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Nb-rod-method Cu-Nb/Nb_3Sn wires for practical React-and-Wind applications

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Introduction

- The superconducting performance of Nb_3Sn wires changes due to strains.
- In the Wind and React (W&R) method, the Nb_3Sn filaments are subjected to large compressive residual strain and the superconducting property deteriorates.
- In the React and Wind (R&W) method, the bending strain (pure-bending strain) remains in Nb_3Sn filaments of the wire and reduce the superconducting property.
- In both methods of the W&R and the R&W, several strains add to the Nb_3Sn filaments by electromagnetic forces during energizations of the high magnetic field magnets.
- To deal with these problems, we have successfully developed the Cu-Nb reinforced Nb_3Sn wires for the R&W method.
- In this study, the Cu-Nb/Nb_3Sn wires of new cross-sectional designs were investigated to improve the engineering critical current density (J_e) under some strains by applying the pre-bending treatment. Also, we discussed the cross-sectional design of Cu-Nb/Nb_3Sn wire suitable for practical R&W Nb_3Sn applications.

Cu-Nb/Nb_3Sn Wire Parameters

MAIN PARAMETERS OF CU-NB/NB_3SN WIRES

Design	New		Previous
Wire	H-Jc	REC	25-CSM
Dimension (mm)	φ0.80	1.13^t x 1.7^w-0.3^R	φ0.80
Filament dia. (μm)	3.0	3.2	3.3
Twist pitch (mm)	24	50	24
Bronze	Cu-15.7wt%Sn -0.3wt%Ti		Cu-14wt%Sn -0.2wt%Ti
Sn diffusion barrier	Nb		Ta
Cu/Cu-Nb/non-Cu (%)	30 / 20 / 50		20 / 35 / 45
Superconductor	Bronze- processed Nb_3Sn		
Reinforcement	Nb-rod-method Cu-20vol%Nb		

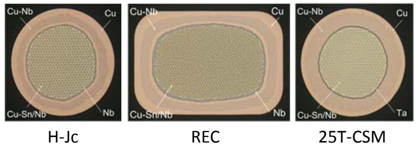

Fig. 1 Cross-sections of unreacted Cu-Nb/Nb_3Sn wires.

Performance Test Results

Non-Cu-J_c under Compressive Stress

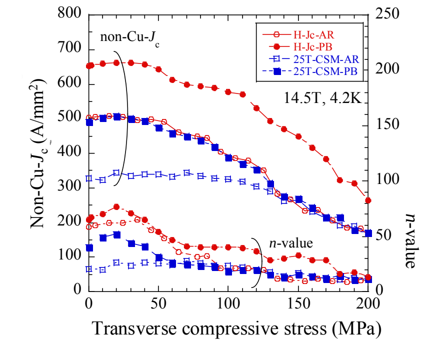

Fig. 5 Non-Cu-J_c and n-value characteristics of round wires under transverse compressive stress. (I_c def. 10μV/m)

Non-Cu-J_c under Pure-Bending Strain

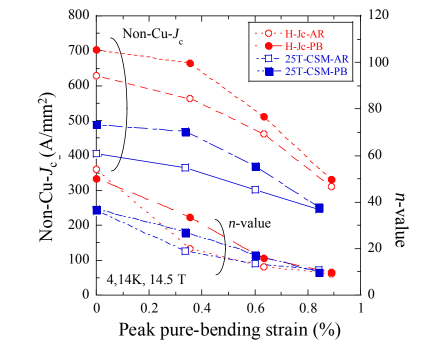

Fig. 6 Non-Cu-J_c and n-value characteristics of round wires under Peak pure-bending strain. (I_c def. 10μV/m)

Non-Cu-J_c– B Characteristics

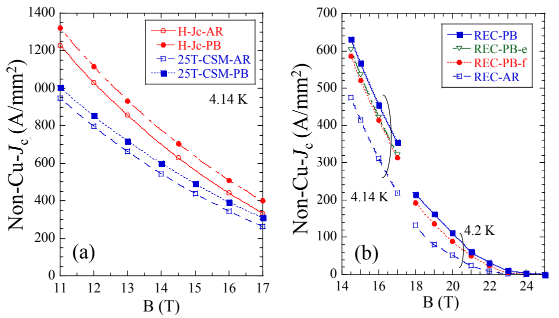

Fig.2 Non-Cu-J_c-B Characteristics (I_c def. 10μV/m)

