§4. Strain Characteristics of Advanced Superconducting Wires at High Fields

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Because the superconductors for nuclear fusion devices are subjected to a huge electromagnetic force, problems of degradation in critical current I_c caused by damages in the conductor is serious. Increase in the magnetic fields, which is effective for the efficiency of the device, will results in the increase in the force. Developments of high performance conductors with strength and strain tolerance are one of the key technologies for the next device equipped with high-filed magnets.

In this study, we have evaluated the mechanical properties and stress/strain characteristics of some advanced high strength intermetallic compounds- and oxide- superconducting wires at high fields.

i) $(Nb,Ta)_3Sn$ wires

5 kinds of single core $(Nb,Ta)_3Sn$ wires fabricated by a quite novel process with powder core and Nb/Ta sheath by Prof. Tachikawa[1] were evaluated. Measurements were conducted at 4.2K and 14T by using the tensile device[2] in the 50 mm bore of 15T superconducting magnet at the High Field Superconducting Material Research Laboratory, MRI, Tohoku University.

Although the mechanical properties of the wires changed slightly to each other depending on the wire construction, they were essentially the same as those in the conventional bronze processed wires. The characteristic point of these wires is that the very low strain sensitivity of I_c, which is by far small if its higher upper critical field of 26 T is taken into account (Fig. 1). Another point is that the strain corresponding to the peak I_c is small. The former appears to be based on the intrinsic characteristics of the superconductor. The latter is due to small effect of the constituents in the wire, which give rise to a compressive residual strain in the superconductor. The reversible strain limit of the wires was small, 0.25% at the most, and the degradation behavior beyond it was very steep. Changing the wire construction, adopting reinforcements, which result in high compressive residual strain in the superconducting core and multiplication of the number of core, will improve the inferior strain characteristics mentioned above. Observations on the longitudinal sections of the samples degraded by straining clarified that cracks are nucleated and propagate associated with the voids in un-reacted Ta-Sn-Nb core and $(Nb,Ta)_3Sn$ superconducting core adjacent to it. Fracture surface showed the evidence of grain growth occurred at heat treatment, which will control the I_c and its strain characteristics.

ii) Silver alloy sheathed Bi-2223 tapes:

Tensile tests and bending tests on commercial 57 core and 55 core Bi-2223 tapes with silver alloy sheath were measured at 77K, zero field and 4.2K, 14T. The mechanisms of degradation of the I_c by stressing were investigated through the SEM observations of the damages both in macroscopic and microscopic scales.

Effects of external reinforcement by soldering with stainless steel and brass tapes onto the Bi-2223 tapes on tensile and bending strain characteristics of I_c were examined. The tensile stress-strain characteristics were improved by the reinforcements. On the other hand, no significant change was found in the str ain characteristics of I_c. This is because that the yield stress of Ag alloy was essentially high and the strain state in Bi -2223 cores is not significantly changed as the thermal expansion coefficient of reinforcing metal is close to that of the Ag alloy.

An improvement of the characteristics was expected due to the movement of neutral axis towards the tensile side of the cross section. Contrary to the expectation, the bending strain characteristics beyond 0.2% strain was markedly degraded by the reinforcement on both situations; reinforcement on the inside of the center of curvature and that on the opposite side (Fig. 2). It was clarified by the observations of the longitudinal section of the tapes that localized damages in the Bi -2223 core by buckling of the tape have taken place.

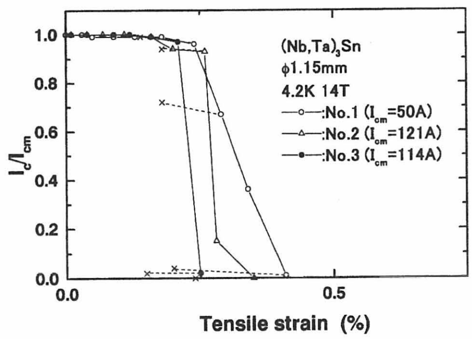

Fig. 1 Strain dependence of I_c in $(Nb,Ta)_3Sn$ wires.

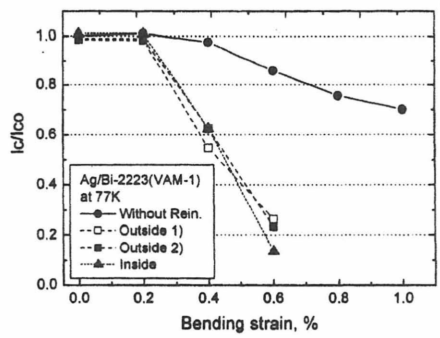

Fig. 2 Bending strain dependence of I_c in externally reinforced Ag alloy sheathed Bi-2223 tapes

Reference

1) Tachikawa, K. et al, Adv. Cryog. Eng. Ma ters. **46**, (2000) 1027
2) Katagiri, K et al, Adv. Cryog. Eng. Maters. **36**, (1990) 69