§3. Thermo-Mechanical Strength Parameters of Single Crystal Rare-Earth High T_c Bulk Superconductors

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Studies on the strength of rare-earth high T_c superconducting bulks, single crystalline ceramics, have been carried out at room temperature and their data base has been constructed. The aim of this study is to clarify the change of mechanical properties caused by cooling –heating thermal cycles, which is required for the practical applications of the bulk. This may help obtaining the directions for design of the large capacity current lead for large superconducting magnet such as magnetically confined fusion reactor, and also the processing the bulk fabrication.

Test pieces were cut from commercial $DyBa_2Cu_3O_x$ (Dy_2BaCuO_5 being 25 % mol fraction) bulk samples with 46 mm diameter and 25 or 15 mm thickness. The temperature dependence down to 7K of the Young's modulus, E, and the strength by bending tests of 36x3x4 mm specimens were measured. The E and strength increased 32% and 36%, respectively.

A 14x11x15(c-axis) mm specimen cut from the sample of $DyBa_2Cu_3O_x$ with 10% Ag was cooled and heated between 77K and 393K for 110 cycles. The tensile tests on the two kinds of 3x3x4 mm specimens, loading in the c axis and perpendicular to it, were conducted using a 2 kN Shimadzu servo-pulsating universal testing machine at the cross head speed of 0.15 mm/min. Non-steady state thermal stress analysis during cooling has been made using finite element method analysis ANSYS.

As shown in Fig. 1, the average tensile strength for the specimens thermal cycled 110 was not changed for both loading directions compared with those without thermal cycles. This is different from the results in the similar experiment on the specimens without Ag addition conducted last year. It can be concluded that Ag addition is effective from the strengthening and reduction of the thermal stress against the damage by the thermal cycle.

The changes in the maximum value of non-steady state tensile thermal stress on rapid cooling to the liquid nitrogen temperature of commercial (non Ag added) bulk sample analyzed were shown in Fig. 2. The specimen diameters are 30, 46 and 60 mm. In the calculation, thermal conductivity, the coefficient of thermal expansion, specific heat and Young's modulus for the bulk were used and the boundary temperature 77K and heat transfer coefficient 260 W/mm^2K were used.

The tensile strength of this material were 65 MPa in the a, b axis and 9 MPa in the c-axis. Comparing these to the thermal stresses in the figure, the thermal stresses in c-direction in all the sizes exceed the material strength and, in the case of 60 x 15 mm, even in the a-axis the thermal stress exceeds it. Therefore, it is anticipated that in the case of rapid cooling of commercial Dy123 bulk, the a-b plane cracks can be formed in all the size, and a(b)-c plane cracks can be formed.

References:

1) K. Katagiri et al., Supercond. Sci. Technol. 19 (2006) S1-S5

2) S. Sato, K. Katagiri et al., Preprint 42th Ann. Mtg. Tohoku, JSME (2007)

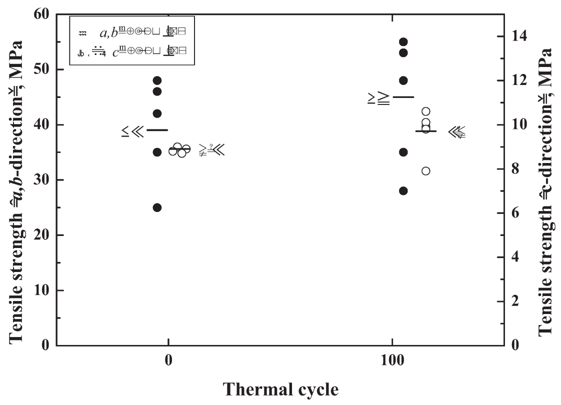

Fig. 1 Ultimate tensile strength of Ag added Dy123 prior to- or post-heat cycles

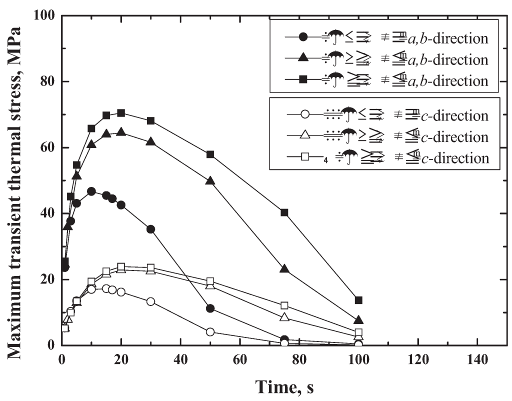

Fig. 2 Maximum stresses as a function of time (non-steady state thermal stress analysis)