Non-Cu-J_c under Tensile Stress at 14.5 T

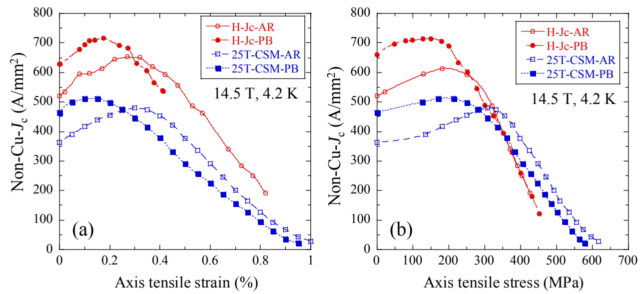

Fig. 3 Non-Cu-J_c characteristics at 14.5 T of H-Jc wires under tensile strain and stress, which are compared with 25T-CSM wires. (I_c def. 10μV/m)

Non-Cu-J_c under Tensile Stress at 18 T

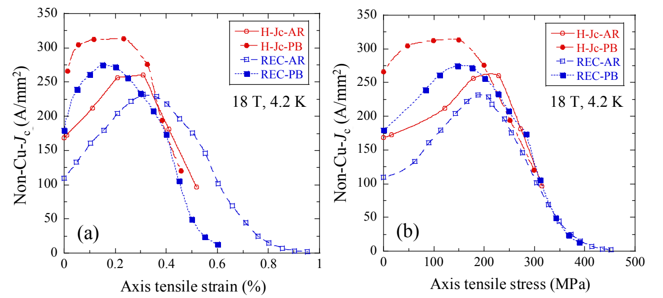

Fig. 4 Non-Cu-J_c characteristics at 18 T of Rectangular wires under tensile strain and stress, which are compared with H-Jc wires. (I_c def. 10μV/m)

Mechanical characteristics at Room Temperature

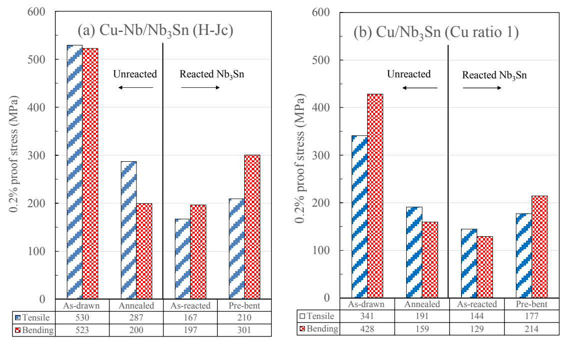

Fig. 7 Comparisons of 0.2% tensile proof stress and 0.2% bending proof stress at R.T. between Cu-Nb/Nb3Sn wire (H-Jc) and conventional Cu/Nb_3Sn wire (Cu ratio 1)

Advanced design of Cu-Nb/Nb_3Sn wire

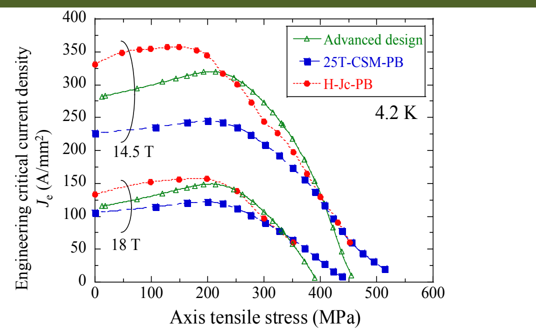

Fig. 8 Comparison of engineering critical current densities under axis tensile stress between Cu-Nb/Nb_3Sn wires with different cross-sectional designs.
(Properties of the advanced design were calculated by using measured values of H-Jc-PB and 25T-CSM-PB.)

Conclusions

- New-designed Cu-Nb/Nb_3Sn wires were successfully developed by composing of high tin bronze (Cu-15.7wt%Sn-0.3wt%Ti).
- The 0.8 mm round wire with pre-bending strain of ± 0.5%, of which non-Cu-Jc was 1150 A/mm² at 12 T and 4.14 K, demonstrated high non-Cu-Jc of more than 600 A/mm² until tensile stress of 250MPa at 14.5 T, 4.2 K.
- The rectangular wires of 1.13^t x 1.7^w-0.3^R mm² achieved the highest non-Cu-J_c of 355 A/mm² at 17 T, by alternately pre-bending of ± 0.5% from both directions of flatwise and edgewise.
- The appropriate pre-bending treatment enable the Cu-Nb/Nb_3Sn wires to increase not only superconductive characteristics at cryogenic temperature, but also mechanical characteristics for R&W process at room temperature.
- The advanced Cu-Nb/Nb_3Sn wires are able to be designed to optimize superconducting properties according to the target application.