Creating a Reel-To-Reel System for REBCO Test at 4.2K

FSU | FLORIDA STATE UNIVERSITY

Cesar Aguirre, Eric Hellstrom, Aixia Xu

NATIONAL MAGLAB

FSU UNDERGRADUATE RESEARCH OPPORTUNITY PROGRAM
CENTER FOR UNDERGRADUATE RESEARCH & ACADEMIC ENGAGEMENT

Introduction

Superconductivity, the conducting of electricity with zero resistance, begins once a given superconducting material goes below its critical temperature (Tc), which is typically incredibly low [1].

High-temperature superconductors (HTS) were first discovered in 1986 and have a Tc above 77K, the boiling point of liquid nitrogen [2]. REBCO, rare earth barium copper oxide, is one such HTS considered to have potential for practical applications due to its high critical current density (Jc) and ability to operate under strong magnetic fields [1]. REBCO coils have been recently successfully used at the MagLab to break the world record for the world's strongest sustained magnetic field, creating 17.6T of field with one coil and a total field of 48.7T [3].

For reference, a junkyard magnet capable of lifting full cars has around 1T of field [3].

Its effectiveness under magnetic fields has also led researchers to note its possible effectiveness in magnetic fusion, a vast sustainable energy source, highlighting REBCO's importance and practicality [4].

REBCO tape's performance (Jc) is significantly stronger when cooled with 4.2K liquid helium, but researchers have noticed that liquid-helium cooled REBCO tape does not have a homogeneous flow of current throughout the tape, instead decreasing along the length of each sample. The exact characteristics of this decrease is not known, nor the reasons for the decrease in performance, making it an unknown variable for researchers.

One reason this is important to REBCO's use in creating stronger magnets is determining if current decreases steadily or if there are sharp drop offs in Jc, as sharp drop-offs cause loss of magnetism. A reel-to-reel probe that characterizes the Jc of REBCO tape cooled by liquid nitrogen already exists, but liquid helium being much harder to work with means that no reel-to-reel probe capable of characterizing REBCO below 63.5K exists [5].

Creating such a tool to characterize the non-homogeneity of Jc in REBCO samples through this experiment will open doors for future researchers and assist in the development of practical applications.

System Design and Operation

Initial Setup:

- A G10 base for the reel-to-reel probe is mounted on a large metal frame with wheels.
- On the G10 base, there are two spools attached to motors; one empty, and one full of REBCO superconductor tape.
- A G10 probe is nearly completely inserted into a powerful magnet, with the area used for measurement at the bottom-end and a small amount of the probe sticking out of the magnet.
- The metal frame is placed above the magnet, with the section of the probe that sticks out of the magnet going through a slot in the G10 base.
- The REBCO tape is led from the full spool through the probe and attached to the empty spool.
- A cold-resistant wire connects the bottom of the probe, where the wire is manipulated into being a flat surface, to a room-temperature nanovoltmeter outside of the magnet.
- The magnet and the probe are in a sealed environment such that the liquid helium cannot be exposed to air.

Experimental Procedure:

- The magnet is activated and is cooled with the probe to 4.2K with liquid helium.
- The motors attached to the spools on the G10 base activate, moving around 100-200 meters of REBCO tape (a full spool) from the full spool to the empty one through the magnetic probe.
- As the tape moves through the bottom surface of the probe, where the tape is flat, the nanovoltmeter uploads the Jc of ~1mm of REBCO tape at a time to a laboratory program.
- The experiment is completed once all of the REBCO tape has been transferred to the originally empty spool, signifying that Jc of each section of tape has been measured.
- The machine will first be tested with copper wire to avoid damaging the REBCO tape.

Current Design Progress

- Parts were modeled in Autodesk Inventor.
- Machinists at the ASC then utilized 2D and 3D part drawings to create them.
- Parts not created in-house, like the motor, were obtained from the manufacturer or ordered from McMaster-Carr.
- Some of the 3D modeled parts are displayed in this section.
- Limitations: REBCO is expensive.
- Machining and part-ordering is inherently time consuming.
- Materials had to be stable under cryogenic temperatures and high magnetic fields.

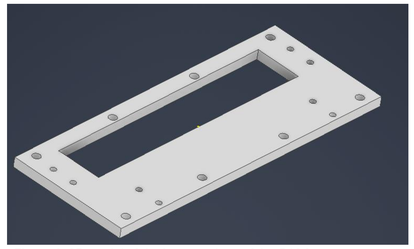

Figure 1. 3D model of the bottom piece of the G10 frame.

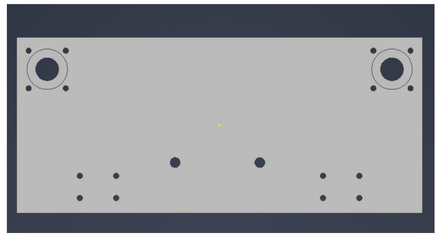

Figure 2. 3D model of the top piece of the G10 frame.

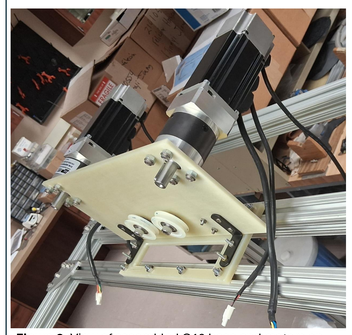

Figure 3. View of assembled G10 base and motors on physical metal frame.

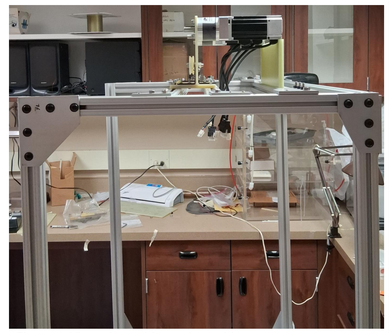

Figure 4. View of metal frame from side.

Future Work

- Although a machine test has not yet been fully carried out, the data from it could be useful to the field in multiple ways.
- This reel-to-reel probe, a tool that able to precisely characterize REBCO's current flow when cooled by liquid helium, can be used by many other researchers.
- Comprehensive specifications for REBCO materials are currently limited to only being available at liquid nitrogen temperatures, meaning that this probe's development would be a large step forwards.
- This will help the manufacturer of the tape optimize the process of creating the superconductor and correct the error.
- Researchers working with REBCO will also obtain more accurate information for magnet design.
- The main benefit in regard to magnet design will be understanding if REBCO samples have sharp drop-offs in Jc, which would decrease magnetism.
- Other experiments this tool would aid include the MagLab's efforts to create the world's first all-superconductor 40T magnet, for which REBCO has been successfully tested to be a strong candidate [6].
- The reel-to-reel probe would be a useful tool for determining if specific REBCO samples are particularly effective or non-effective for this project.
- A WIP prototype assembly of the probe is pictured below.

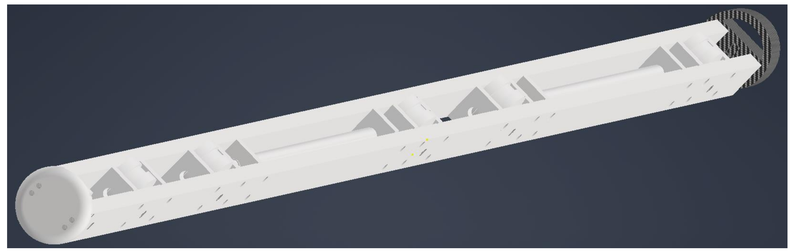

Figure 5. 3D Autodesk assembly of a prototype of the G10 probe.

Acknowledgments

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References