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Effect of Tape Inhomogeneity on the Critical Current Estimation of HTS Coil

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INTRODUCTION

The commercially available HTS tapes like $REBa_2Cu_3O_x$ (where RE = Rare Earth) tape always present a certain critical current (I_c) inhomogeneity along the tape due to manufacturing defects and process variations. It is necessary to take into consideration the I_c inhomogeneity of tape for an accurate estimate on the I_c of HTS devices. There are various characterizations on the tape's I_c inhomogeneity. From the detailed I_c data, one can characterize the tape's I_c inhomogeneity with the maximal I_c, minimal I_c, mean I_c and the so-called overall I_c.

This work is to estimate the I_c of several HTS DP coils in consideration of the varied characterizations and two different criteria, i.e., MAX and AVG criteria. Through a comprehensive comparison on the coil I_c between the calculation and measurement, a few appropriate characterizations on the inhomogeneity are determined for estimating the I_c of HTS coils during their design and operation stages. This study can provide useful implications for the design of HTS coils that are wound by the tapes with noteworthy I_c inhomogeneity.

SIMULATION AND EXPERIMENT

I. Characterizations of Tape's I_c Inhomogeneity

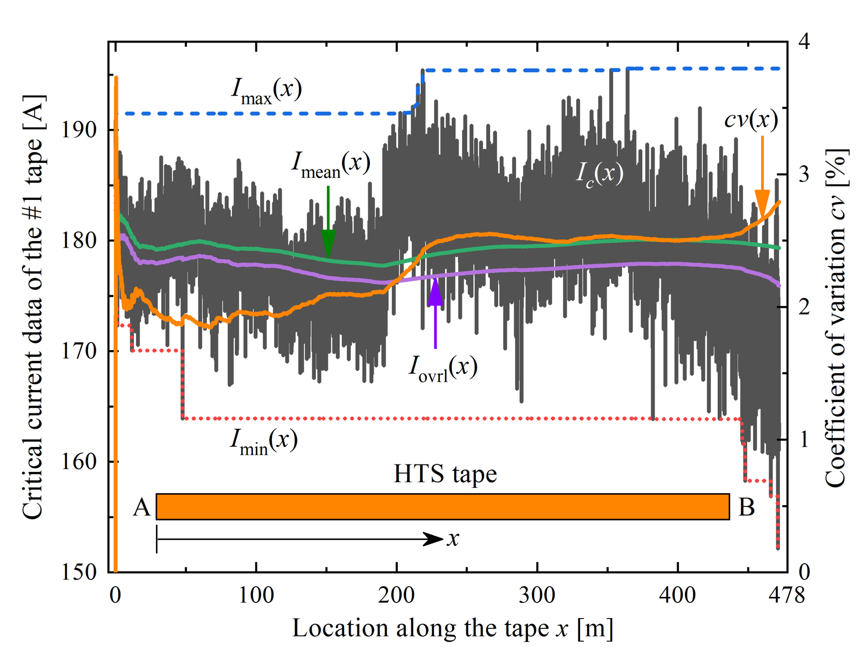

Fig. 1. Characterizations on tape's I_c inhomogeneity.

It is clearly evident that $I_{max}(x) > I_{mean}(x) > I_{ovrl}(x) > I_{min}(x)$ and $I_{ovrl}(x) \approx I_{mean}(x)$. The $I_{max}(x)$ and $I_{min}(x)$ monotonically change with the location x. However, the $I_{mean}(x)$ and $I_{ovrl}(x)$ are not monotonous because of the inhomogeneity, which are able to better characterize the tape's I_c inhomogeneity.

