DSEND Additively Manufactured Dive Suit Piece

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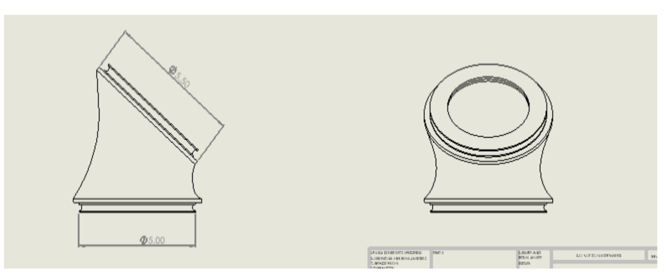
USNA Engineering Capstone Design Project 2023-2024

Mission: Assist in the development of the DSEND 1 atm dive suit by producing an additively manufactured wrist piece.

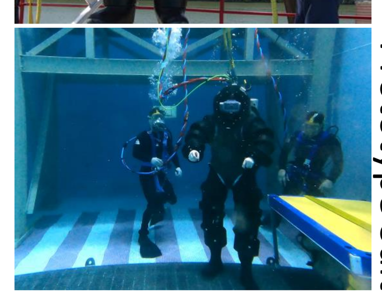
Why?

The Navy needs a lightweight dive suit that eliminates the need for decompression stops during operations while providing dexterity to the diver.



Conventional Wetsuit

ADS 2000



DSEND Prototype Suit

Advantages of AM Dive Suits:
- Quick to produce
- Custom fit for the diver

Considerations:
- Strength at Depth
- Corrosion resistance
- Compatibility with rest of the suit

Testing

Stage 1 Testing - Ensuring a quality seal/assembly

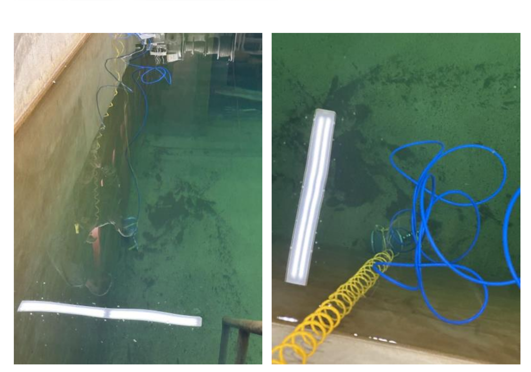
Goal: Ensure that the test assembly is capable of holding air in, and water out, when submerged at high pressures.
- Internal vacuum test
- Internal vacuum + shallow submergence

Stage 2 Testing - Material Performance Analysis

Goal: Examine and note any material changes of an AM resin print after long term submersion in water. Note particularly any corrosion, or water absorption by the AM resin.
- Several week submersion of a printed resin cylinder in a saltwater environment test tank

Stage 3 Testing - Seal Duration Analysis

Goal: Ensure that the AM wrist piece is strong enough to withstand higher pressure environments and maintain an internal vacuum for extended periods of time.



Initial Results

Stage 1: Seal/Assembly Testing

Test Type	Depth (ft)	Pressure Held (inHg)	Duration	Notes
1.1 Internal Vacuum	N/A	- 20.5	60 min	Initial vacuum test
1.2 Internal Vacuum + submergence	4	- 24.7	20 min	Preliminary submergence test

