Study on High Jc and Low AC Loss NbTi/Cu5Ni Superconducting Wire for HIAF Magnets in WST

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Introduction

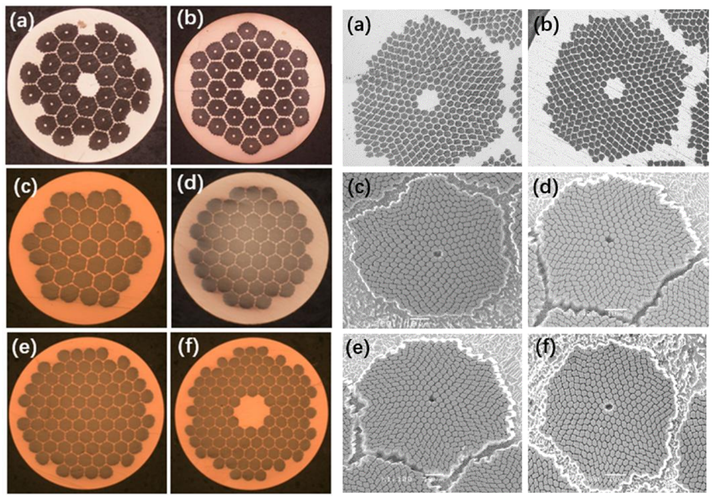
HIAF(IMP, China) is High Intensity Heavy-Ion Accelerator Facility , which works with fast pulse current. Parts of the accelerator magnets will be built by superconducting wires. Low AC losses was required in coils of HIAF magnets. The main contribution of the AC losses are hystere-sis loss and eddy current losses. Thin filaments to reduce hysteresis loss and a resistive (Cu-0.5%Mn or Cu-5-10% Ni) inter-filamentary matrix to reduce the inter-filamentary eddy current losses are needed in a superconducting wire. And the wire with a filament twist pitch as small as possible without degradation of the critical current density has to be developed for HIAF magnets.

Experimental

The Cu-5 wt.% Ni alloy, Nb47-wt.% Ti and oxygen free copper(OFC) were used to manufacture superconducting wires. The design meets these specifications: outer diameter 0.80mm, filament size less than 5 μm. These wires were twisted with a pitch of 9-11 mm and annealed at the final size between 210 - 250℃.

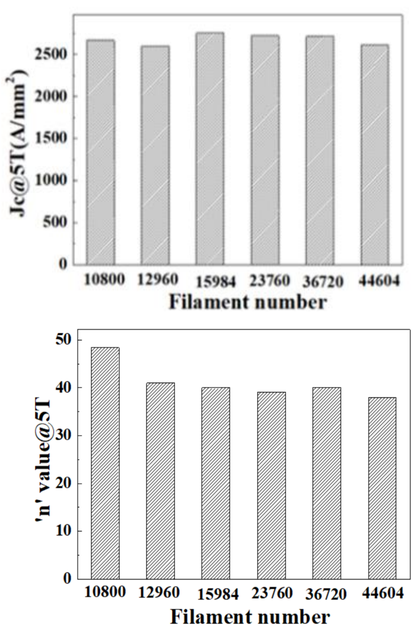
Critical current, I_c, were measured using the standard procedure with the criterion E= 0.1μV/cm on 1.5m long samples. The Residual Resistance Ratio (RRR) were tested according to the International Standard requirements IEC 61788-4. According to IEC 61788-13, Hysteresis losses were measured using a vibrating sample magnetometer with magnetic field amplitude up to ±3 T in Ningbo Institute of Industrial Technology, CAS. The effective filament diameter, D_{eff} , was estimated by a width magnetization loop at 3 T, using equation: $D_{eff} = 3\pi\Delta M/4\alpha J_c$ (where α is the volume fraction of superconducting filaments, J_c is the critical current density at 3 T).

Results and Discussion



The cross sections of the 0.8 mm wires : (a), (b), (c), (d), (e), (f) are the wires with the filaments number of 10080, 12960, 15984, 23760, 36720 and 44064

- Each subelement has its own CuNi matrix and these CuNi barriers forms a special barrier against coupling currents.
- The wires are evenly distributed and the filaments are well deformed with different design.
- Some filaments in the outer region of the wire were elongated during the drawing process.



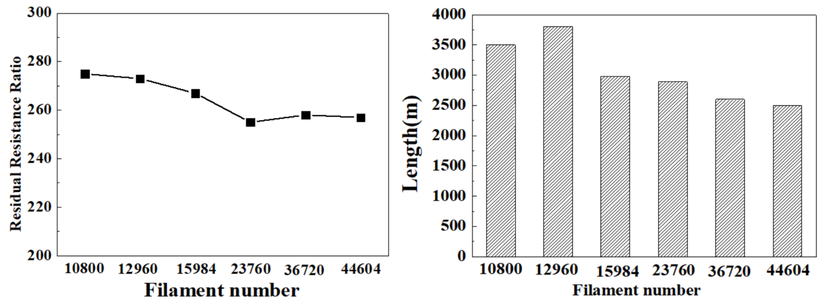
Critical current density and the 'n' value of the wires with different design at 5 T&4.2 K

- The J_c at 5 T&4.2 K with different design wires are between 2600 and 2700 A/mm². The *'n'* value with different design wires are between 35 and 48, which demonstrates there is no filament breakage occurs in the wire and a high filament quality.

HYSTERESIS LOSSES AND EFFECTIVE DIAMETER

Type of wire	Losses, ±3T (mJ/cm³)	D_{cal} (μm)	D_{eff}, ±3T (μm)	D_{eff}/D_{cal}
Design 1	38.5	4.5	4.9	1.08
Design 2	34.7	4.1	4.6	1.12
Design 3	34.3	3.8	3.9	1.03
Design 4	33.6	3.3	3.6	1.12
Design 5	32.7	2.8	3.3	1.18
Design 6	26.2	2.5	2.6	1.06

- When the diameter of NbTi filament reduces from 4.5 to 2.5 μm, the hysteresis losses with different design reduces from 38.5 to 26.2 mJ/cm³ at ±3T. The ratio of D_{eff} / D_{cal} for these wires is 1.03 to 1.18, which indicates that the wire has both high critical current density and small hysteresis loss.



- The RRR is more than 200, which could meet the engineering application requirements.
- All designed wires have been obtained a kilometer long length and the maximum drawing length is about 3800 m.

Conclusion

- The NbTi wires with Cu-5 wt.% Ni inter-filament matrixs were successfully fabricated by double stacking method. The best performance was achieved in the wire with 4 HT at 4.2 K a J_c =2757 A/mm² at 5 T. A wide database on J_c and hysteresis losses data were obtained for the wires with the filament diameter of 2–5 μm and Cu-5 wt.% Ni inter-filament matrix.
- When the diameter of NbTi filament reduces from 4.5 to 2.5 μm, the hysteresis loss reduces from 38.5 to 26.2 mJ/cm³ at ±3T. The ratio of D_{eff} / D_{cal} for different design wires is 1.03 to 1.18.
- The NbTi/Cu5Ni superconducting wire with the J_c of 2616 A/mm² at 5 T&4.2 K, with the filament diameter of 2.5 μm, with the hysteresis of 26.2 mJ/cm³ at ±3T, with the average length of 2500 m per piece, was achieved during the mass production in WST.
- WST has successfully mastered the production technology of fine filament, low loss and high J_cNbTi/Cu5Ni superconducting wire.

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