

# Super Conducting REBCO Cable Wrapper

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**Abstract**— This project focuses on improving a cable wrapping system used at Fermilab for wrapping REBCO superconducting tape onto a rectangular Rutherford copper cable core. The previous system had limitations in the efficiency and adjustability of the wrapping. To address this issue, a mechanical adjustment mechanism was designed to provide angular positioning of the tape on the cable while also including a tensioning mechanism. The angle and tension assembly is attached to a motor which will automate the wrapping process. This process involved evaluating multiple design concepts, selecting optimal features, and integrating them into a final design. CAD modeling was used to verify special positioning and fabrication planning. Additional work included developing a table and adjusting controller software for the system.

## I. Introduction

Upcoming upgrades to the CERN particle accelerator require the use of high temperature superconducting materials to enhance system performance and efficiency. A critical step in this process is the fabrication of superconducting cables, where a rectangular Rutherford copper cable core is wrapped with REBCO (Rare-Earth Barium Copper Oxide) tape. REBCO is a high temperature superconducting material composed of ceramic layer that can carry extremely large electrical currents with little to no resistance when cooled to temperatures around 77 K. Because of these properties, the accuracy of how the tape is applied directly impacts the performance of the final cable.

At present, the REBCO wrapping process is completed manually. This approach is time-intensive but also introduces inconsistencies in wrap angle and spacing, which can lead to variation in cable quality. These issues highlight a need for a more controlled and repeatable method of fabrication.

The goal of this project is to modify an existing wrapping machine to automate the application of REBCO tape onto the cable. This involves redesigning portions of the mechanical assembly and incorporating a controlled tension system to improve consistency during operation. The project focuses on integrating these improvements within the constraints of the current system while ensuring reliable performance.

By automating the wrapping process, this system aims to improve accuracy, reduce production time, and increase overall reliability. This work supports the advancement of superconducting cable manufacturing and contributes to the development of next-generation accelerator technology.



Figure 1: REBCO wrapped Rutherford type cables

## II. Methodology

The project began by evaluating an existing wrapping machine previously used for Fermilab's Mu2e project to identify reusable components. To reduce manufacturing costs and ensure compatibility with current infrastructure, the new system was designed to utilize these existing parts, including the motor, encoder, driver, and guides. The entire mechanical wrapping assembly was modeled using CAD software to verify spatial positioning and motion constraints. This digital modeling guided the construction of a modular base mounted on an adjustable aluminum T-slot frame.

To simplify future maintenance and lifecycle replacement, commercial off-the-shelf components were prioritized over custom-machined parts whenever possible. The core mechanical development focused on two main systems:

**Angle Adjustment:** Custom spools mounted to an adjustable spindle were designed to allow for repeatable wrap angles between  $10^\circ$  and  $45^\circ$ . To ensure these angles hold securely during operation without premature wear, tool steel was selected as the optimal material for the gears and locking arms.

**Tension and Synchronization:** Because the REBCO tape features a brittle ceramic core, a tensioning mechanism was integrated to maintain precise force and prevent material damage during wrapping. Furthermore, the system relies on software to synchronize the motor speeds with the cable feed speed via the encoder, ensuring consistent tape layering and spacing.

To address safety, a polycarbonate protective shield was modified to enclose all rotating mechanical components, preventing user injury. The system also incorporates an emergency stop feature to rapidly de-energize the machine if necessary.

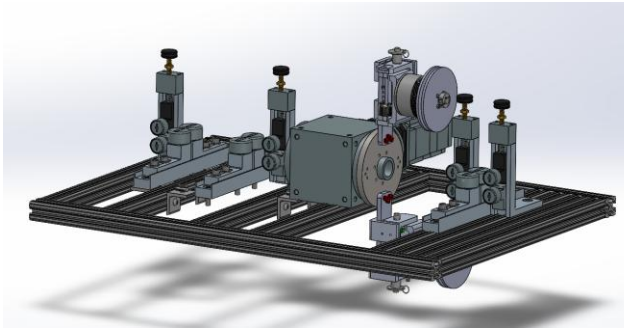


Figure 2: REBCO wrapping machine with custom T-slot frame final CAD model

### III. Results

Due to manufacturing delays for the custom aluminum/tool steel parts, the team utilized 3D-printed assemblies to mockup the physical system. This agile prototyping step allowed the team to prove out the footprint and component alignment on the T-slot frame prior to final integration.

The controller software proved to be difficult to repurpose. Since the computer used for the controller has not been used in many years, it was locked by Fermilab IT. During the unlocking process, the computer hard drive was accidentally wiped which deleted all previous configuration and data collection. Luckily, an engineer at Fermilab had the software and coding calculations downloaded to another computer.[3] The software was reinstalled on the computer for the controller and reconfigured for multiple hours.

The synchronization for the motor and encoder will need to be fine-tuned when the aluminum/tool steel parts arrive. Currently the sensitivity has been lowered to prevent the 3D printed parts from breaking. The strength of 3D printed PETG-CF for the gear is inadequate for the weight of the tensioner.



Figure 3: 3D-printed assemblies mounted to motor hub

### IV. Discussion

The 3D-printed system has been successfully assembled, but full functional testing has not been completed. All custom-made parts were produced and were verified to fit correctly within the overall assembly. One issue identified during assembly was gear slippage associated with the 3D-

printed components. Due to the material properties of the printed parts, the gear teeth did not provide the same level of rigidity and friction as the fabricated gear (A2 Tool Steel). This leads to inconsistencies during the operation. While this issue was observed under the current setup it has not yet been fully evaluated using the intended material properties the system was designed for. Future improvements include replacing the current heavier magnetic tensioner with a lighter one, however, this would require designing a new magnetic tensioner bracket.

The existing motor system and controller software were also implemented into the overall assembly. This allows for adjustable speed and controlled motion of the wrapping mechanism, which is essential for when the custom parts are acquired by Fermilab.

A key limitation of the current setup is the lack of experimental validation. Without testing, it is not yet possible to quantify the improvements in wrap quality, tension control, and angular adjustment. Future work should focus on running the system under real operating conditions and collecting data such as wrap consistency and reliability.

### V. Conclusion

This project resulted in the successful design and assembly of an automated wrapping system for REBCO superconducting tape. While testing is incomplete, the system has been built and prepared for operation.

The project has achieved its goal of developing a solution to replace the current wrapping process. The completed system provides a foundation for future tests and optimizations. With additional validation, this design has the potential to improve the efficiency of the REBCO cable fabrication process.

### VI. Acknowledgement

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