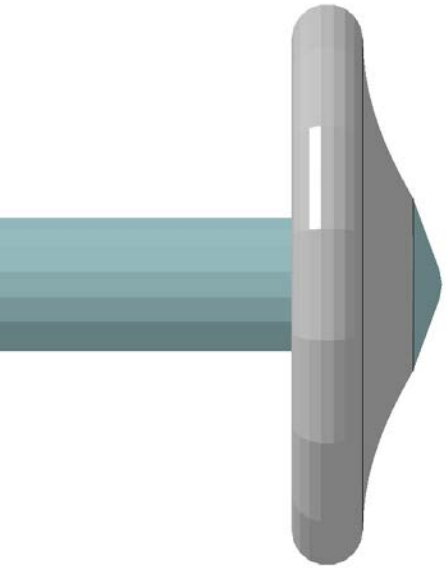
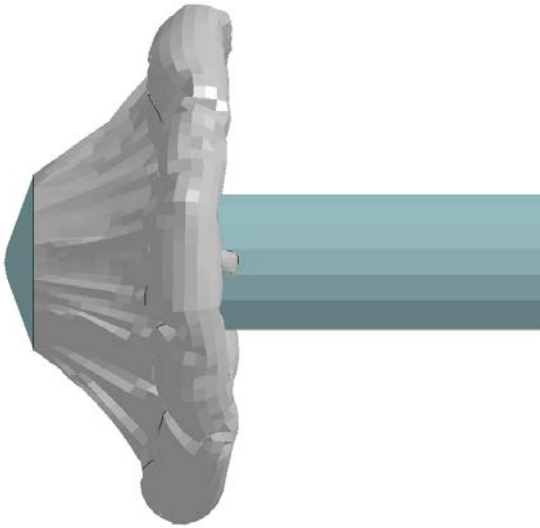
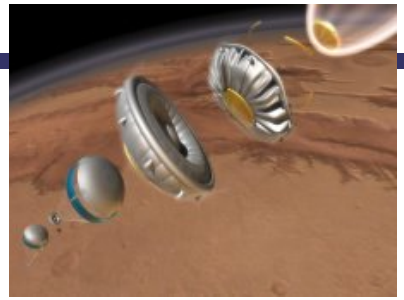
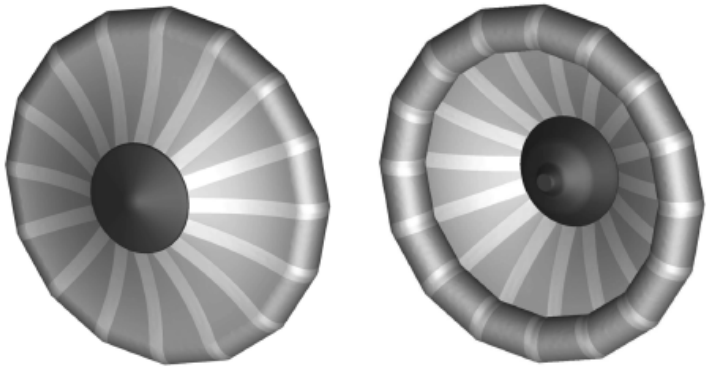




Introduction and motivation



- SIADs can enable an expansion of capabilities key to future Mars exploration.
- FSI simulations serve the community to gain insight on the behavior of non-rigid structures. SIAD dynamics, inflated shape, aero coefficients, and stiffness effects are all of interest and can be better understood using a validated simulation.
- A FSI simulation framework is presented for highly deformable structures that fold and form a complex boundary with the fluid. These structures are loaded under supersonic flow conditions.
- Discussion of the simulation framework employed; its advantages and drawbacks.
- Partial inflation and buckling behavior results are presented for a tension cone geometry.



Kramer et al.

Wind tunnel deployment

- SIAD deployment timescales are acceptable for the restrictions imposed by the simulation solving method.

