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Final work : Modeling and analysis of composite pressure vessels

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Modeling and analysis of composite pressure vessels

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In recent years, the use of green fuels such as compressed natural gas or hydrogen has increased enormously, so it has become necessary to improve their storage technology: pressure vessels, which must be as cheap as possible without compromising their structural integrity.

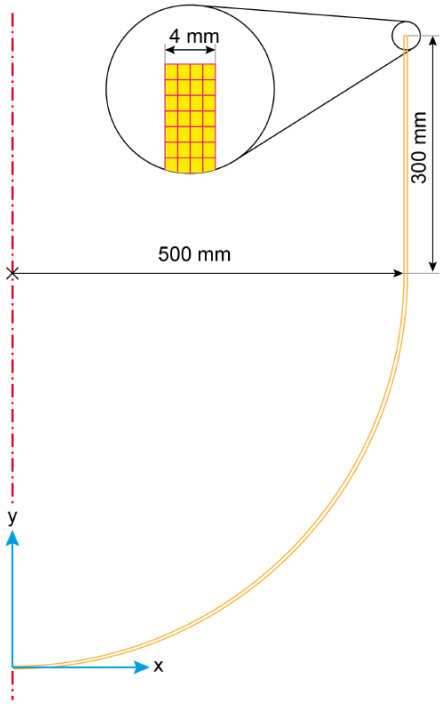
From this situation arises the need to develop models capable of faithfully predicting the behavior of the structure. Having a reliable damage and stress calculation model means being able to operate with lower safety factors, which reduces weight and costs.

During this project, the main objective will be to validate different approaches to address the problem. For this purpose, the finite element software Samcef will be used to predict damage propagation, especially in the dome region where the laminate becomes extremely complex.

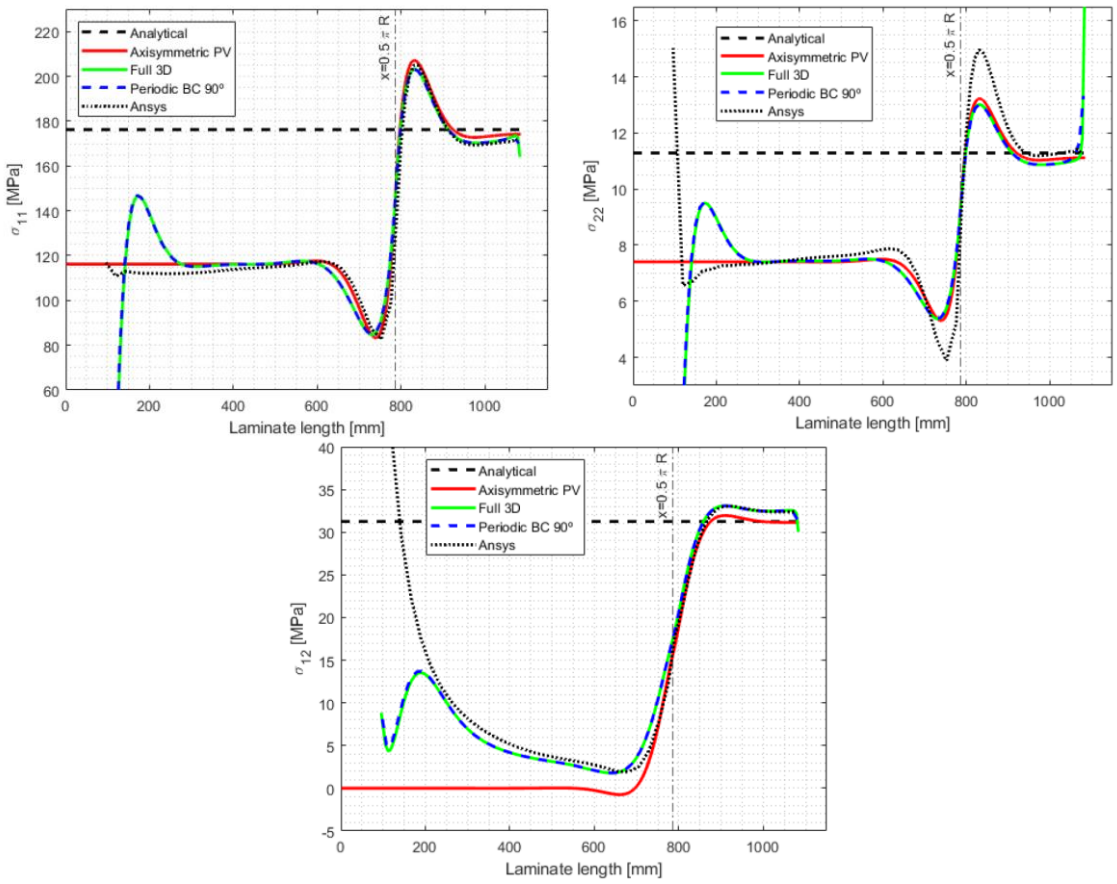
The first iterations consist of a series of 2D axisymmetric models, 3D models where a single portion of the structure is modeled by implementing periodic boundary conditions, and a full 3D model that will serve as validation. Once a reliable model with low computational cost is available, different techniques will be implemented to predict the appearance and evolution of damage in the structure, so that it will be possible to predict both the burst pressure and the failure mode of the structure. Among these techniques are the classical failure criteria (Max. Stress, Tsai-Wu and Hashin), the advanced failure material models, which make use of an iterative calculation process in order to solve the problem in discrete times and thus, evaluate the degradation of the material and the appearance of plastic strains over time. Finally, the possible onset of delaminations will also be evaluated thanks to the use of cohesive elements.

