Irreversible Strain Limit of Technical RHQT Nb_3Al Superconductors

MT25-Mon-Af-Po1.08-09 [118]

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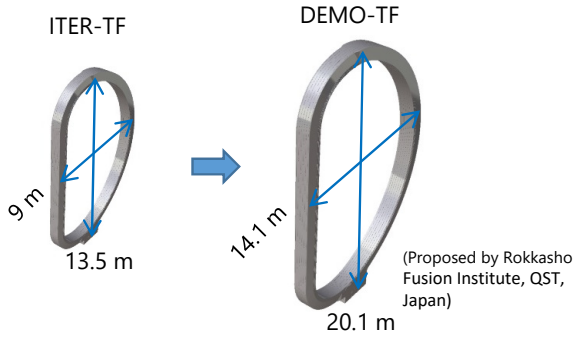
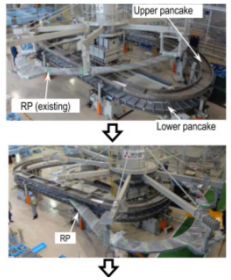
Background



ITER Coil fabrication: "**Wind & React**" process
Problems
- Complicated process for conductor transfer into radial plate
- Influence of thermal contraction
- Large facility for heat treatment

DEMO → more serious



Conductor transfer

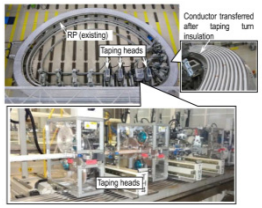


Fig. 2. Transfer of the conductor with turn insulation of the proto regular DP.

K. Koizumi, M. Nakahira, M. Matsui, T. Hemmi, et al., "Progress in procurement of ITER toroidal field coil in Japan," *IEEE TAS.*, (26) 2016, 4203004.

One solution: "React & Wind" process

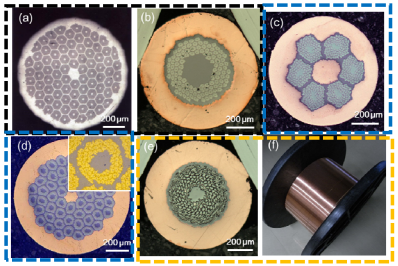
Nb_3Al strand is one of the alternative conductors, because it has less strain sensitivity to J_c characteristics

Irreversible strain limit:
An important factor as well as the strain sensitivity
An index indicating how much the strand is bendable

Objectives in this work

- Comparison of the irreversible strain limit of various technical RHQT (rapid-heating, quenching and transformation) processed Nb_3Al strands
- Observation of micro-cracks in the filaments

Standard Nb or Ta matrix Restacked fine filament



Ag barrier

Recent development
- Good drawability for precursor wire.
- Suppression of filament coupling

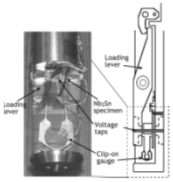
N. Banno, T. Takeuchi, Y. Iijima, G. Nishijima, H. Kitaguchi, K. Miyashita, "Development of Ag-barrier RHQT Nb_3Al wires," *IEEE TAS.*, (27) 2017, 6000304.

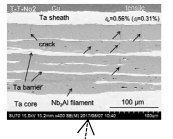
TABLE I
SPECIFICATIONS OF TESTED Nb_3Al STRANDS

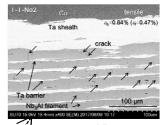
Sample No.	1	2	3	4	5
Sample ID	ME282	T-T-No2	M37-1	M28-4	ME618
Wire diameter (mm)	0.98	0.85	0.81	1.0	0.85
(Diameter of filamentary region)	(0.88)	(0.47)	(0.61)	(0.78)	(0.47)
Filament diameter (μm)	108	31.3	17.8	7.7	23.2
Number of filaments	84	114	468 (=78 × 6)	3564 (=66 × 54)	222
Sheath material	Nb	Cu/Ta	Cu	Cu	Cu/Ta
Barrier material	Nb	Ta	Nb	Ta and Nb	Nb/Ag/Nb
Matrix ratio to filaments	0.59	1.34	0.85	1.654	1.11
Stabilizer/non-stabilizer ratio	–	1.78	1.3	0.84	2.49
I_c (A)	400@17 T	71.6@15 T	177.1@15 T	223@15 T	103@15 T
(Non-Cu J_c (A/mm^2))	(530.3)	(350.8)	(790.5)	(522.4)	(633.5)

Experimental results

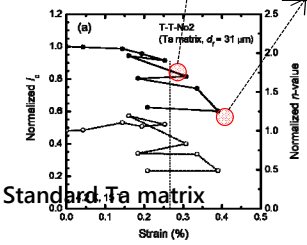
Ic-strain equipment
(G. Nishijima, IEEE TAS (20) 2010, p1391)

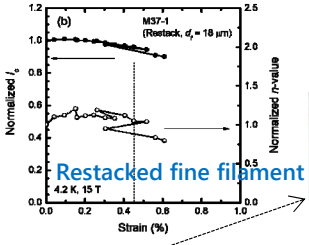




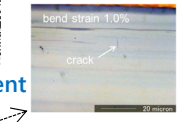


Partly, cracks are concentrated.
→ rapid Ic degradation



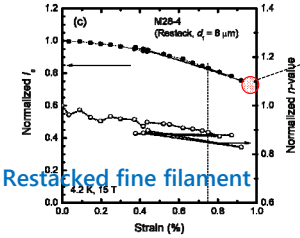


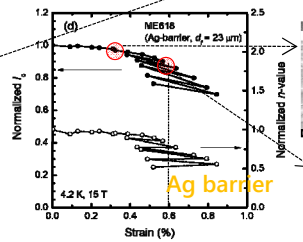
Almost no cracks



Standard Ta matrix

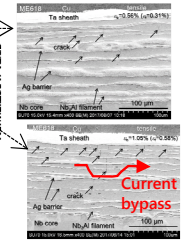
Restacked fine filament





Restacked fine filament

Ag barrier



Cracks are distributed. Slow Ic degradation.

Conclusion

- **Refinement of the filament diameter** allows significantly to improve the irreversible strain limit of the RHQT Nb_3Al wires.
- In a practical point of view, **Ag-barrier structure** wires appears attractive. The Ag-layer located between the filaments could act as a cushion to mitigate the stress concentration under the strain
  and also play an important role of current bypass in the existence of cracks.