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Characteristics of critical current of HTS Conductor on Round Core

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Abstract

The bend and transposition of high-temperature superconductors (HTS) have great influence on the characteristics of critical current. For Conductor on Round Core (CORC), twist pitch and diameter will influence the characteristics of critical current. The influence of twist pitch and diameter on the critical current characteristics of CORC was studied. In this paper, the simulation of magnetic field distribution of the conductor using FEM was accomplished, and the critical current of the conductor was calculated and discussed in different twist pitch and diameter. Then, the sample of HTS CORC was fabricated, and the critical current was measured at liquid nitrogen temperature and self-field. The test results correspond with simulation.

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Keywords: CORC;HTS;Critical current; Electromagnetic design

1. Introduction

With the development of HTS, advantages of HTS in the large fusion magnet design and manufacture will be significant. The bases of realizing HTS applied for fusion magnet are high current conductors [1]. The cabling method of high current conductors is usually a parallel arrangement of tapes. If bundling HTS tapes together directly to form high current conductors, it will generate high AC loss which disturbs working state of the conductors [2]. So it is necessary to consider the transposition of conductors for reducing AC loss, but the characteristics of critical current will be influenced by transposition. Twisting could not be directly implemented owing to the craftsmanship

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of HTS tape itself. It is demanded to design a more reasonable structure of large current conductor. In 2010, University of Colorado presented CORC (Conductor on Round Core) design of spiral-winding tapes on a small round former [3-4]. In this paper, the magnetic field distribution of this kind conductor in different twist pitch and diameter (77K) is simulated and critical current is calculated. The measure experiment of critical current is carried out to verify simulation results.

2. Model of conductor structure

In this paper, 4 tapes of SuperPower SCS4050 are spiral-winded uniformly on a round epoxy former which does not share current, so the effect of former could be ignored. The width of SuperPower SCS4050 tape without insulation is 4mm, thickness is 0.1mm, the critical current at 77K and self-field is 117A, and the total current of 4 tapes without degradation is 468A. Fig. 1(a) shows the structure of conductor. COMSOL Multiphysics mf module is used for simulation. It is based on Ampere's law: $\nabla \times H = J$ where H is magnetic field intensity, J is current density.

In this paper, diameter is from 16mm-60mm, twist pitch is from 50mm-250mm. The least bending diameter of SuperPower SCS4050 is 11mm and the critical tension strain is 0.45%. We consider extreme condition that diameter is 16mm and twist pitch is 50mm, the strain can be calculated from equations (2) in reference [5] and is -0.25%, and there is nearly no reduction in I_c. Moreover, the actual strain of tape will be reduced when a small gap exists between conductor and former. So the influence of magnetic field on critical current is dominating relative to strain

The tetrahedron is used to generate mesh of conductor in detail and mesh of air roughly. Fig. 1(b) presents the mesh shape of conductor. For simplicity we consider the tape as YBCO superconductors, and define resistivity for different materials in the model. For air, we use ρ=1000 Ω m; for superconductors, we use the E-J power law: E= $E=E_0(J/J_c)^n$, where J_c is defined as the current when $E_0=1\times10^{-4}$ V/m is reached under DC I-V measurements, n=30, $J_c=2.5\times10^8$A/m^2, single coil module is used to apply current load for conductor. Critical current is calculated by obtaining max magnetic flux density and load curve of conductor, combined with critical current curve of tape. The point of intersection between load curve and critical current curve corresponds to the critical current of conductor. Because it is a homogeneous 3D model, it is very hard to identify which component is longitudinal or lateral, we use $B_{norm} = (B_x^2 + B_y^2 + B_z^2)^{1/2}$ as magnetic flux density. I_c (1μV/cm criterion) of SuperPower SCS4050 in different magnetic field angle (77K) is presented in Fig. 1(c), critical current curve in perpendicular field (90°) is adopted in this paper.

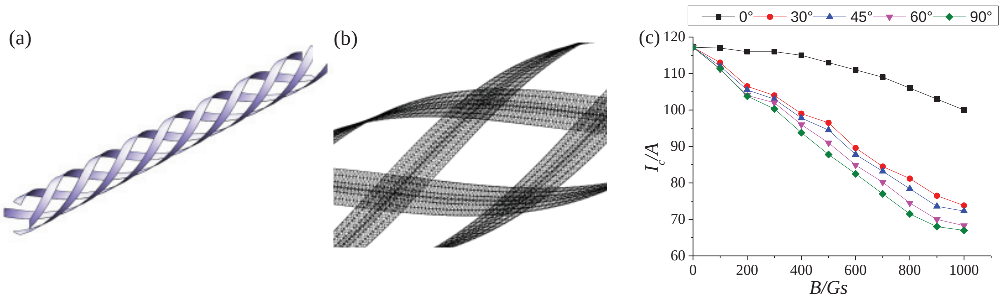

Fig. 1. (a) Conductor on Round Core; (b) Mesh shape of conductor; (c) The curve of critical current of SuperPower SCS4050

3. Results and Discussion

The steady-state current of each tape is 60A DC. Table 1 shows max magnetic flux density and critical current of the conductor in different twist pitch when diameter is 16mm, Fig. 2(a) presents curve of critical current with different twist pitch. As twist pitch increases, the maximum magnetic flux density decreases gradually, the critical current I_c increases gradually. The results show that the variation trend of critical current I_c is not linear. The critical current I_c increases sharply when twist pitch is between 0-100mm, while decreases slowly when twist pitch is between 100mm-250mm and tends to 388A gradually at last. When twist pitch is 250mm, the maximum magnetic