Stage 2: Material Performance Test

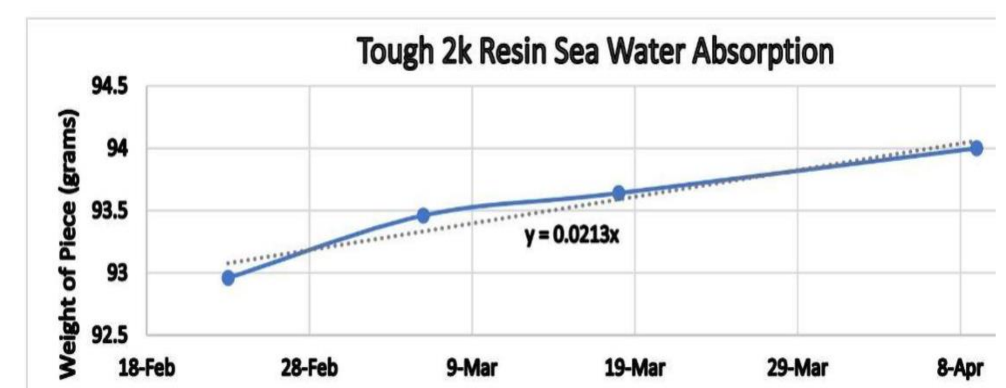
Test Cylinder Characteristics

Tough 2K density: 0.04 lb/in^3

Volume: 4.71 in^3

Surface Area: 23.56 in^2

Absorption (in grams per day, per in^2) = 0.000904

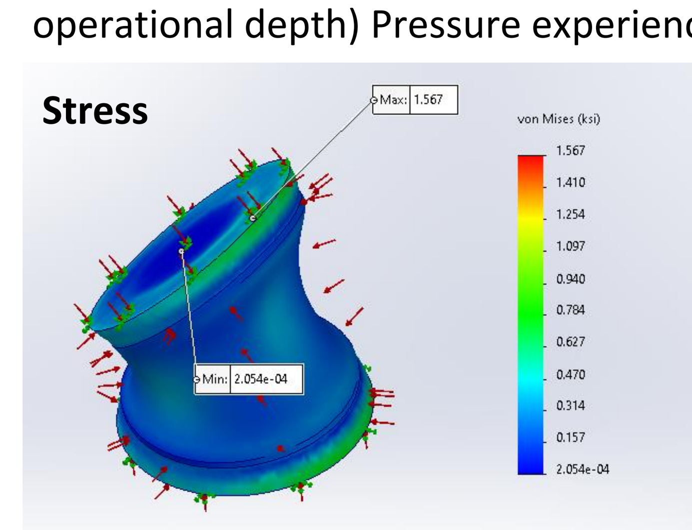


Stage 3: Seal Duration Tests

Test Type	Depth (ft)	Pressure Held (inHg)	Duration	Notes
3.0 Internal Vacuum + submergence	16	-18.5	24 hrs	Slight decrease in internal vacuum
3.0 Internal Vacuum	N/A	-14.5	12 days	Continuation of Test 3.0 in air

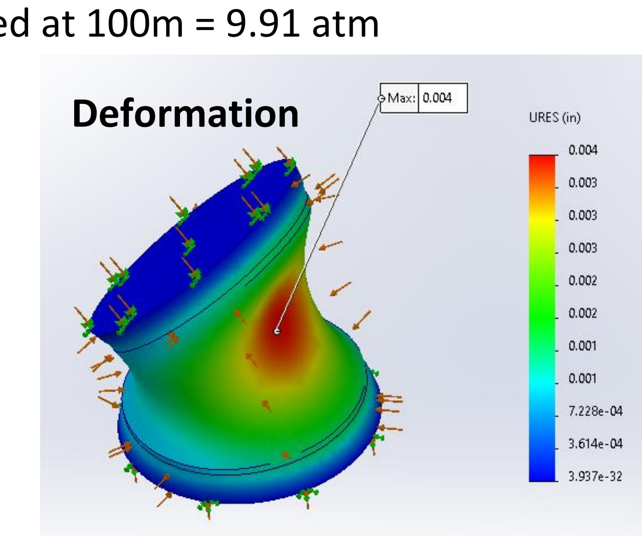
Solidworks FEA

Simulated depth of submergence = 100m of saltwater (considered a deep, operational depth) Pressure experienced at 100m = 9.91 atm



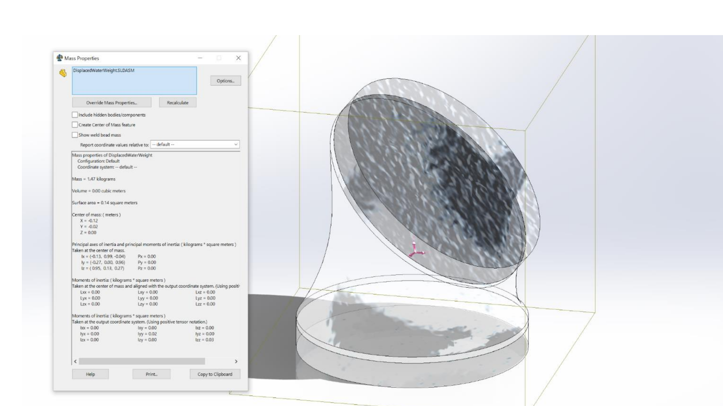
Maximum Stress is experienced on the outer edges of the shell caps

Max Stress = 1.57 ksi



Maximum deformation experienced on the outer edges of the shell caps

Max Deformation = 0.004 in



Solidworks Buoyancy Analysis

Solidworks modeling was used to estimate buoyancy by comparing the weight of displaced water to the weight of the piece itself

Displaced water weight = 3.24 lbs

Metal Coating (RePliForm Labs)

Composition: ⅓ Cu, ⅓ Ductile Ni, ⅓ Hard Ni

Why?
- Adds strength to the suit
- Limits material off-gassing considerations
- Helps to maintain a slightly negative buoyancy (desirable for suit ergonomics)

Conclusions

- **Through the use of additive manufacturing, the Navy will likely soon have a viable method to inexpensively and rapidly produce adaptable 1 atm suits for its diving teams around the world.**
- Our testing shows that additive materials can be strong enough to endure exposure to high pressures at depth, while undergoing little to no material changes.

Future Work

- AM Produced suit at large
- Integration with adjoining suit pieces
- Testing of different AM materials, and at further depths
- Testing of the long term effects of seawater on AM materials

Acknowledgements

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Special thanks to all of our supporters who made this project possible

RLP

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