Geodome Ltd; Cost effective rocket propellant tanks

Executive Summary

Geodome Ltd has been engaged in R&D of light-weight and cost-effective cryogenic vessels of volumes ranging from 3.2lt to 3200lt and subject to working pressures of 50Bar and 0.3Bar, respectively.

In the course of this limited R&D effort, several types of vessels have been modelled and investigated, including steel vessels, a composite reinforced polyethylene vessel and a composite reinforced stainless steel vessel.

The principal results of this work have yielded the following conclusions:

a) Experimental evidence gained in this research effort, suggests that it should be possible to utilise a composite casement as a light-weight means for liner reinforcement. Such reinforcement must be able to expand at a different rate from the steel liner that it encloses and enable axial liner expansion, due to dissimilar rates of expansion of different materials when subjected to high pressures and exposure to low temperatures of cryogenic material.

b) In order to prevent failure due to inter-laminar shear between liner and composite casement, due to different thermal and mechanical properties at Cryogenic temperatures, it was found that a 'slip-membrane', placed between GFC casement and the Stainless Steel liner of a test vessel, enabled relative movement that lead to enhanced structural capacity.

c) Since the principal failure mode is due to 'Hoop-stresses' and the domed ends are inherently stiffer than the main cylindrical body, the composite casement should cover only the cylindrical section of the vessel in order to allow for axial movement.

d) FE simulation results show that it is possible to achieve a theoretical net structural weight of 118Kg of CFC reinforced SS vessel representing an inert mass fraction of 0.03 with a 3200 litre LOX vessel weighing 3651Kg. For comparison, the feasible inert mass fraction (ratio of structure to propellant) needs to be of the order of 0.12-0.14 for launch vehicle applications. These preliminary results show a potential vessel weight reduction of some 73%. (Based on weight of a 3.2m3 LOX vessel of some 438Kg and a LOX density of 1141Kg/m3).

e) Computational and experimental results suggest that it is possible to use commercially available Stainless Steel (SS 316) vessels with a composite reinforcement casement for the intended application(s).

f) Initial FE modelling has demonstrated that the most structurally effective shape of a composite pressure vessel has an elliptical form. Such form leads to minimal weight and reduced stress concentration, compared to a cylindrical vessel with hemispherical or elliptic ends.

g) Comparative analysis results between vessels of different form and material, yielded the following:

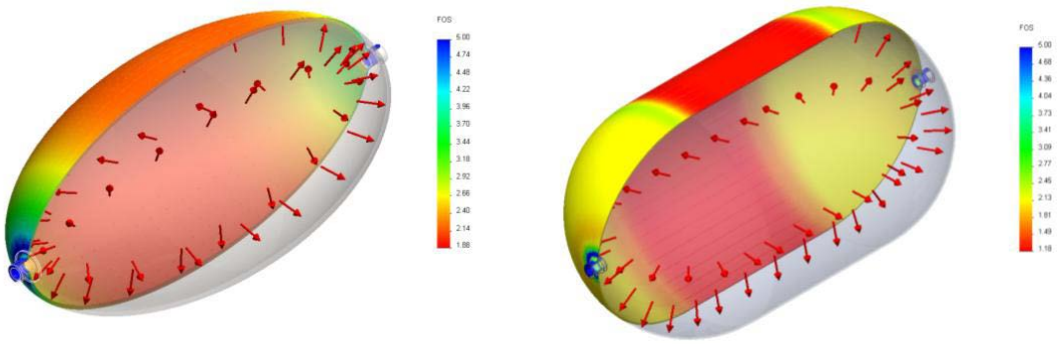
a. Form has little effect on structural weight at low pressure. At higher pressure, form becomes more dominant and helps reduce weight.

b. The Elliptical vessel offer best structural capacity and weight saving potential but does not offer significant weight savings at low internal pressure.

c. Stainless steel vessels are only slightly heavier than elliptical vessels at low pressures and are therefore more cost efficient than composite equivalent.

h) Results from a limited literature search have identified a paper (AIAA-97-1107) that claims that a stand-alone composite shell can be used for cryogenic space applications without the need for a liner. Such a vessel could benefit from an internal barrier that could be sprayed on internally in order to improve protection of the resin system.

Results presented in this report should be viewed with caution and should only be considered as potential and initial trend indicators. Therefore, further work must be done if the new design concepts are to be implemented in further development of a launch vehicle vessel.



Factor of Safety distribution due to Internal Pressure of 75 Bar applied to Composite Elliptical Vessel and Stainless Steel Cylindrical vessel, showing superior structural utilisation of elliptical vessel.