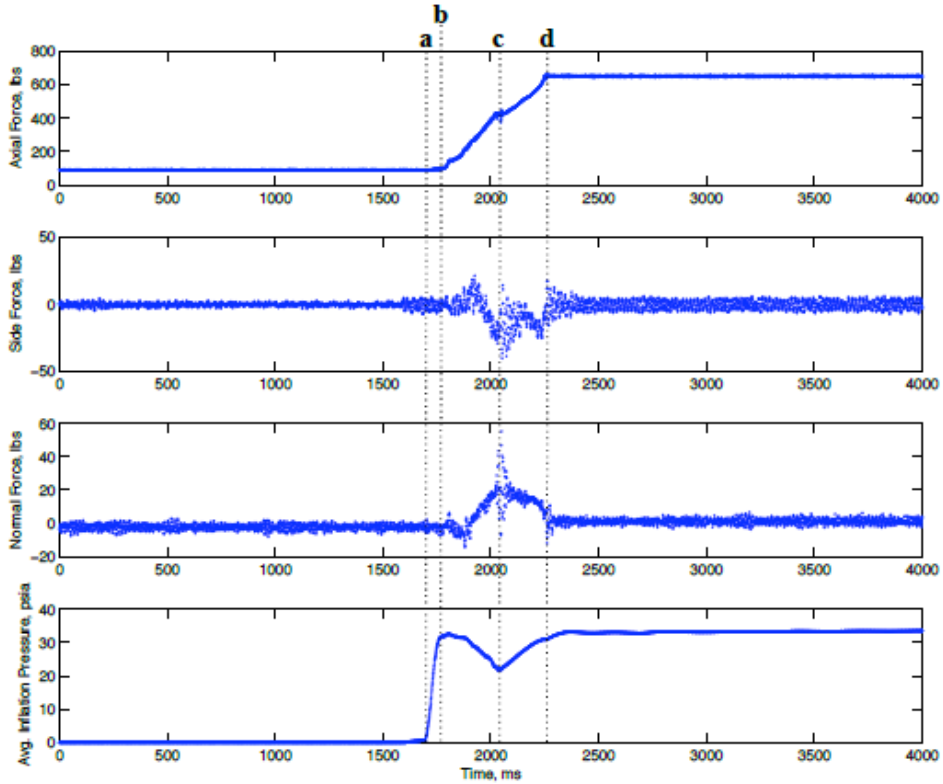


Figure 59: Force history during deployment of an inflatable model at a Mach number of 2.5 and dynamic pressure of ~150 psf. Figure letters correspond to events shown in Figure 60.

