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Hydrogen Power: The Use of Filament-Wound Carbon Composite Pressure Vessels in small scale Ammonia Storage.

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Introduction

With increasingly Stricter regulations on automobiles being regularly introduced, there is clear incentive to investigate into the use of cleaner, more efficient modes of transportation.

Hydrogen fuel is one possibility, producing no instantons pollutants when used within a fuel cell. However, hydrogen has its drawbacks. It is expensive to manufacture and uses natural gas and CO2 during reformation.

Ammonia, which already has a large dedicated transport network, could be the answer too these problems.

Project Aims

The use of Ammonia comes with its own problems however, it is a corrosive alkali, and is highly toxic to wildlife and humans, therefore the aims of this project are;

- To Investigate the use of Hydrogen Fuel for the applied design of a storage tank, that holds true to a thorough research informed specification.
- To Evaluate the performance of such a design, through Simulated Software and mathematical analysis, to conclude the performance characteristics necessary for the part to be fully functional.

Methodology

It was decided that the design would incorporate an aluminium inner tank to allow for additional fixings, with a filament wound composite wrap on the exterior.

Tests were conducted through the use of Solidworks Design, and Genesis FE software, alongside mathematical analysis to provide model verification.

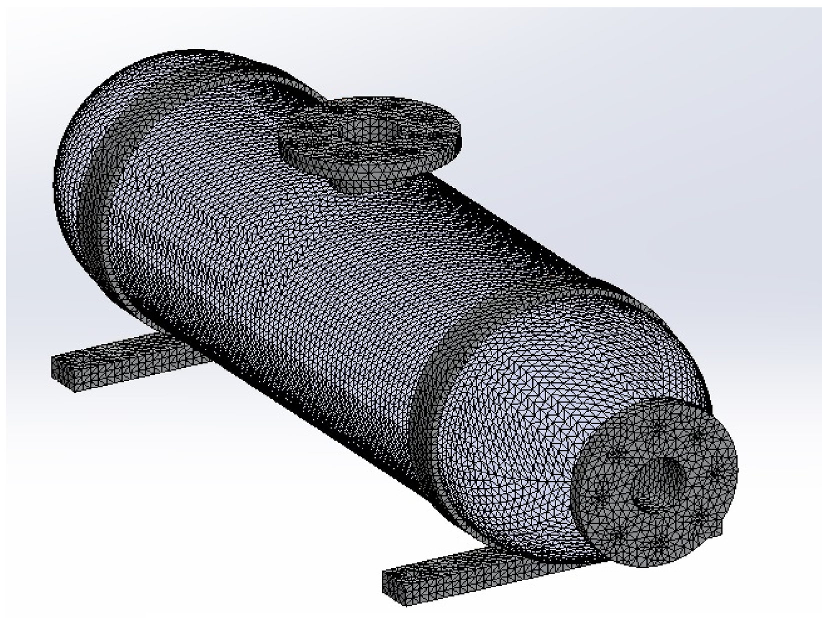

Fig 1: Meshed final design of the fuel Tank

Mathematical analysis was conducted through the use of Classical Laminate Theory [1], to find the apparent principle stresses, these were then inputted into the Tsai Wu failure Criterion [2] for the laminate failure index, and the Von Mises Yield Criterion [3] for the aluminium failure index.

$$H_1\sigma_1 + H_2\sigma_2 + H_6\tau_{12} + H_{11}\sigma_1^2 + H_{22}\sigma_2^2 + H_{66}\tau_{12}^2 + 2H_{12}\sigma_1\sigma_2 < 1 \quad (2)$$

$$UTS \geq \sqrt{(\sigma_H^2 - (\sigma_H * \sigma_L) + \sigma_L^2} \quad (3)$$

Tests were conducted across 4 runs, using the laminate, the inner tube, the combined sections, and the final design.

Results

The laminate tests were conducted at 4 thickness: 2.4, 3.6, 4.8, and 6mm, and at all angular lays from 0 up to 90 degrees.

It was decided that the 3.6mm wall would provide designed safety factors of 2.5, whilst also reducing excessive use of materials.

