Coefficient of Friction of Polymers in Liquid Nitrogen for DUNE

Joshua Truchon, Prof. Franklin Miller, Prof. Greg Nellis

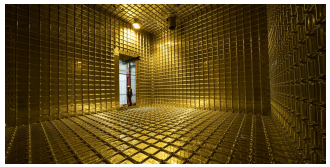
M1Po2D-04

DEEP UNDERGROUND NEUTRINO EXPERIMENT

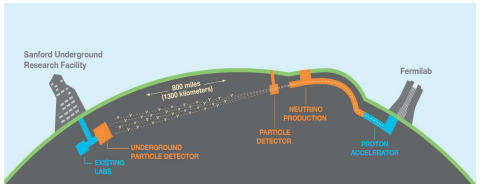
Motivation and Background

Problem- When submerged in liquid argon, the neutrino sensors require supports that minimize the effects of thermal contractions.

DUNE -Deep Underground Neutrino Experiment studies the nature of neutrinos by using a particle accelerator to project neutrinos at a detector. This detector records the electron trail left from the neutrinos' reaction with the liquid argon to decipher which flavor state the neutrino is in after traveling the distance to the detector.

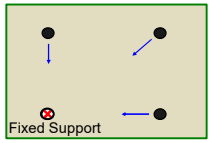


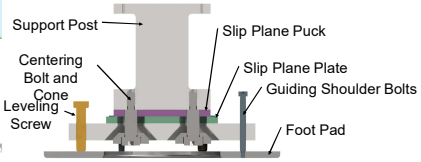
Membrane Floor- The cryostat utilizes a corrugated membrane floor design, allowing for thermal contractions of the membrane without creating stresses on the external support structure.



Solution

Solution – A support was designed with an intermediate slip plane, which provides a stress relief point. One fixed foot will provide a reliable center of contraction to ensure predictable positioning.





Slip Plane -To properly design the support, tests were required to find which materials should be used to have a low intermediate slip plane Coefficient of Friction (COF) and high support to membrane interface COF.

Test System

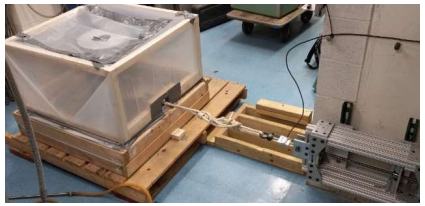
Tub Cryostat- The tub is designed to closely simulate the membrane floor using 316 stainless steel sheet metal and is insulated with polystyrene.

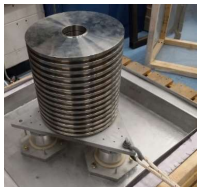
Test Sled -A steel plate is used to fix three prototype supports together and provides a surface for applying a known force with reference weights.

Linear Motion Device -A linear motion device applies a force on the test sled by moving the carriage with a screw.

Load Cell - A load cell records the force accumulated during the displacement of the linear motion device.

Enclosure - An enclosure prevents moisture from condensing inside the tub cryostat and causing impurities in the liquid nitrogen.

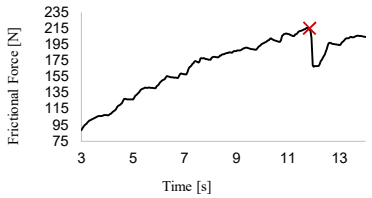




Sample Test/Test Process

As force was applied, the point of slip was recorded at the apex of force. The load was released and repeated until the support was maxed out.

Example of a sample collected



Tests requiring isolation of force at the intermediate slip plane used blocks on the feet preventing movement at the support to membrane interface

The reference weights were hung, and the force was recorded with the load cell to increase confidence in the data acquisition system.

Loads from 150N to 2200N were measured, and a deviation of about 1N was measured through the entire spectrum of loads.

A combination of PEEK, nylon, stainless steel and aluminum were tested. These materials were selected due to cost, machinability, and cohesion with other DUNE technology.

Moisture

During early testing, environmental contaminants in the liquid nitrogen affected results. It was believed that the COF of metals should be nearly the same at cryogenic temperatures, but the room temperature dry tests had lower COF than those submerged in fluid. Grinding noises could also be heard during slip indicating contaminates, which may cause skewed results.

An enclosure was built, and tests were repeated to verify concerns.

Material combination	Mean (SD) without encloser	Mean (SD) with encloser
Aluminum on Stainless Steel	0.436 (0.010)	0.342 (0.017)
Stainless Steel on Stainless Steel	0.234 (0.033)	0.195 (0.006)

Polymer Testing

As polymer hardness is inversely proportional to temperature and liquid nitrogen provides lubrication, we hypothesized COF of 77K LN2 tests would be lower than Room Temperature dry tests. Our data did not support this hypothesis.

PEEK on PEEK			
Temp	Test	Samples	Mean (SD)
295 K	3	45	0.216 (0.023)
77 K	3	83	0.274 (0.017)

Conclusion

It is suspected that the polymers' COF were increasing due to moisture retained within them. The DUNE project will have a purge cycle to remove moisture from the cryostat before filling, but it is unclear whether that would remove moisture from inside the polymer slip plane. Due to this, it was safer to simply use metals for the slip plane, resulting in a more predictable behavior without more extensive testing.

For the support design, it has been decided that further testing with a stainless steel on stainless steel intermediate slip plane should be preformed. The data retrieved previously gives confidence this will be a adequate solution.

Slide 1

JT0 Material tested

Joshua Truchon,
2023-06-30T17:22:44.432