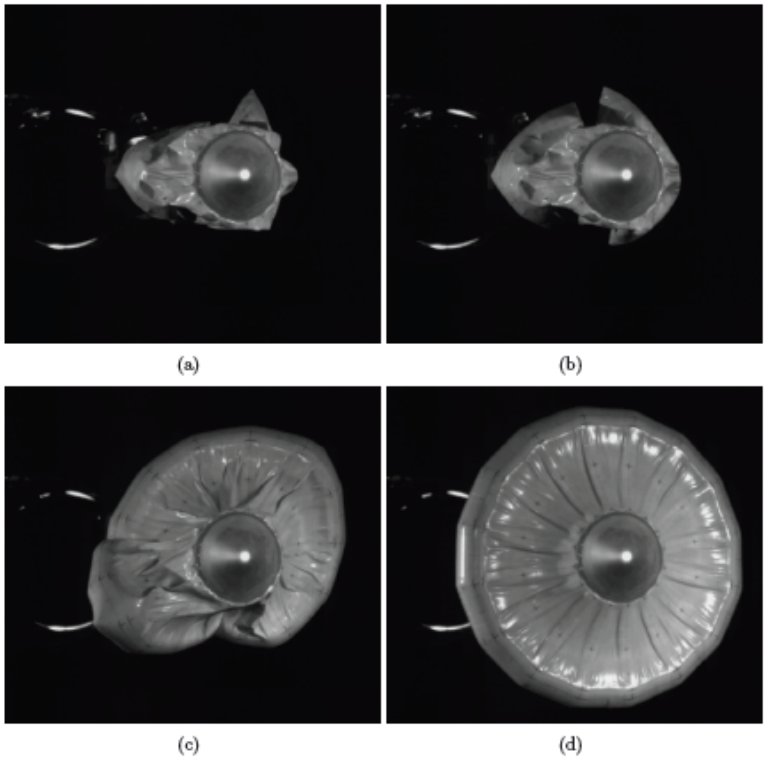


Figure 60: Deployment sequence images for an inflatable model at a Mach number of 2.5 and dynamic pressure of ~150 psf. Figure letters correspond to events shown in Figure 59.

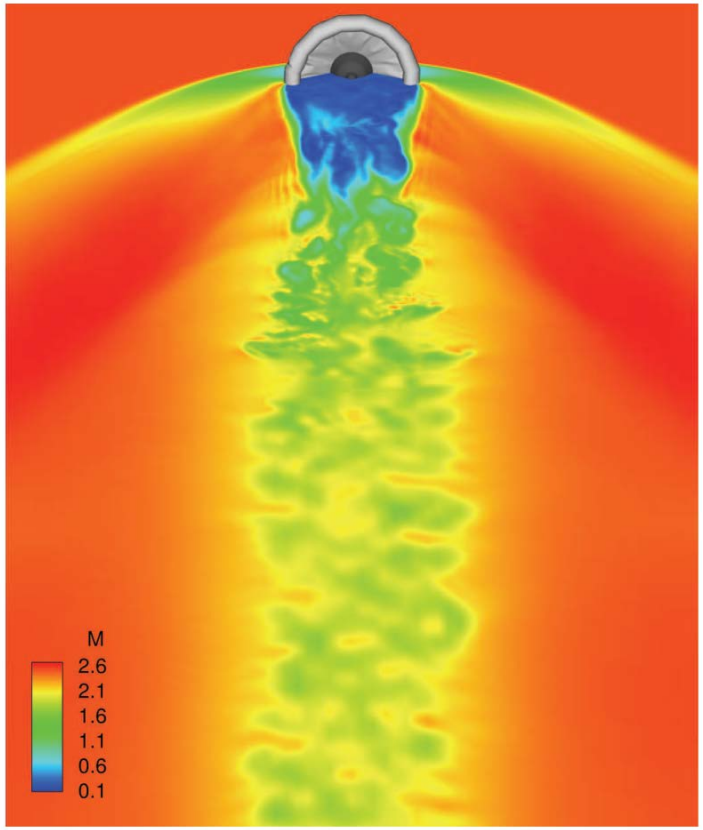
Ian Clark, PhD Thesis

State of the art: fluid and structure interaction

- Kramer et al. successfully performed simulations featuring:
  - Large deformation analysis of thin shells.
  - Large-eddy simulation of compressible turbulent flows.
  - Loosely coupled approach.

- Furthermore, efforts by Tanner showed that a commercial structural solver (LS-DYNA) could be used to correctly describe the flexible structure.

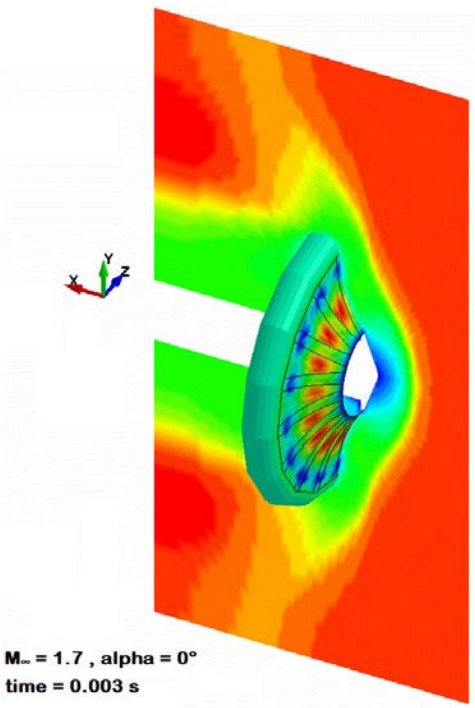
- FUN3D coupling and later NASCART-GT (Bopp).