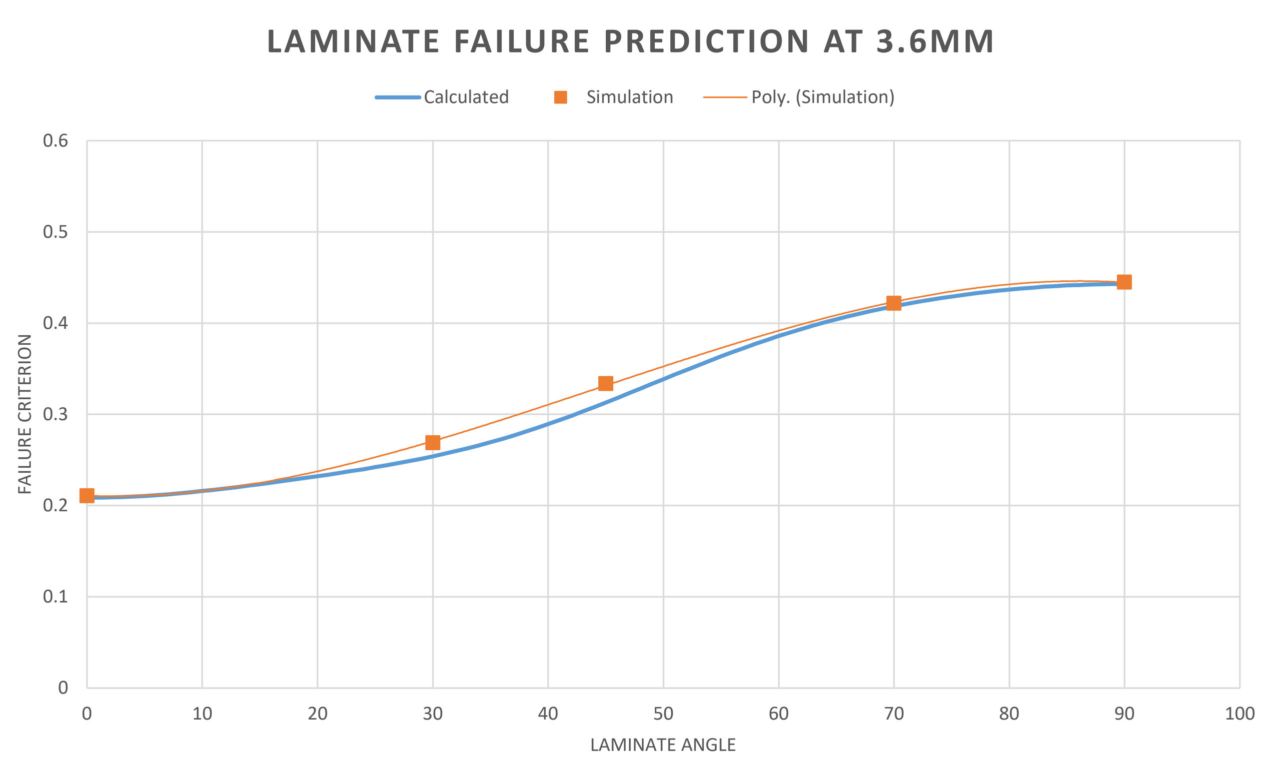

Fig 2: Laminate Failure at 3.6mm

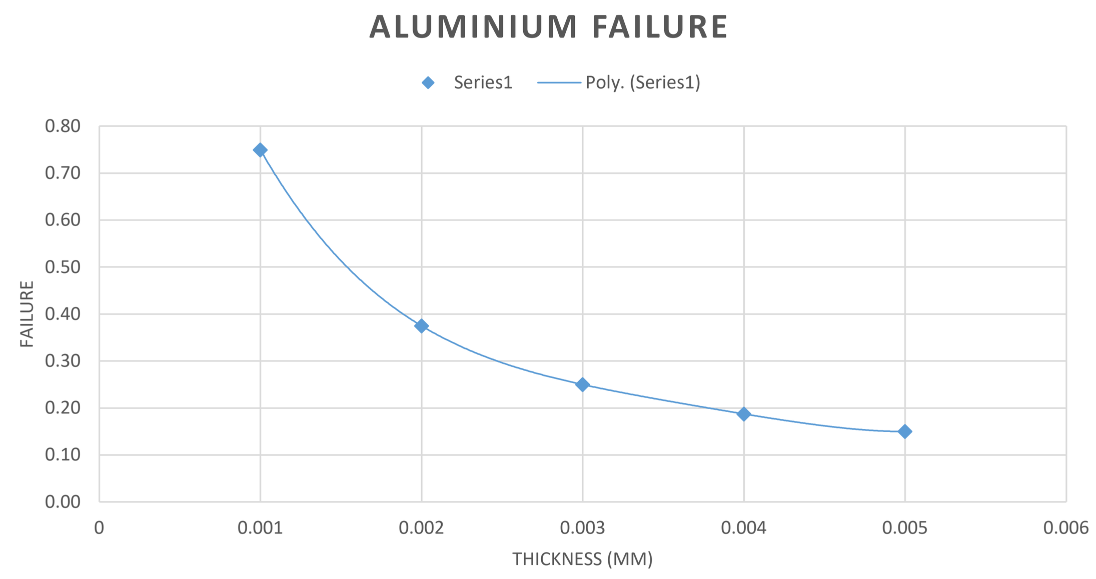

Fig 3: Aluminium Failure Predictions

It was decided that the combined test would include a laminate thickness of 3.6mm at 30 deg, with an aluminium liner of 3mm.

Table 1: combined Failure Predictions

property	value
Aluminium Thickness (mm)	3
Wrap Thickness (mm)	3.6
Angle (deg)	30
Failure (CF) [sim]	0.0536
Failure (CF) [calc]	0.0525
error %	2.05%
von mises [sim]	2.01E+07
Aluminium failure	0.155

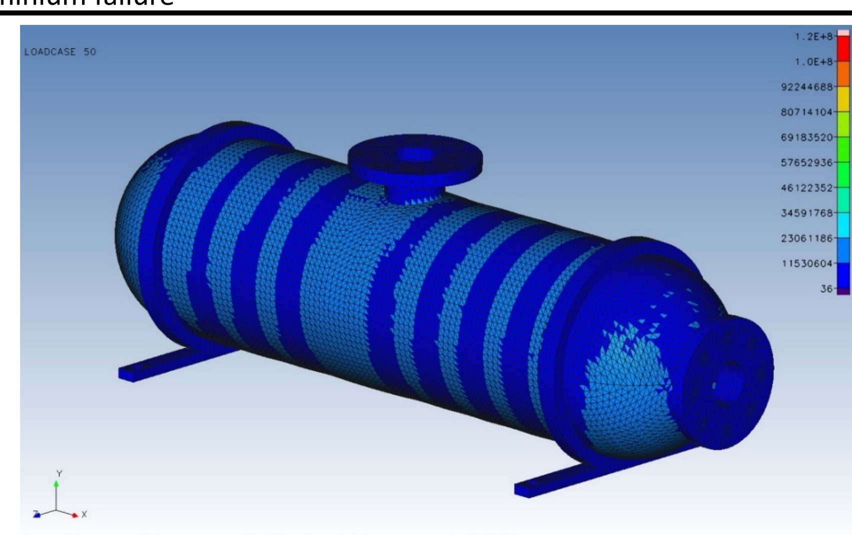

Fig 4: Final Design Failure Distribution

Conclusions

Ammonia as a fuel:

- • Ammonia is viable option for hydrogen-based fuelling, provided strict safety measures and controls are imposed.

The Design was found to operate within safety protocols, with good agreement between mathematical analysis and FEA:

- The final design was found to have safety factors in the composite layer ranging between 16.95 and 47.62, with the aluminium exhibiting SF's in the range of 6.41 to 8.77.

References

(1) (2) Herakovich, C. T., 1998. Mechanics of Fibrous Composites. Virginia: University of Virginia.
(3) Meyers, M. & Chawla, K., 2009. Mechanical Behaviour of Materials. 2nd ed. New York: Cambridge University Press.