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Design and Electromechanical Properties of HTS Twisted Stacked-Tape Conductor with Three Stepped Slots

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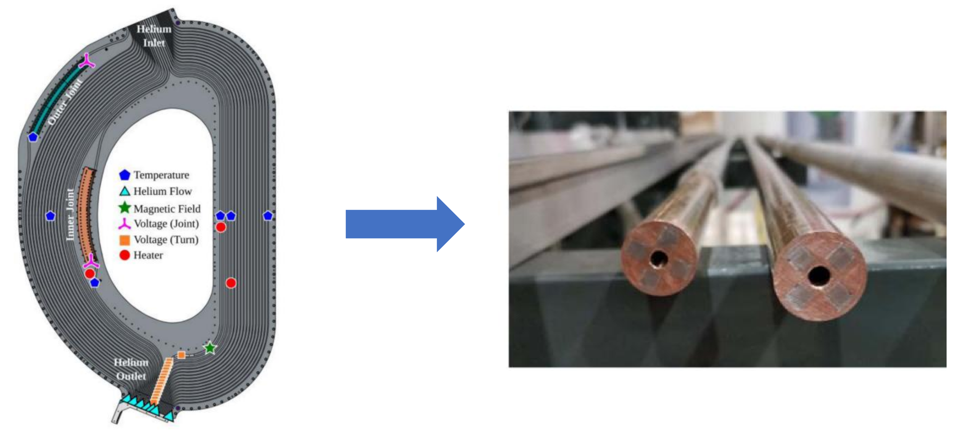
ABSTRACT

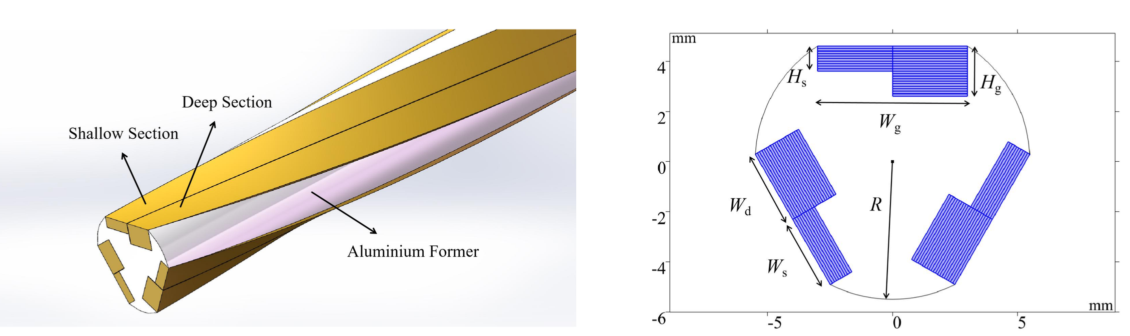
The high temperature superconducting (HTS) twisted stacked tape cable (TSTC) is one of the methods to improve the current-carrying capability of a superconducting cable. A three stepped grooves with twisted stacked YBCO tapes is presented in this paper. The YBCO tapes embedded in the stepped grooves of two different depths. A 2D finite-element model is used to computes the magnetic field and current distribution. A 20+10 tapes in each single groove configuration cable of YBCO is fabricated using the twisted stacked-tape method, and the bending test of the samples at 77 K in self-field are performed to verify the electrical characteristics.

INTRODUCTION

- In order to form, control, and drive the tokamak plasma in fusion systems, excellent high-field and high-current performance of superconducting conductors and cables is required.
- Inspired by the VIPER cable, a compact TSTC design featuring three stepped grooves, each embedded with twisted stacked superconducting tapes of two different depths is presented. This innovative configuration aims to distribute the magnetic field and current more uniformly, thereby improving the cable's overall efficiency. The stepped grooves are designed to accommodate a specific arrangement of YBCO tapes—20 tapes in the long groove and 10 tapes in the short groove—allowing for a comprehensive analysis of their electrical characteristics.



