§5. Evaluation of Mechanical Properties of Superconducting Wires and Investigation of their Damage Process

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1. Introduction

Due to its high Bc_2, Nb_3Sn superconducting wires are widely used for high field superconducting magnets. However the critical current, I_c, of them is known to be very sensitive to the applied stress/strain. Therefore the effect of stress/strain especially in high magnetic field on I_c has to be evaluated. Allowable space for the experiment in the 15 T magnet is a bore with 50mm diameter. Since a magnetic field perpendicular to a wire axis is more sensitive to I_c than the other directions, a wire has to be located and loaded along the direction of the bore diameter. The tensile experimental Rod of this research is the apparatus with which the above required experiment in a narrow space can be conducted. In this year, modifying the Rod for cyclic load being applied, cyclic stress/strain effect on I_c of one of the bronze process Nb_3Sn wires (diameter d=0.75mm, initial critical current I_{c0}=140A), was evaluated with it.

2. Experimental results

Stress/strain and I_c degradation curves at 4K, 14.5T are shown in Fig.1. General characteristics of Nb_3Sn wire, that compressive strain as well as tensile strain equally degrades I_c and I_c increases at initial tensile loading because of pre-compression of Nb_3Sn by cooling, were obtained also in this wire. After the static loading test up to 182MPa, the cyclic stresses, 182MPa N=100 then 226MPa N=100, were applied to this wire. Fig.2 shows the results of the cyclic stress tests. Strain and I_c at unloading after each cyclic stress stage (open circle plots of the figure) kept the values of around 0.5% and 93% of I_{c0} respectively. These values are on the curves of initial static stress/strain and I_c degradation curves (dot lines), hence the wire behaves reversibly on cyclic stresses. The following 226MPa degraded I_c at initial loading to 75% of I_{c0}. Although I_c at unloading kept 92% of I_{c0} for initial 10 cycles, it decreased gradually after that cycle. The wire after this I_c degradation experiment was glued in resin and ground the sections for SEM observations of longitudinal sections. Fig.3 is one of the SEM observations. Micro-cracks initiated on some filaments are the one of the causes for irreversible behavior on 226MPa cyclic loading. However these micro-cracks were found on the very few filaments in the wire.

From the results above, irreversible stress/strain and I_c degradation by cyclic stress are not observed when the applied stress corresponds to less than 20% of I_c degradation. On the other hand, those are observed when the applied stress corresponds to 25% of I_c degradation. Micro-cracks are initiated on the very few filaments and grow slowly.

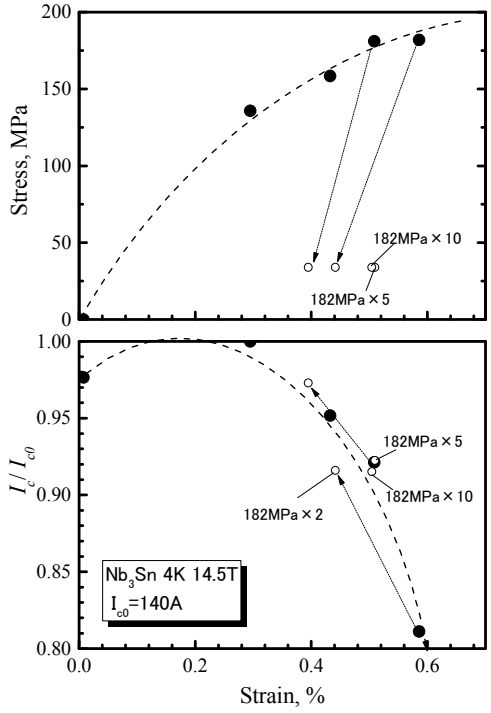

Fig.1 I_c dependence on static loading (cyclic data to N=10 are also in the figure)

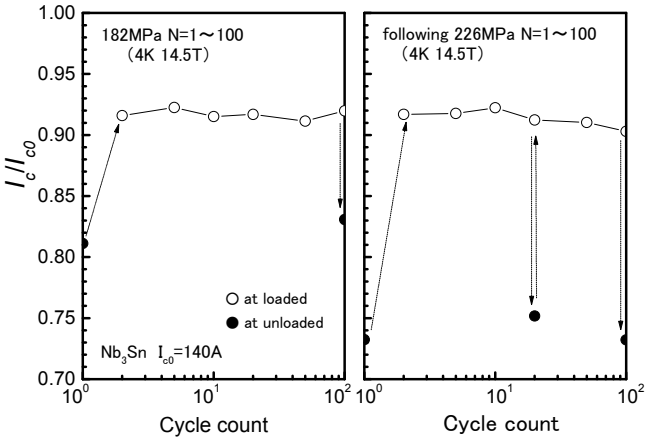

Fig.2 I_c dependence on cyclic loading 182MPa N=100 and the following 226MPa N=100

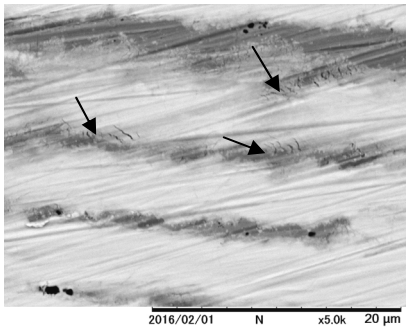

Fig.3 Longitudinal section of the wire after cyclic loading 226MPa N=100. Micro-cracks (indicated by arrows) are initiated on one of the filaments of the wire