Once it has been determined in which situation it is more convenient to use one or another of the previously generated models, a real case will be studied and an attempt will be made to predict the burst pressure and the failure mode. Subsequently, the limitations of the model generated during this project will be evaluated and improvements will be proposed in order to enhance its accuracy.

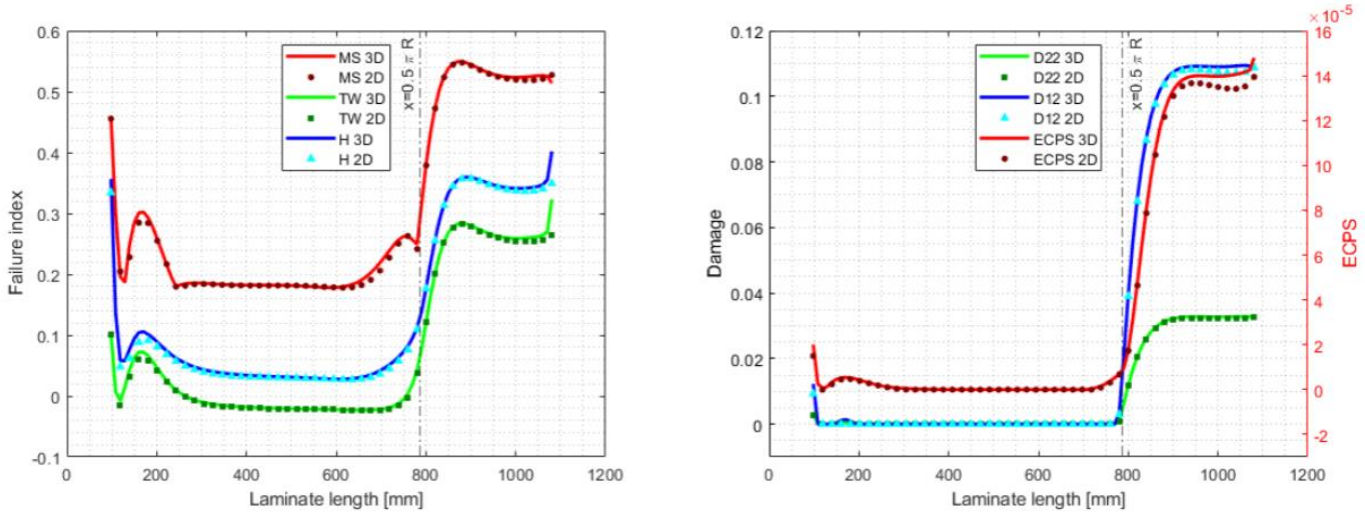
The following figures have been used throughout the report to describe the most important findings of the project:



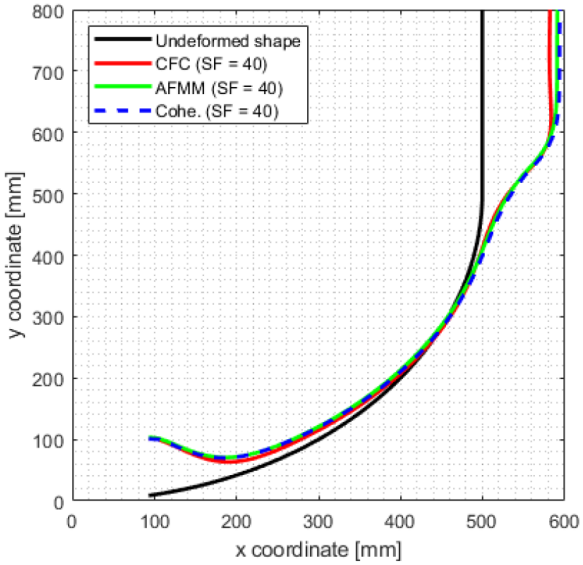
Geometry and mesh (fine) used in the 2D axisymmetric PV model.