II. Homogenized Self-Consistent Mode

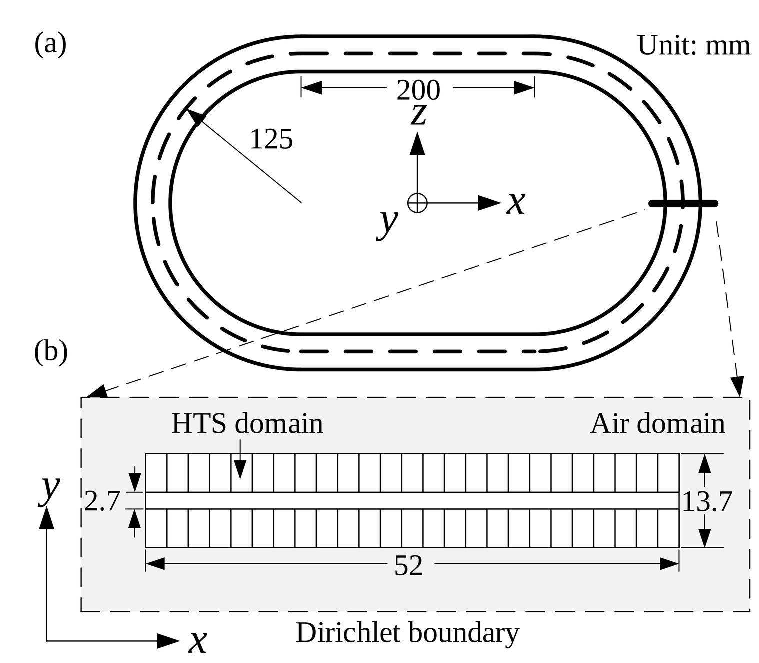

Fig. 2. Geometric layout (a) and the homogenized self-consistent model (b) of the HTS DP coil.

The self-field of the racetrack HTS double-pancake (DP) coil, obtained by resorting to a numerical model, is applied as Dirichlet boundary condition on the outer boundary of this model including only the HTS domain and a thin air domain.

III. Manufacture and measurement

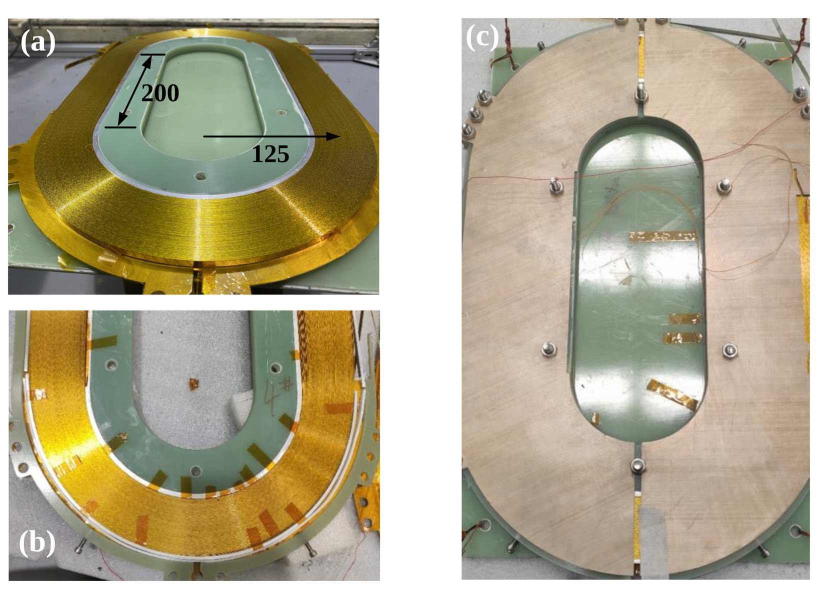

Fig. 3. Manufacture of the racetrack HTS DP coil, (a) the winding of DP coil, (b) the coil fastening, and (c) one fabricated DP coil.

With the HTS tapes described in Fig. 1, four racetrack HTS DP coils were fabricated and their critical currents were measured at liquid nitrogen temperature.

