#ArchitectingAviation

Assessment and Optimization of CFRP Liquid Hydrogen Tanks

Design of Composite Tanks from Automated Fiber Placement and Winding including manufacturing constraints

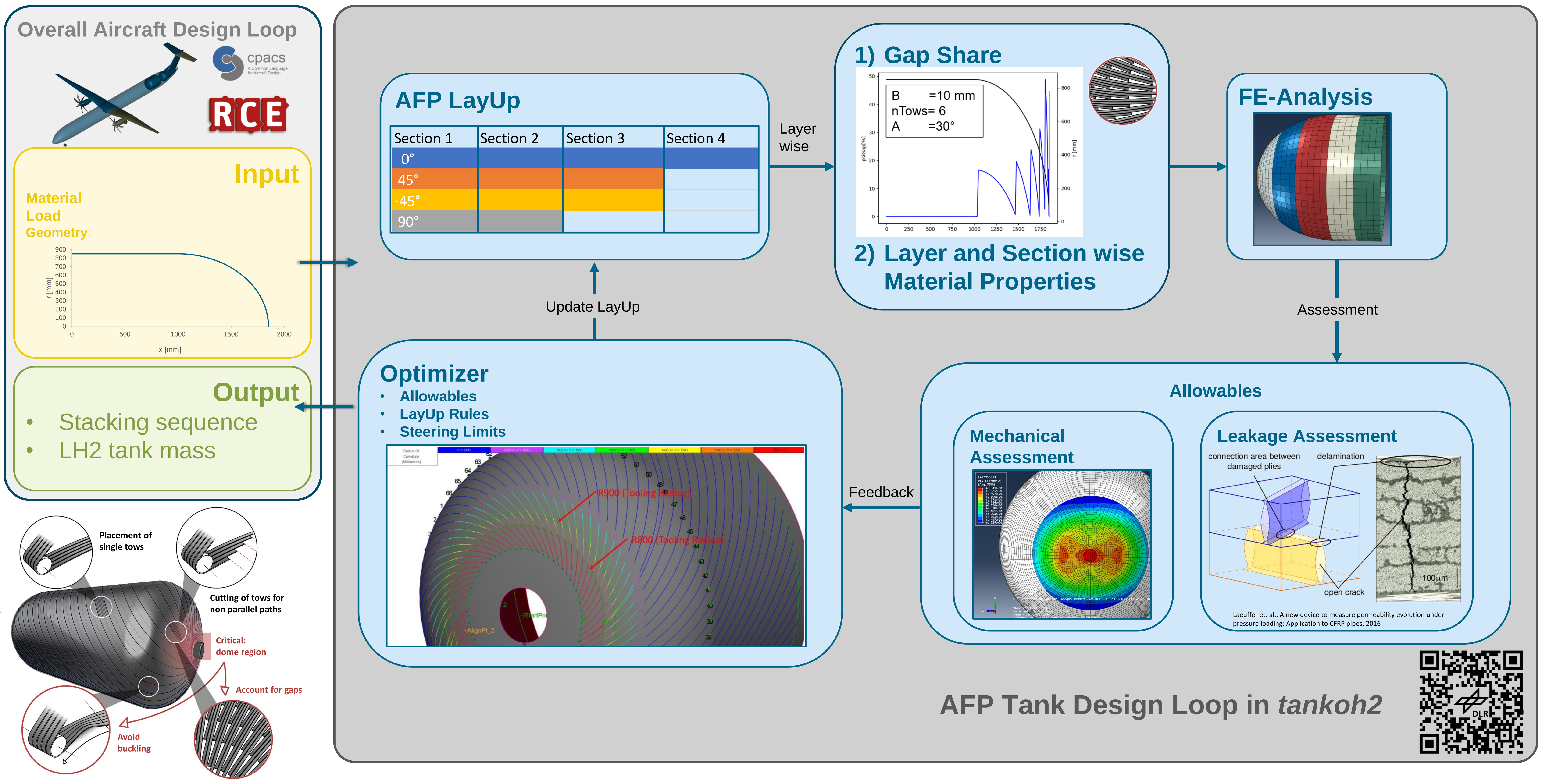

Figure 1 AFP Tank Design Loop: For modelling an AFP tank, the geometry is split into sections. Each section has its own composite layup. The design loop starts with an initial layup. Following up, the gap share due to tringle gaps is calculated for each layer. Homogenized material properties are calculated according to the gap share. An FEM-Analysis is carried out and the results are assessed from a structural and leakage perspective. The optimizer updates the layup based on the structural and leakage assessment with steering limits and layup rules as constraining factors. The AFP Design Loop requires geometric, material and load data as input and returns the mass and designed layups. The results can be saved within a CPACS file, while the design method can be provided as a service over RCE.