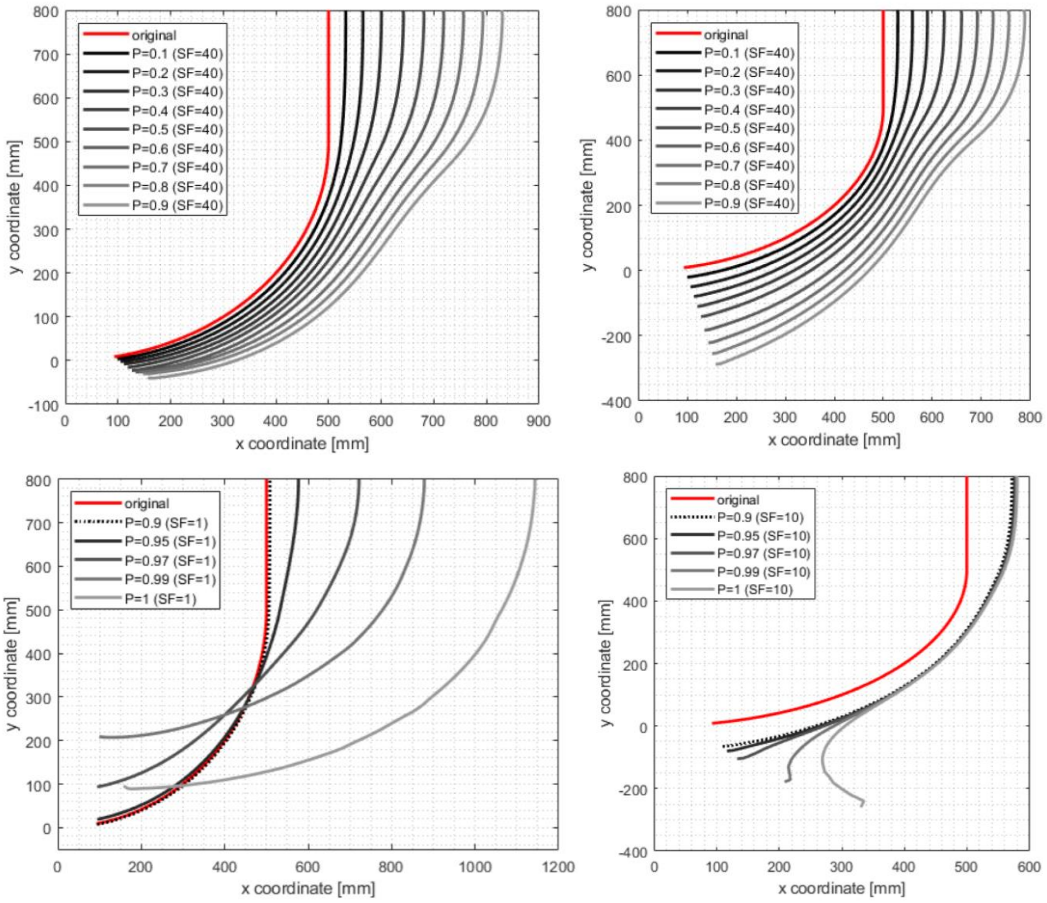
Comparison of stress distribution for different models.



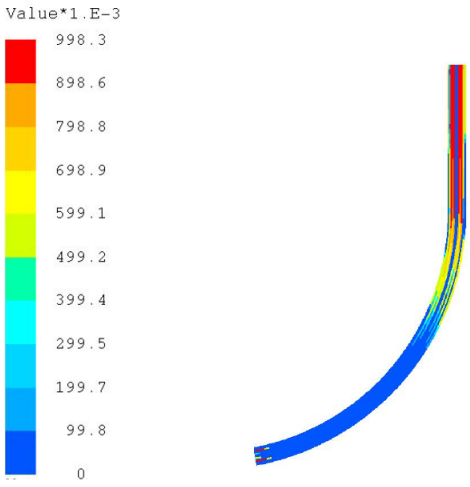
Classical failure criteria (a) and advanced failure material model (b) result comparison between 2D axisymmetric and 3D with periodic BC on ply 1.