Toroidal field model coil and VIPER cables designed by PSFC



Structure of the proposed HTS TSTC with three stepped grooves

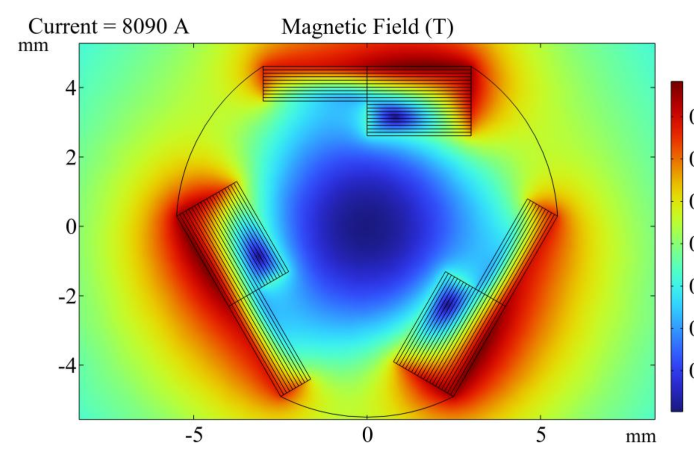
REQUIREMENT

- High current-carrying capability
- Strong mechanical stability
- Operating in the LN temperature zone
- Easy to operate in high field

SIMULATION ANALYSIS

STRUCTURE

- Tape size: 3mm * 0.1mm
- Number of slots: three
- Number of strips per slot: 20+10



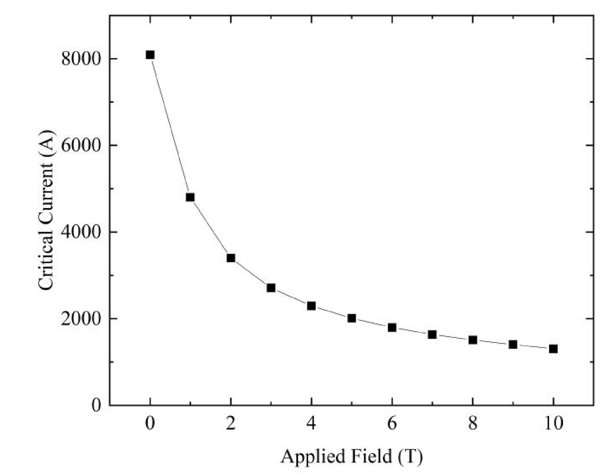
Magnetic field distribution

ANALYSIS

- The magnetic field shows a decreasing trend from the outer layer to the inner layer, with both the maximum and minimum magnetic fields occurring in the deep section.
- The critical current obtained from simulation decreases with a decreasing rate as the vertical external field increases. Under a 10 T vertical external field, the critical current obtained from simulation is 1310 A.

CRITICAL CURRENT DENSITY

$$J_c(B_{perp}, B_{para}) = \frac{J_{c0}}{\left(1 + \frac{\sqrt{k^2 B_{perp}^2 + B_{para}^2}}{B_0}\right)^{\alpha}}$$