RESULTS AND DISCUSSION

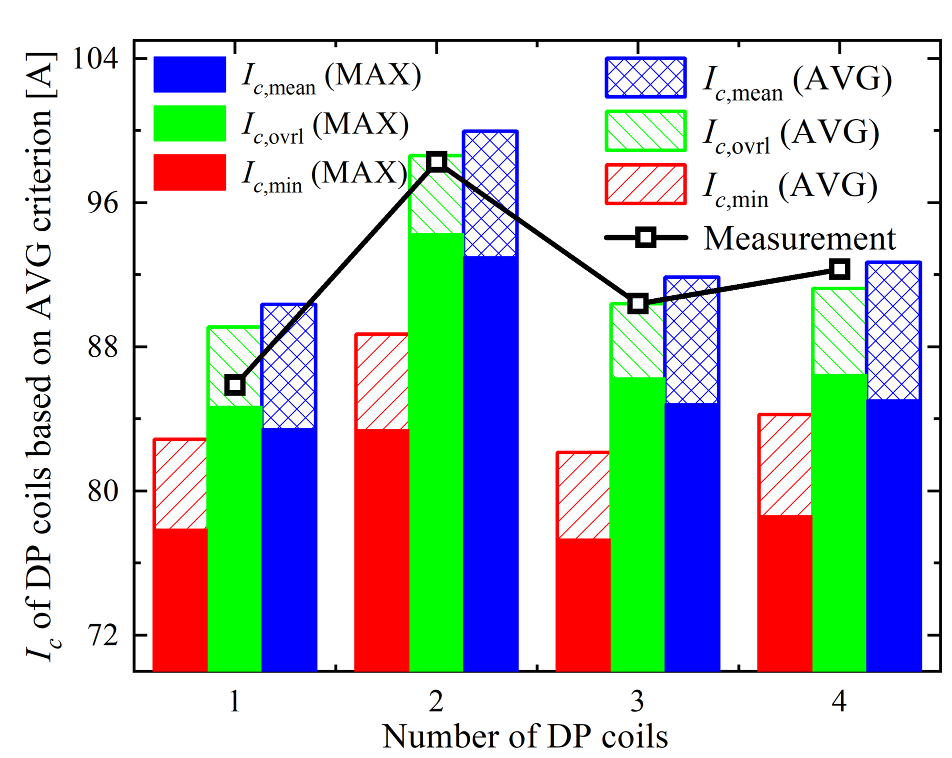

Fig. 4. Comparison of Ic of the four HTS DP coils from the measurement and calculation.

- ✓ I_c of all DP coils meet $I_{c,mean} > I_{c,ovrl} > I_{c,min}$;
- ✓ I_c (AVG) is higher than the one (MAX);
- ✓ $I_{c,ovrl}$ (AVG) is closest to the measured one;
- ✓ all the calculated I_c (MAX) are below the measured values;
- ✓ the measured I_c are within the certain range of $I_{c,min}$ (MAX) and $I_{c,mean}$ (AVG).

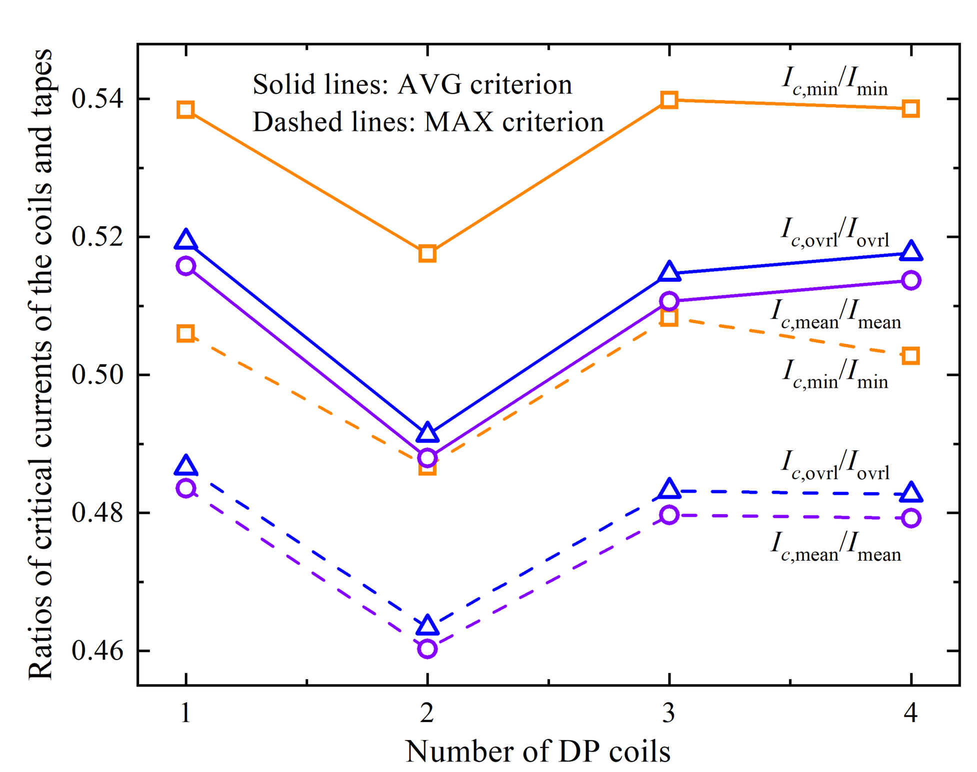

Fig. 5. Ratios of the I_c of the four HTS DP coils to the corresponding tapes.