Modelling & Optimizing of Tanks

Liquid hydrogen (LH2) tanks made from composite materials (CFRP) promise the mass savings in skin mass by a factor of 3 compared to metal tanks. In contrast to wound CFRP vessels, tanks made from Automated Fiber Placement (AFP) enable a much higher degree of freedom of the stacking sequence, high tape placement precision, a higher deviation from the geodesic path (steering) and allow the manufacturing of segments. This way composite layers can be tailored to local mechanical and leakage allowables. On the other hand, the steering curvature must be limited in order to prevent buckling of the tape laid (steering constraints). Another feature introduced with AFP is the cutting of single tows within a tape to maintain a uniform layer thickness on the double curved tank domes. This leads to the formation of triangle gaps and hence a local stiffness and strength knockdown.

To account for the huge design space, steering constraints and triangle gaps, the software tankoh2 was developed. It automatically creates FEM tank models taking gaps into account by means of homogenization approaches. Additionally, layer angles can be defined by location variable angle settings or by selecting a certain layup strategy such as constant angles or geodesic layup.

In the future tankoh2 will be extended with an optimizer to close the design loop. The optimizer will adapt the layup according to the results of the structural and leakage assessment to reduce weight while being constrained by the steering and other manufacturing limits.

Leakage

Matrix cracking is the predominant mode of failure which occurs in CFRP. A network of interconnected matrix cracks in the layers of a LH2 tank will lead to leakage, which eventually leads to the loss of vacuum between the inner and outer vessel. Both analytical and numerical models are built with the aim to predict leakage onset as design allowable.

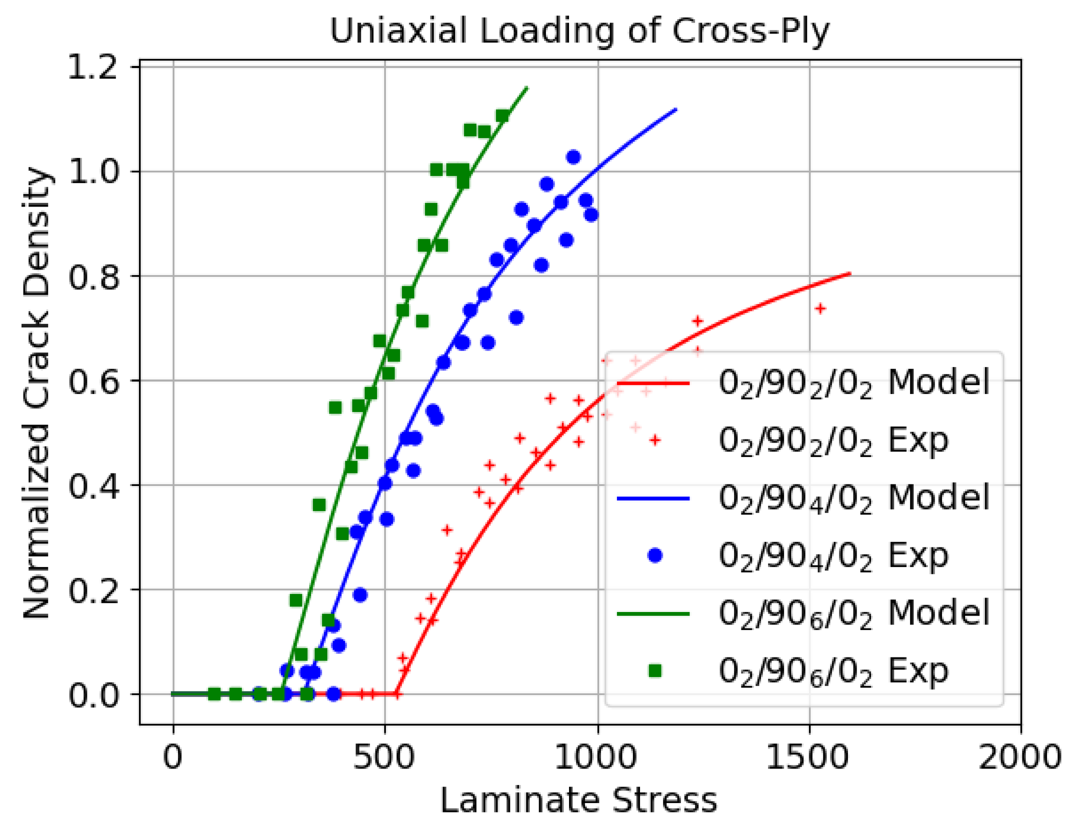

Figure 2: Analytical prediction of crack density in 90° plies. The leakage and crack onset highly depends on stacking sequence.

Key Take-Aways

Features

- Automated CGH2 and LH2 tank mass assessment available
- AFP tank analyses considers manufacturing constraints

Challenges

- *High degree of freedom: stacking cutouts, thermo-mechanical coupling*
- *Leakage allowable depends on loading, stacking sequence and fracture mechanical properties*

Outlook

- Analytical leakage criterion constitutes a new allowable
- Optimization procedure of AFP tanks

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