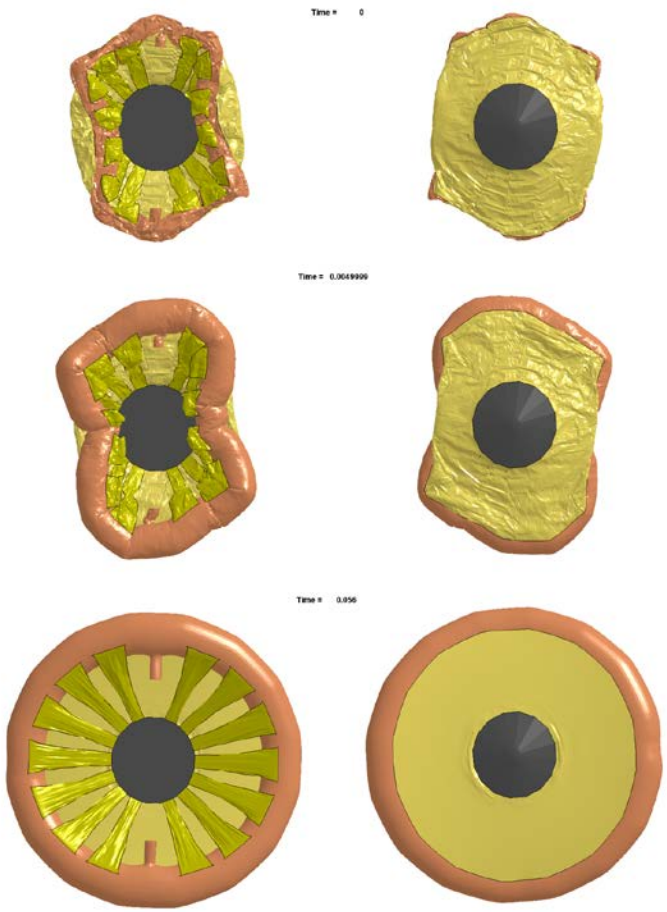
Turbulent wake, Mach number

Loaded SIAD response under decreasing inflation pressure

Simulation: airbag inflation contributions



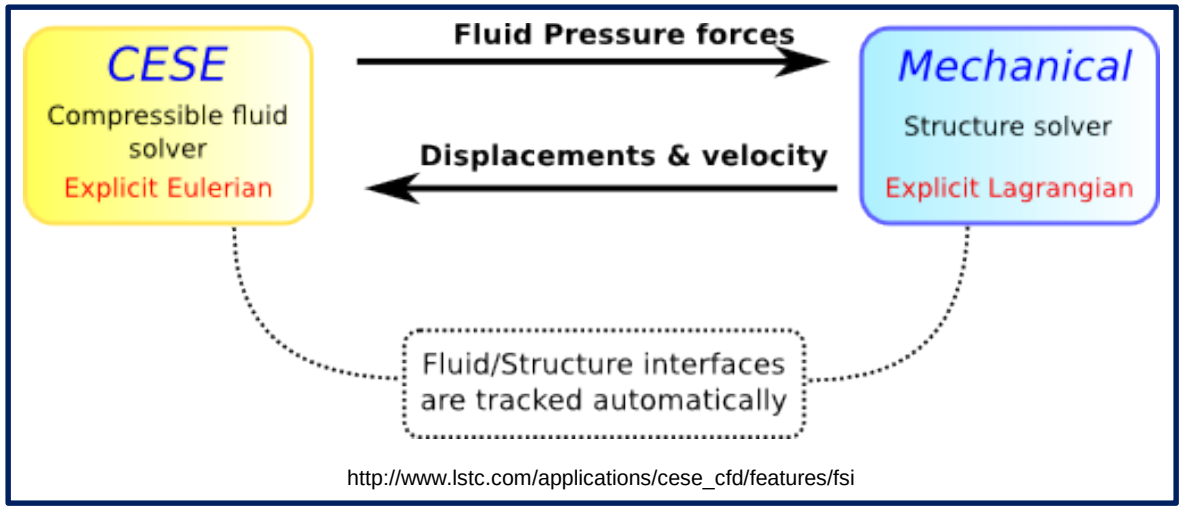
- The commercial solver LS-DYNA was used. It enables non linear analysis of the structure.
- Fabric and liner properties are defined for 4-noded shell elements with no bending stiffness (Belytschko-Tsay membrane).
- Contact definitions are enforced.
- Multiple structure loading methods are available to characterize inflation and internal pressure.