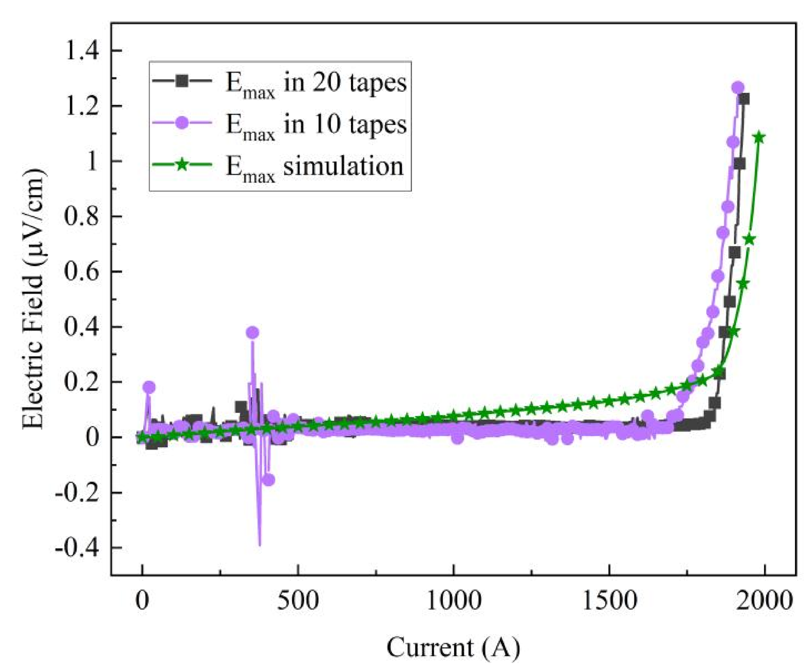


Critical current vs the external field

EXPERIMENT RESULTS

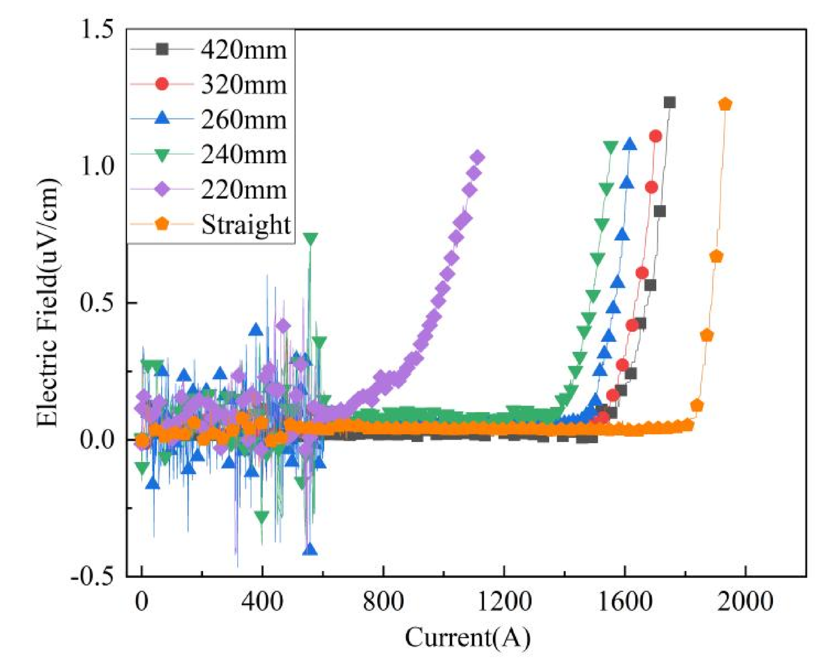
CRITICAL CURRENT TESTS

- The current ramping rate was set to 10 A/s.
- The results of two tests are 1920 A and 1900A, respectively.
- The results are in good agreement with the simulation result of 1980 A.



BENDING TESTS

- Five bending tests with bending diameters of 420mm, 320mm, 260mm, 240mm, and 220mm.
- At a diameter of 420 mm, nearly a 10% reduction.
- A significant drop observed at a bending diameter of 220 mm.



EXPERMENT CONFIGURATION

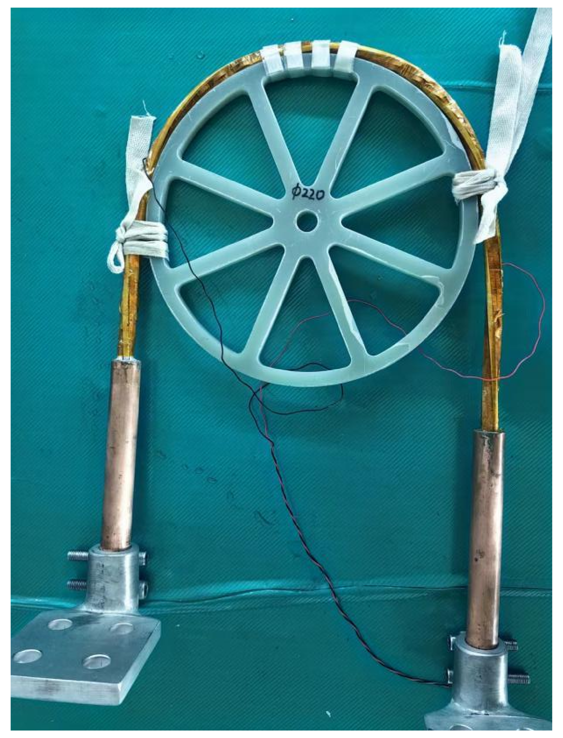
TSTC CABLE FABRICATION

- A sample with a length of 1 meter and a pitch of 300 mm.
- Consists of 18 superconducting tapes and 72 copper tapes.

BENDING FABRICATION

- The middle section of the cable was first fixed to a circular epoxy resin frame using tape.
- Gradual force was then applied to the copper tubes at both ends to make the cable conform to the epoxy frame.
- the ends were fixed with tape or cloth strips.

Sample Cable



Bent Cable

CONCLUSION

- **A stepped groove structure is proposed and demonstrates a higher current density compared to a standard TSTC cable.**
- **The results of the bending test indicated a significant decline in current-carrying performance.**
- **FURTHER STUDY**

Stepped groove structure optimization.
Contrast verification.