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ATPV

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Acoustically Transparent Pressure Vessel

Introduction

Who: Ultra Electronics Maritime Systems Inc. is a defense contractor which specializes in ocean based military threat detection. Ultra's products include sonar systems, underwater sensors and sonobuoys.

What: Ultra Electronics' Active ring-shaped sonar transducers.

Why: Sonar transducers are designed for deep sea applications, characterized by an environment of high pressure. Ultra must travel off site to test at a lake to simulate ocean pressures.

How: By simulating deep sea pressure using a pressure vessel, full power projector testing can be conducted. If the vessel is constructed from acoustically transparent materials, projector output can be recorded outside the vessel.

Design Considerations

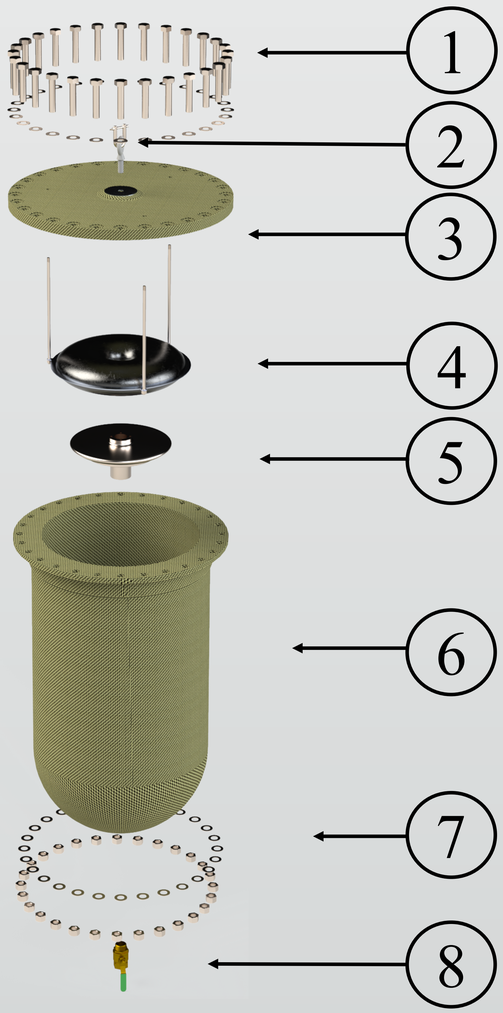
Acoustic Performance vs Mechanical Performance
Design must maximize acoustic transparency while maintaining a total (static and dynamic) pressure of up to 350 psi. Acoustic transparency is inversely proportional to mechanical strength. A balance of these factors was desired.

Geometric Size
Design must house Ultra's largest Free-Flooded Ring sonar projector measuring 28" in diameter with a mass of 207kg.

Safety
Vessel shall conform to ASME Section X.

Numerical Performance Estimations
Design includes Acoustic Energy Model, Acoustic Spherical Wave Pressure Model, Structural Static FEM Model and Structural Dynamic FEM Model.

Design Overview



Number	Component
1	Retaining Bolts
2	Eye-Bolt
3	Blind Flange
4	Projector and Mounting
5	Polar Boss Opening
6	Fiber Reinforced Plastic (FRP) Vessel Cylinder
7	Washers and Nuts
8	Drain Valve

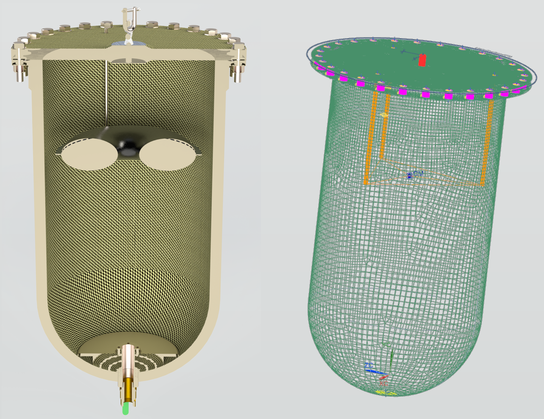


Figure Left: Pressure Vessel, assembled Section view.
Figure Right: Vessel FEM Mesh for Mechanical Performance predictions.

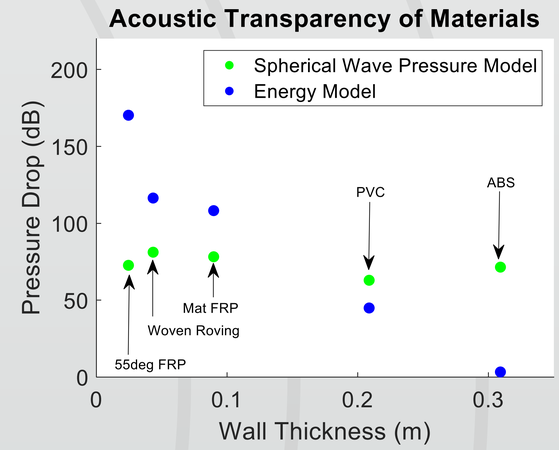
Filament Wound Construction
The Vessel Applies +/- 55 Degree filament wound composite construction. 55 Degree winding angles provide the vessel with a hoop strength 2 times that of the axial strength, which corresponds to basic equations where hoop stress is 2 times greater than axial stress for constant diameter and thickness.

Circles in background are 1:1 with vessel from smallest to largest
- Inner Vessel Wall
- Outer Vessel Wall
- Flange Diameter

Figure: Filament Winding Process [1]

Results & Conclusions

Acoustic Performance:
Figure shows acoustic transparency and required wall thickness predictions. 55° FRP chosen for vessel. Spherical model produces more accurate predictions.



Mechanical Performance:
Figure describes resonant response characteristics of pressure vessel from excitation frequencies over the range of sonar projector operation.

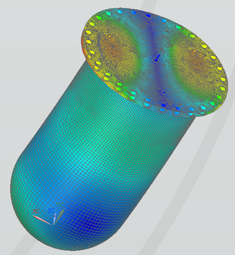
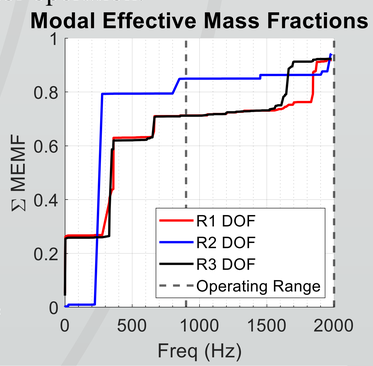


Figure: Strongest Mode Shape (253 Hz)



Future Recommendations:
- Add damping to Acoustic and FEM Models.
- Test vessel empirically according to ASME Section X Article RT-223.

References
- [1] Zu. L, Xu. H & Wang. H. (2019). Design and Analysis of Filament-Wound Composite Pressure Vessels based on Non-Geodesic Winding. *Composite Structures. 207()*.41-52.

Acknowledgements
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