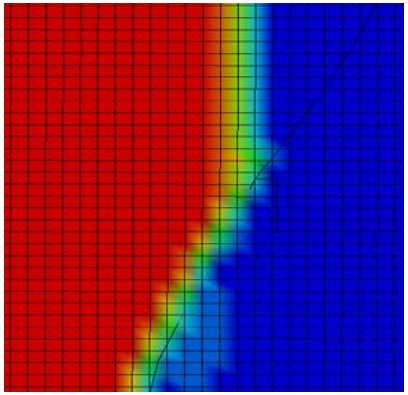


Simulation: Conservation Element / Solution Element

- The complex loading conditions given by the supersonic flow are solved using CE/SE.
- Simulations feature inviscid compressible flow and EOS is ideal gas.
- The method doesn’t impose structured mesh requirements making the study of the deflation cycle and the intricate packed-stowed configuration possible.
- A fluid mesh overlapping that of the structure with effective constrains can be used to model the fluid flow.
- The solution is explicit and it does require additional resources. Stability parameters have to be introduced (e.g. CFL).

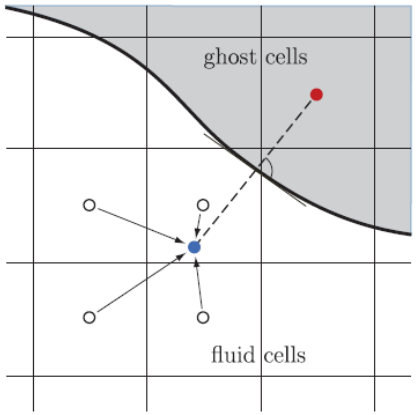
Simulation: fluid and mechanical coupling

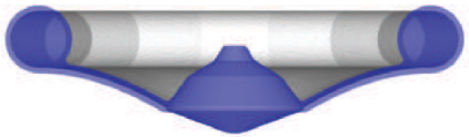




Example of fluid overlapping a structure (also an example of leakage)

- The method described corresponds to an immersed boundary type with a *direct-forcing ghost-fluid approach strategy.*
- Direct forcing methods do introduce non-smoothness across the embedded boundaries limiting the accuracy.





