INVESTIGATIONS ON THE STABILITY OF HTSC USED TO HIGH MAGNETIC FIELDS AT 4.2K AND 77K

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ABSTRACT

Bi-based oxide superconductors show high critical current density even in very high magnetic fields. This means that they could be used to high field superconducting magnets. In this paper, the flux-jump stability of HTSC superconducting magnets was studied. A critical state model is proposed for HTSC which shows anisotropy and weak-link, the effects of anisotropy and weak-link on the stability are discussed. The mechanical stability was also considered.

INTRODUCTION

Since the discovery of high Tc oxide superconductors (HTSC), much research has been conducted to find application for them on high magnetic fields. It has been shown that Bi-based silver sheathed wires could be used to high field magnets with central field of 20-40 T at 4.2 K1-5 and that Y-based wires could be used to superconducting magnets with central field of 1-5 T at 77 K6-8. Although HTSC superconducting magnets show much better stability than the conventional superconducting magnets5, the anisotropy of critical current density Je with respect to the direction of magnetic field and weak-link current of HTSC will have serious effects on the stability of these magnets, especially of these magnets run at 77 K and 1-5 T where anisotropy and weak-link are much more serious. For example, the magnetic field component of radius direction is very large at two ends of the solenoid magnets. For this reason, the anisotropy will affect the stability of the superconductor here. At lower fields, the weak-link current may have an important impact on the movements of flux in superconductors and consequently on the stability. In this paper, the flux-jump stability were analysed and the effects of anisotropy and weak-link on the stability were also studied.
FLUX-JUMP STABILITY

Adiabatic Flux-jump Stability

Since the magnetic diffusivity of HTSC is much larger than that of thermal diffusivity, it is reasonable to apply the adiabatic stability criterion to HTSC superconducting magnets. An isolated filament is adiabatically flux-jump stable, provided its diameter $W$ is less than some value $W_{Fj}$ given by:

$$W_{Fj}=2(3T_cC_v/\mu_0)^{0.5}/J_c$$  \[1\]

while $C_v$ and $J_c$ are specific heat and critical current density respectively. Taking $T_*=T_c-T_b=70$ K (with background field of 25 Tesla and bath temperature of 4.2 K), $C_v=2200J/m^3K$, $J_c=10^5A/cm^2$, it is found that $W_{Fj}=1.2$ mm.

Dynamic Flux-jump Stability

In order to enable it to cope with the possibility of frequently repeated disturbance, the superconductor must be associated with a high conductivity metal which in turn is closely coupled to the cryogen bath. Thus dynamic stability calls for a cryogenically cooled composite conductor. Under these conditions the filament size limitation for dynamic flux-jump stability becomes the following expression:

$$W_{Fj}=[(8K_{sc}/R_{Ag})T_*(1-\epsilon)/\epsilon]^{0.5}/J_c$$  \[2\]

while $\epsilon$, $K_{sc}$ and $R_{Ag}$ are the filling factor of the superconductor, the thermal conductivity of superconductor and the resistivity of silver matrix respectively. Taking $K_{sc}=0.5W/mK$, $R_{Ag}=1.4\cdot10^{-10}\Omega\cdot m$, $\epsilon=0.4$, it was found that $W_{Fj}=1.7$ mm. If the magnetoresistance effect of silver is taken into consideration, $W_{Fj}$ will be decreased. For example, the resistivity of silver which is under background of 25 T is $R_{Ag}=1.0\cdot10^{-9}\Omega\cdot m$ and $W_{Fj}=0.65$ mm.

Self-field Flux-jump Stability

The diameter of the untransposed strand made up of filaments of diameter less than $W_{Fj}$ embedded in stabilizer is limited by self-field induced flux-jumping. Under adiabatic conditions flux-jumping will occur as soon as the self-field gradient across the half-width of the strand equals $H_{Fj}/(D/2)$. This premise leads to the following expression for maximum stable diameter:

$$D_{max}=[10^9(8\pi C_{av}T_*)^{0.5}/\epsilon J_c]^{0.5}$$  \[3\]

where $C_{av}=\epsilon C_{sc}+(1-\epsilon)C_{Ag}$ is the average specific heat of the composite strand. Substituting the $C_{Ag}(4.2K)=1500J/m^3K$, $\epsilon=0.4$ and some numerical values as mentioned above, we got $D_{max}=4.3$ cm. According to the above calculations, the stabilization parameters of the Bi-based silver sheathed tapes or wires are listed in table 1.

THE EFFECTS OF ANISOTROPY AND WEAK-LINK ON THE STABILITY OF SUPERCONDUCTING MAGNETS

A Critical State Model for Anisotropy and Weak-Link

Although HTSC superconducting magnets show much better stability than the conventional superconducting magnets, the anisotropy of Jc with respect to the direction of magnetic field and weak-link current of HTSC will have serious effects on the stability of these magnets, especially those magnets run at 77K and 1-5 Tesla where anisotropy and