§10. Tensile and Bending Mechanical Properties of Bulk Superconductors

Katagiri, K., Kasaba, K., Shoji, Y. (Fac. Eng., Iwate Univ.)
Iwamoto, A., Mito, T.

Investigations in the mechanical properties of high performance RE123 (RE: rare earth elements) single-grain bulk superconductors are important for their practical applications such as current leads. Since bulk superconductors are brittle, their mechanical properties are commonly evaluated by the bending tests. However, it is preferable to carry out the tensile tests, because detailed distribution of the mechanical properties in a bulk superconductor can be evaluated. They are different to each other, because there is a stress gradient in the bending test specimen. It is well-known that the bending strength is commonly higher than the tensile strength. Recently, the present authors carried out the tensile tests by using the small specimens cut from bulk samples. However, the correlation between the mechanical properties obtained from the tensile tests and those from the conventional bending tests has not been clarified sufficiently. In this study, the tensile and the 3-point bending tests of the $YBa_2Cu_3O_x$ (Y123) and the $GdBa_2Cu_3O_x$ (Gd123) bulk superconductors were carried out at RT.

An Y123 without Ag_2O and a Gd123 with 10 wt%Ag_2O bulk superconductors with the dimensions of 46 mm in diameter and 25 mm in thickness were fabricated by using the modified QMG process. They are denoted as Y0 and Gd10, respectively. Specimens with the dimensions of 3 x 3 x 4 mm^3 for the tensile tests and those with the dimensions of 4 x 3 x 36 mm^3 for the bending tests were cut from the samples such that the longitudinal direction of them corresponded to the direction perpendicular to the c-axis of the bulk samples. The tensile and the 3-point bending tests were carried out under the stroke control mode with the crosshead speed of 0.15 mm/min by using the 3 kN Shimadzu Servopulser testing machine. The fulcrums span for the bending tests was 30 mm. The load and the strain were measured by using a 3 kN load cell and the Kyowa KFL-1-120-C1-16 strain gages attached to the center of the specimens. In the tensile tests, two strain gages were attached to the opposite sides.

Although some of the stress-strain curves obtained from the bending tests of the Gd10 sample clearly showed the non-linear behavior, others are almost linear until fracture. These are presumed to reflect the extension or opening of the pre-existing large defects in the bulk superconductors. It appears that a definite difference between the Young's moduli obtained from the tensile tests and those from the bending ones. The Young's moduli obtained from both tests are summarized in Fig. 1. The average Young's modulus by tensile tests of the Y0 and the Gd10 bulk samples were lower than those by bending tests. This is consistent with the result for the Y15 bulk sample[1]. This is ascribed to the behavior of the compressive stress region which is induced in the half of the volume in the bending test specimens. Recently, some of the present authors reported that the Young's modulus in the direction perpendicular to the c-axis at RT obtained from the compressive tests of the Sm123 bulk sample is larger than that from the tensile tests.

The tensile and the bending strength are shown in Fig. 2. The tensile strengths of the Y0 and the Gd10 bulk samples were lower than the bending strengths. This is consistent with the result for the Y15 bulk sample [1] and also with common relationship. Contrary to the tendency in the Young's modulus, the strength of Gd10 bulk sample is higher than that of Y0 bulk sample. This discrepancy appears mainly due to the addition of Ag in the former. There was no difference between the Weibull coefficient for the tensile strength and that of the bending strength for the Gd10 bulk sample, 6.9, while the coefficient for the bending strength, 17.6, was significantly larger than that for the tensile strength, 6.8, for the Y0 bulk sample. This indicates that these data came from two groups, between which the mechanisms controlling the fracture was different.

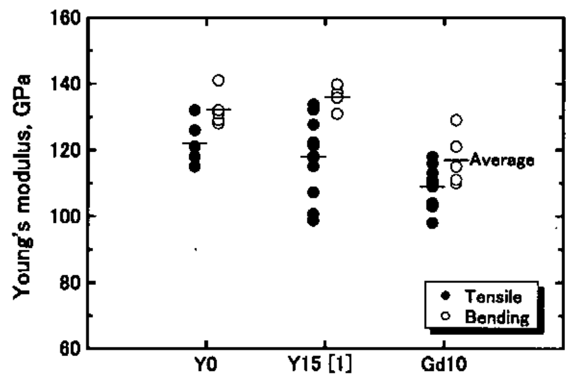

Fig.1 Young's modulus obtained by tensile and bending tests (RT)

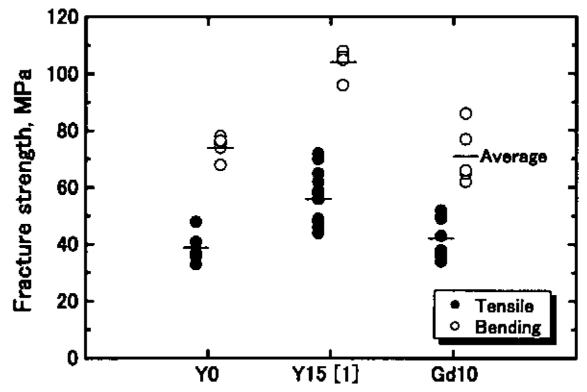

Fig.2 Tensile and bending strength (RT)

Reference
[1] T. Okuder, et al, Physica C 392-396 (2003) 628.