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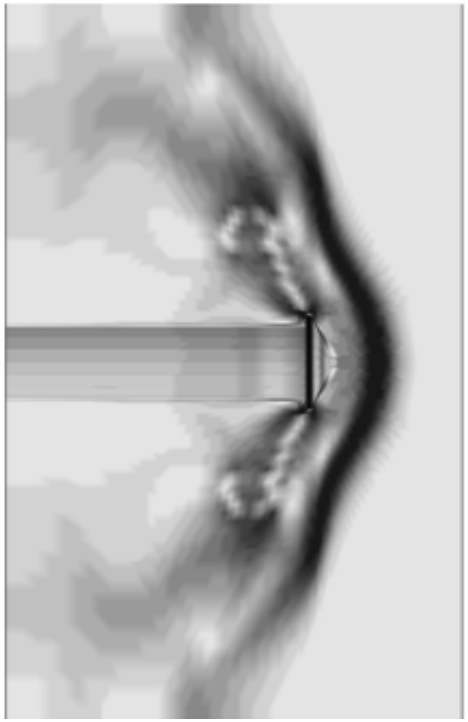
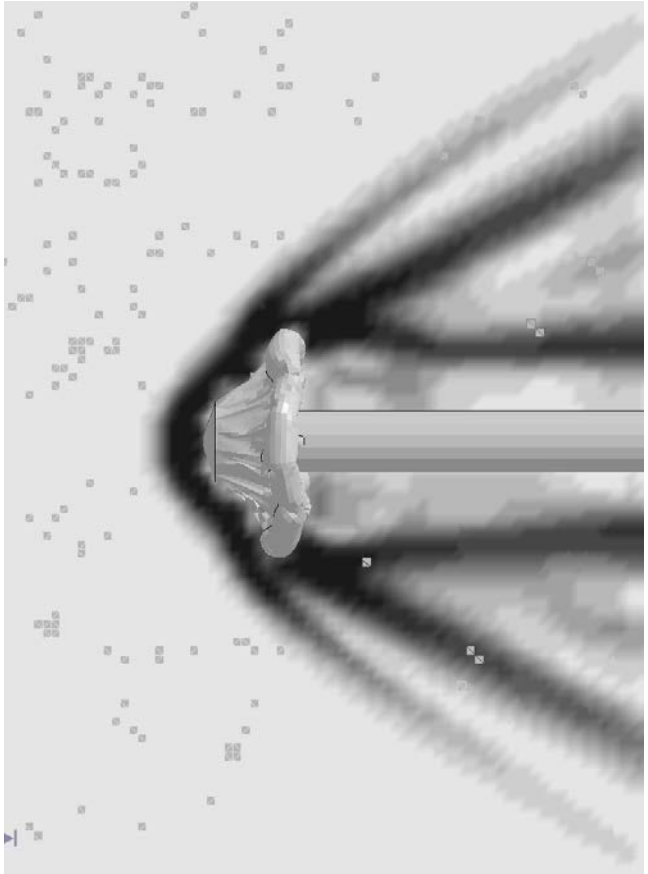
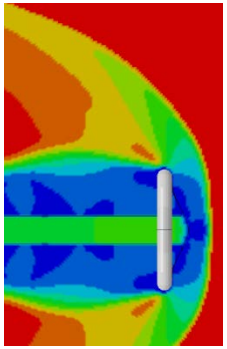
Results: shock formation and pressure distribution

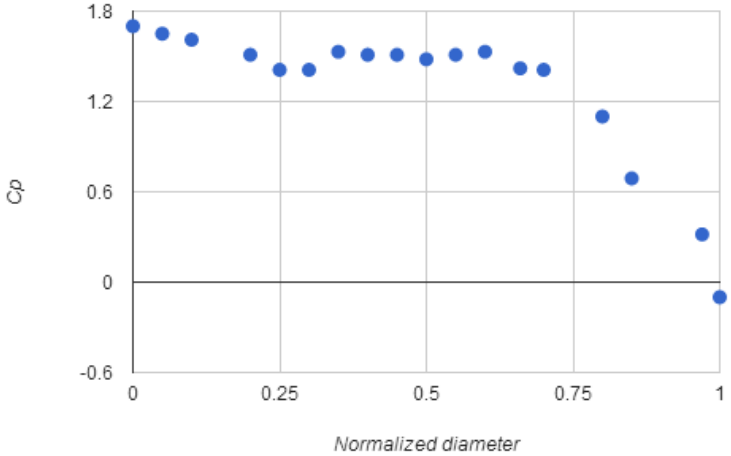


- Method is stable, predicts shock formation and position in a comparatively coarse mesh (750k elements for a 3D volume).
- Does not require remeshing to achieve solution.
- Structure boundary does not act as a perfect wall, at least from the simulations performed to date.
- Pressure distribution serves as an indication that the simulation needs work before it can be validated with existing experiments and CFD.