- ✓ The attenuation factor is about 0.5 after these tapes are wound into DP coils;
- ✓ The ratio of I_c of coil to tape little depends on the inhomogeneity and the selected criterion;
- ✓ As for the MAX and AVG criteria, the latter gives a greater ratio;
- ✓ I_c of a DP coil can be estimated by the ratio of the I_c between these tapes.

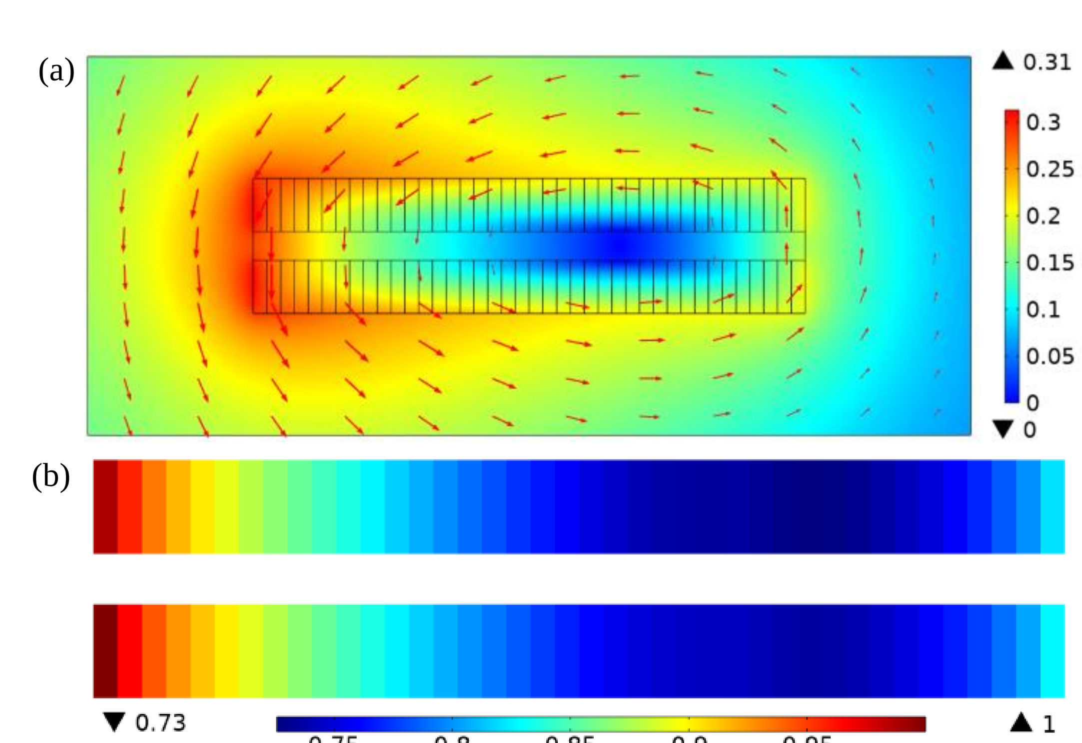

Fig. 6. Distribution of (a) the magnetic flux density (unit: T) and (b) load factor in the DP4 for the case of the tape's I_{min} and MAX criterion.

- ✓ The magnetic flux density mostly concentrates on the inner of coil, giving rise to the highest load factor. This finding implies that the inner turns of the coil should be wound with the tape section having a higher I_c.

CONCLUSIONS

http://www.asclab.cn http://userweb.swjtu.edu.cn/Userweb/gtma/index.htm

1. **With the tape's I_c inhomogeneity considered, the I_c of four HTS DP coils was estimated by means of a homogenized self-consistent model. Detailed comparison and discussion on the I_c of the calculation and measurement were conducted.**
2. **The I_c of a HTS coil can be better estimated in consideration of the I_{ovrl} of tape and AVG criterion. By contrast, the I_{mean} of tape and MAX criterion are a better combination for obtaining a conservative estimate on the I_c of a HTS coil during the design stage. Normally, the measured critical current of a HTS coil must be within the certain range of $I_{c,min}$ (MAX) and $I_{c,mean}$ (AVG).**
3. **The ratio of the I_c of these DP coils to their tapes little depends on the I_c-inhomogeneity characterization and the selected criterion.**