Z-2 Suit Support Stand &
MKIII Suit Center of Gravity Test

Tuan Nguyen, E.I.T.

Senior Mechanical Engineering Student | California State University, Long Beach


Introduction

NASA’s next generation spacesuits are the Z-series suits, made for a range of possible exploration missions in the near future. The prototype Z-2 suit has been developed and assembled to incorporate new technologies that has never been utilized before in the Apollo suits and the Extravehicular Mobility Unit (EMU). NASA engineers tested the Z-1 suit extensively in order to develop design requirements for the new Z-2 suit. As of the end of 2014, NASA will be receiving the new Z-2 suit to perform more testing and to further develop the new technologies of the suit. In order to do so, a suit support stand will be designed and fabricated to support the Z-2 suit during maintenance, sizing, and structural leakage testing. The Z-2 Suit Support Stand (225SS) will be utilized for these purposes in the early testing stages of the Z-2 suit.

Design Parameters

Using Creo Parametric, the support stand is designed and fabricated using 80/20 Inc. t-slot profiles as the main support structure. T-slot framing is more versatile, efficient, and economical than welding. In addition, 4-slotted frames are easily modified and disassembled to tailor to the user’s needs. The design requirements of the Z-2 suit support stand are as follows:

- Support 2x the total weight of the Z-2 suit (340 lbs)
- No interference with umbilical routing
- Ability to attach & detach casters for transport and testing
- Accessibility to Z-2 suit components for test technicians
- Other features that will facilitate test technicians such as tool holders, push handles, etc.

Stress Analysis

One part of the 225SS is the latch mechanism interface between the suit and the stand. The mechanism consists of the latch mount and the suit latch. The suit “sits” on the latch and is locked in place with pins. It is important to consider the stress and displacement produced by the weight of the suit. The latch mechanism interface is designed by Mr. Charles Alton for the Z-2 donning stand.

Results

Stress analysis shows that the stand interface will be able to support the weight of the suit. Deflection analysis of the column supports that will mainly experience the weight of suit shows that the beams will deflect 0.0164 in. with a moment of 680 lbs-in. Therefore, it is important to consider the center of gravity (CG) of a spacesuit when developing design requirements for the next generation of spacesuits. The closer the CG of the suit is to the CG of the crew member, the easier it will be for the crew member to balance when performing Extravehicular Activities (EVA). This in turn will conserve more energy that the crew member can use for mission tasks or perform longer EVAs.

Center of Gravity Test

MKIII Suit Center of Gravity Test

It is important to consider the center of gravity (CG) of a spacesuit when developing design requirements for the next generation of spacesuits. The closer the CG of the suit is to the CG of the crew member, the easier it will be for the crew member to balance when performing Extravehicular Activities (EVA). This in turn will conserve more energy that the crew member can use for mission tasks or perform longer EVAs.

One method to obtain the CG location of an object is done through a hang test. The CG hang test is used in the industry for various types of rigid objects such as tanks, missiles, airplanes, cars, etc. It involves suspending the object and measuring the suspension force and the tilt angle of the object with respect to a fixed origin. The derivation of the hang test concept is presented below:

**Force Diagram**

For distance a, we take the moment about the origin P (axis of rotation):

\[33M_0 = 0\]

\[W_a - F_b \cdot 0 = W_a - F_b \cdot a = (F_b)/W\]

Therefore,

\[Y_{CG} = a/(\cos(0))\]

**Center of Gravity Board & Software**

Finding the CG of a spacesuit assembly is necessary for future suit design requirements and analysis. Physical CG testing is intensive and involves a thorough set-up of equipment. Furthermore, a few points must be considered when executing these tests:

- Iteration of the CG hang test with different locations of the suspension force will produce more accurate results.
- CG locations change with the configuration of the suit. Therefore, it is crucial to keep the suit in the same posture at all times. This can be achieved by a fixture or other methods of tying down the suit legs and boots.

**Conclusion**

Finding the CG of a spacesuit assembly is necessary for future suit design requirements and analysis. Physical CG testing is intensive and involves a thorough set-up of equipment. Furthermore, a few points must be considered when executing these tests:

- Iteration of the CG hang test with different locations of the suspension force will produce more accurate results.
- CG locations change with the configuration of the suit. Therefore, it is crucial to keep the suit in the same posture at all times. This can be achieved by a fixture or other methods of tying down the suit legs and boots.

**Contact Information**

Website: tuan.nguyen20508.wix.com/aboutme
Linkedin: linkedin.com/in/tuannguyen20508
Twitter: @tuannguyen20508

California State University, Long Beach
1250 Bellflower Blvd
Long Beach, CA 90840

“We came all this way to explore the moon, and the most important thing is that we discovered the Earth.” - William A. Anders