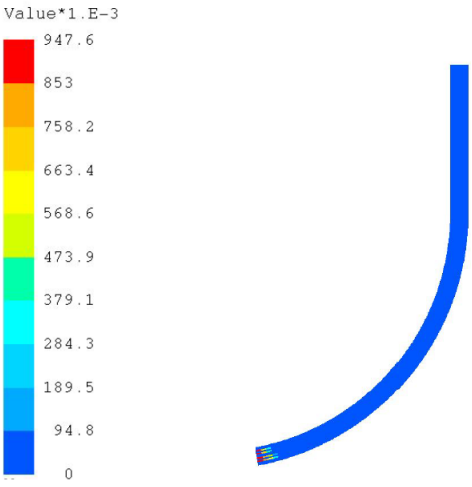
Deformation contour based on the different failure criteria.



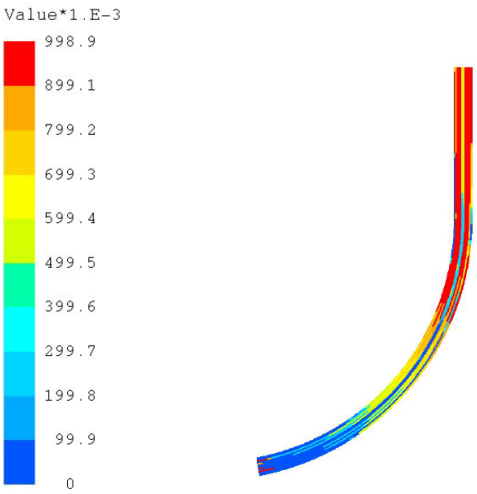
Deformed shape of the cross section. Safe laminate on the left column and unsafe laminate on the right column.



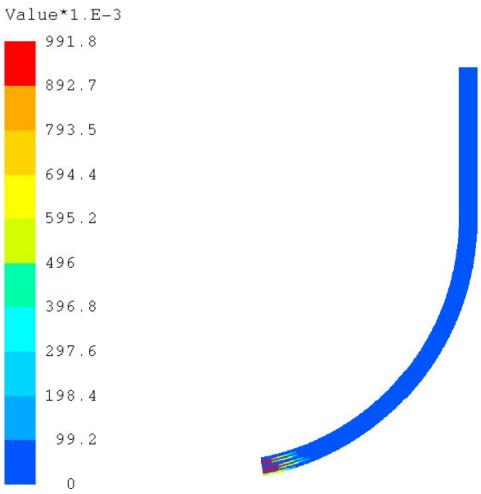
(a) SL P=0.96



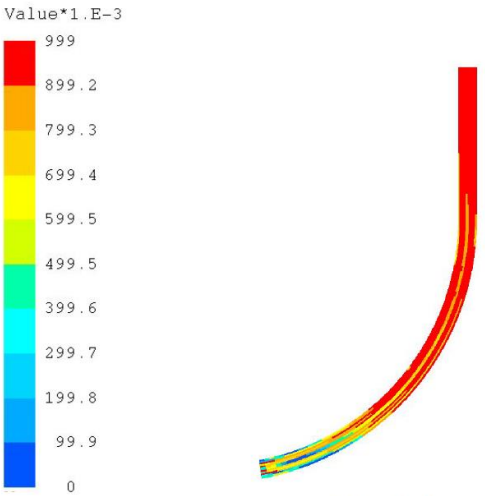
(b) USL P=0.96



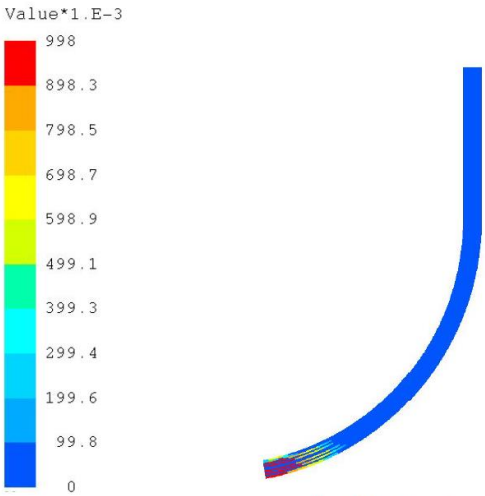
(c) SL P=0.98



(d) USL P=0.98



(e) SL P=1



(f) USL P=1

Ply damage component 11 for different load increments.