HEAT TREATMENT STUDIES OF Nb_3Sn WIRES FOR SUPERCONDUCTING PLANAR UNDULATORS

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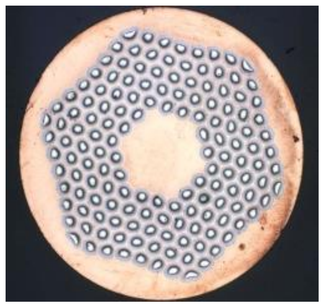
Abstract

An ANL APS group and the FNAL High Field Magnet team paired forces to develop a double undulator of 2.8 m total length made of Nb_3Sn, to be installed in the APS storage ring. In addition to providing a larger temperature margin than NbTi, Nb_3Sn undulators are expected to increase the magnetic field in the electron beam aperture by 50%.

STRAND PARAMETERS

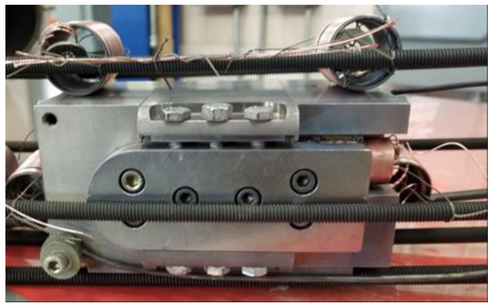


150/169 and 144/169 RRP® wires.

Table 1: Strand Parameters

Strand ID	RRP1	RRP2
Stack design	150/169	144/169
Ternary element	Ti	Ti
Production year	2018	2019
Diameter *d*, mm	0.601	0.602
I_c (4.2K, 12 T), A	345 ± 2	336 ± 3*
J_c (4.2K, 12 T), A/mm^2	2,426 ± 7	2,499 ± 23*
D_S, μm	35	35
Twist pitch, mm	14.5 ± 0.4	16
Cu fraction λ, %	50 ± 0.1	52.4
RRR	93 ± 11	143 ± 11
Final HT step	650ºC/50 h	640ºC/50 h

Sample heat Treatment



Short model SMM5 in reaction fixture.

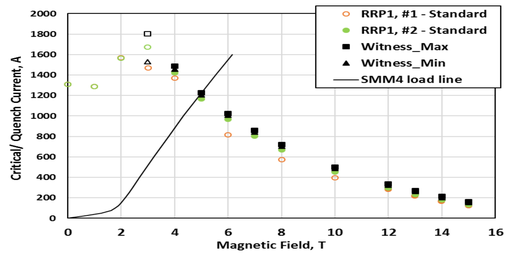
Table 2: Heat Treatment Schedules

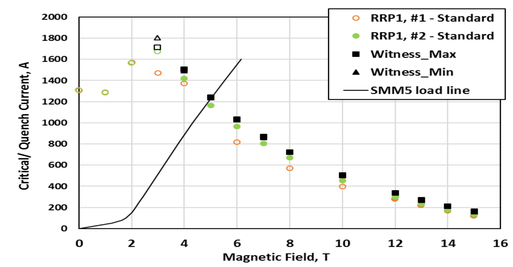
	Step 1		Step 2		Step 3	
Coil	Temp,°C	Time,HR	Temp,°C	Time,HR	Temp,°C	Time,HR
SMM4	209 ± 1	48	369 ± 2	104	651 ± 1	50
SMM5	210 ± 1	48	369 ± 2	104	650 ± 1	50
SMM6	210 ± 1	48	371 ± 1	104	650 ± 1	50
IMM1*	210	48	370	104	650	50
STUDY	210 ± 2	48	401 ± 1	48	649 ± 1	50

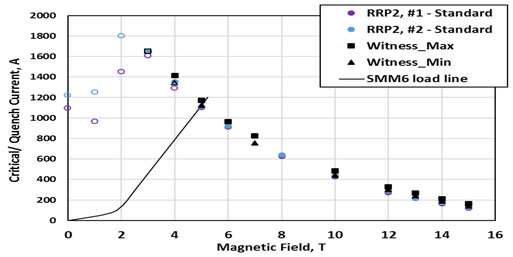
Table 3: Result Summary

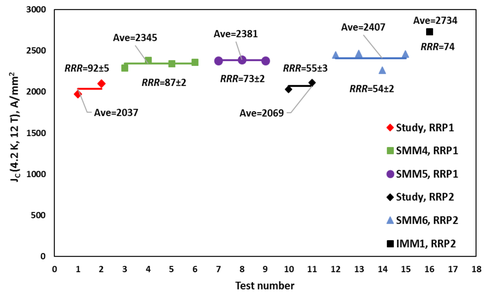
Coil	Wire	Ave. I_C(12 T), A	Ave. RRR	Coil RRR	SSL, A
SMM4	RRP1	332 ± 2	87 ± 2	51	1220
SMM5	RRP1	336 ± 1	73 ± 2	51	1231
SMM6	RRP2	324 ± 6	54 ± 2	52	1132
IMM1	RRP2	368	74		1213
STUDY	RRP1	288 ±6	92 ± 5	-	1183*
"	RRP2	279 ± 4	55 ± 3	-	1114

RESULTS AND DISCUSSION









CONCLUSIONS

- ANL and FNAL develop a double undulator of 2.8 m total length made of Nb_3Sn, to be installed in the APS storage ring.
- Of the three phases of this project, the first one was successfully completed. Six short Nb_3Sn models of 4.5 periods length and 10 poles were designed, fabricated and tested.
- For short magnet models SMM2 to SMM6, a non-standard heat treatment was used to increase the expected Jc and also the desired stability behavior in the operation field region.
- The same two Restacked Rod Processed (RRP®) wires that were used in the winding of the short model magnets were studied when subjected to the standard heat treatment.
- Critical current I_c and Residual Resistivity Ratio *RRR* were measured and compared with those of the witness samples used for short model magnets SMM4, SMM5, and SMM6.
- It was found that whereas the average I_c*(12 T, 4.2 K)* of the witness samples of all three coils was 16% larger than in the standard heat treatment, their stability behavior was better in the low field region.
- The non-standard heat treatment selected for the undulator small models was therefore most appropriate to achieve the expected short sample limits for these magnets.