Concentric Cryogenic Tanks, per se, are of Questionable Utility

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Abstract - Differential thermal expansion between cryogenic tanks must in some means be accommodated by the intra-tank structural support, which implies some degree of "springiness" between the tanks. As the individual tanks empty, the remaining masses will tune to various frequencies that may have harmonics.

In response to Rhodes (2022), I think that thermal issues will require insulation between the LOX and LH2 tanks. With concentric tanks, leak detection in the intra-tank annulus will be problematic.

The large LH2 tank will now be required to be of a toroidal configuration, i.e., an extra tank wall in an already large tank, adds weight and cost.

The whole idea of using LOX/LH2 as the propellant for low cost to LEO is questionable. It implies pump-fed engines, since it is unlikely that LH2 would be pressure-fed at high thrust levels at sea level. Pump-fed engines are not, and never will be, as inexpensive as pressure-fed engines of the same thrust level. Pump-fed engines influence the design of the entire vehicle as well as the complete launch operations as well as the modes available for recovery and reuse. Pump-fed engines are used on vehicles with low pressure propellant tanks. Tank weight becomes a premium, and tanks are made as thin-walled as practical, within the tank pressure requirements/ constraints of pump cavitation. Thin-walled tanks are not physically robust, such as would be desired for recovery and reuse. LOX/LH2 Propellants are therefore not ideal for low cost to LEO propulsion systems.

The Space Shuttle is an example of using LOX/LH2, with the SSME engines. The SSME propulsion system used a Part-Flow Staged Combustion (PFSC) engine cycle. At a nominal mixture ratio of 6, the LH2 was only 1/6th the total engine flow. However, it was used in the pre-burner to drive the turbopumps. The low mass flow available for turbine drive required the turbopumps to be designed up to turbine thermal limits, bearing DN limits, impeller tip speed limits, inter-propellant shaft seals, shaft critical speed limits and several other critical design choices. Operating life of the SSME TPAs was limited and extensive TPA inspection and refurbishment was required between every mission.

A study performed by Cryomec of Anaheim, CA, investigated using the entire SSME propellant flow to drive the TPAs. An oxygen-rich pre-burner was used to drive the LOX TPA, and a Hydrogen-rich pre-burner was used to drive the LH2 TPA. Since the entire propellant flow was used as turbine drive fluid, the cycle was termed the Full Flow Staged Combustion (FFSC) cycle and has been so known as a standard acronym since. The FFSC cycle increased available turbine drive gas flow by a factor of 6. The FFSC cycle offers a plethora of benefits. Cool turbine temperatures, reduced shaft speeds, reduced propellant tank pressures, elimination of inter-propellant shaft seals, elimination of bearings in low pressure LOX, lower bearing DNs, elimination of the shaft seal helium purge, avoidance of hydrogen embrittlement issues, elimination of inter-propellant heat exchangers. The list continues and is lengthy. Unfortunately, NASA has eschewed the FFSC cycle in its use of basically SSME engines for the STS, and continues with the SSME in largely its original configuration, and serious drawbacks. It continues to be an extremely expensive engine to build and fly. Also, it imposes its imitations on the vehicle as

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well as on the launch support systems. These limitations show up in the form of significant, (and unnecessary) costs.

The benefit noted regarding shortening vehicle length is moot if one did not use LH2 that requires gigantic tanks in the first place. This once again harkens back to the misguided view that Isp performance outweighs logic in pursuit of low cost to LEO.

Literature Cited

Rhodes, Russel, 2022. The Benefits of a Rocket Vehicle Concentric Cryogenic Tank Design. SEVO: Brief Communications 12:1.