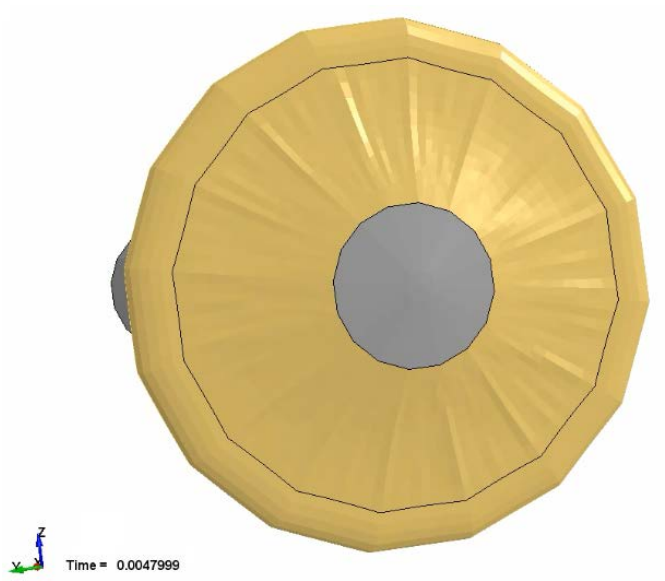


Mach does not extrapolate from 2D test cases

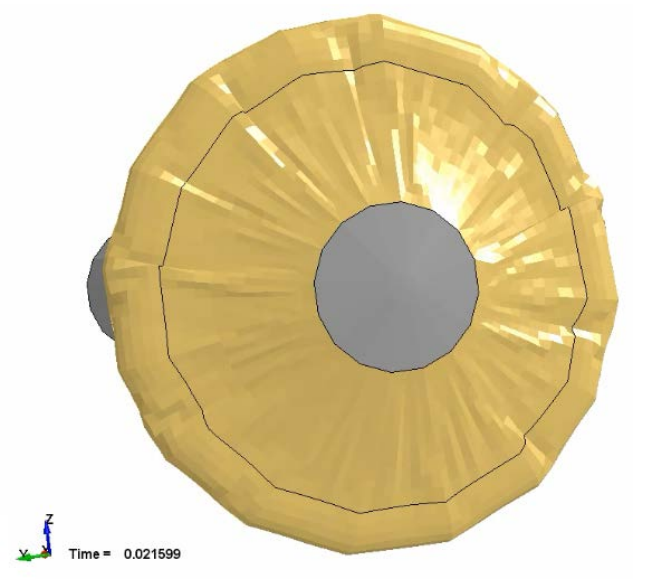


Results: deflation video

- Decreasing internal inflation pressure on the toroid, showing onset of buckling, M=2.5 Re=1.5E6 q=7kPa (150 psf) .
- Tension Cone modeled is a simplified model with reduced elements, linear elastic materials, and no reinforcements.



Realistic “scalloping” at 400 kPa (60 psi)



Non-symmetric buckling at 200 kPa(30 psi)

Summary and conclusions

- The FSI simulations presented are standalone in the sense that the loose coupling between CFD and FEM occurs within the same software.
- Usually in a FSI simulation, a mapping operation must be performed between timesteps in which the aerodynamic and structural grids exchange data.
- This allows for the usually mismatching meshes to exchange displacements and deformed geometry for remeshing, together with pressure and the resulting nodal forces.
- In our approach, the structural mesh overlaps the fluid. This simplifies problem setup time greatly but at the same time, it incorporates disadvantages such as the ability of the fluid to penetrate and pass through the structure for some mismatched meshes.

Summary and conclusions (continued)

- A working methodology was presented. The physics seem to be well represented but the we encountered a problem with the assumptions.
- Re-think approach given the resources available.
- Risk mitigation!

Acknowledgements

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Thank you – Questions?

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