OPTIMIZATION OF THE HEAT TREATMENT SCHEDULE FOR NEXT EUROPEAN DIPOLE (NED) POWDER IN TUBE NB_3SN STRAND*

T. Boutboul, L. Oberli, CERN, Geneva, Switzerland
A. den Ouden, University of Twente, the Netherlands, D. Pedrini, G.. Volpini, INFN, Milan, Italy.

Abstract
A Nb_3Sn strand was successfully developed by the company SMI for Next European Dipole (NED) activity and on the basis of Powder-In-Tube (PIT) method. This strand, after the standard reaction recommended by the firm (84 h @ 675 ^oC), presents attractive performances as a critical current density in the non-copper part of ~ 2500 A/mm^2 for 4.2 K and 12 T applied field, an effective filament diameter of ~ 50 µm and limited flux jumps at low magnetic fields. Heat treatment optimization studies are currently performed at CERN to try to optimize the strand electric abilities. For this purpose, various heat treatment schedules were already investigated with a plateau temperature as low as 625 ^oC. The preliminary results of these studies are summarized here.

INTRODUCTION

The Next European Dipole (NED) project is a Joint Research activity of the Coordinated Accelerator Research in Europe (CARE) program [1]. Initially, the main goal of NED was to design, to develop and to build a large aperture and high-field (~ 15 T) dipole magnet. However, due to financial constraints, NED was mainly limited to the development and the fabrication of a high-performance Nb_3Sn conductor. The strand specifications for NED, summarized in [2], are very demanding. Indeed, in addition to very high critical currents targeted, corresponding to 3000 A/mm^2 in the non-copper part at 4.2 K and 12 T applied field, an effective filament diameter of ~ 50 µm is requested for a strand diameter of 1.25 mm. To achieve this goal it is then necessary to stack between 250 and 300 sub-elements within the final wire, which is obviously not a trivial task. In 2004, two orders were placed at Alstom-MSA (Internal Tin method) and SMI (Powder In Tube route).

During the R&D phase, SMI developed successfully [2] a strand, B215, including 288 filaments (~ 50 µm in diameter). This strand was produced in a lone length of 950 m and the maximal critical current ever measured for the heat treatment (HT) schedule recommended by the firm (84 h @ 675 ^oC) is 1397 A, corresponding to ~ 2500 A/mm^2 in the non-copper part at 4.2 K and 12 T. This strand presents fair RRR values (in the 70-80 range) and magnetization measurements showed only few flux jumps [2-3].

Following the reaction HT, the Nb_3Sn phase of a PIT strand is composed of a coarse grain region (1-2 µm in diameter, ~ 30 % of the A15 phase) and fine grain area (~ 200 nm). These coarse grains have a negligible contribution to the critical current. In addition, smaller fine grains, in principle obtained with lower temperature heat treatments, are more favourable from critical current point of view. Therefore, in this work, the idea was to optimize the critical current of the B215 PIT wire by decreasing the reaction temperature in order to, tentatively, further reduce fine Nb_3Sn grain size and to lower coarse grain ratio in overall A15 phase. The main results of this study are presented here.

*This work was supported in part by the European Community-Research Infrastructure Activity under the FP6 “Structuring the European Research Area” program (CARE, contract number RII3-CT-2003-506395

MAIN RESULTS

Due to limited amount of available B215 strand, a systematic optimization study with a broad scanning of both reaction temperature and duration was not feasible. Instead, a specific HT schedule was selected, the critical current and the RRR were measured and the cross-section of the reacted strand was examined by means of a microscope to evaluate the extent of the reacted area. At last, according to these results, the next HT schedule was chosen. Treatments were performed with a plateau temperature between 625 ^oC and 675 ^oC and a duration in the 84-320 hours range.

120 h @ 650 ^oC

- I_c data was found to be ~ 1 % larger than for standard HT (84 h @ 675 ^oC), in non-copper part J_c ~ 2520 A/mm^2.
- Cabling degradation appeared to be fairly reasonable: 4-8 % as compared to 10-12 % degradation observed for standard HT.
- RRR > 100 for virgin strand, i.e. better than standard HT (70-80). For extracted strands, no observed degradation (RRR ~ 100), contrary to standard HT (RRR ~ 30-60).

320 h @ 625 ^oC

- I_c ~ 1500 A @ 12 T and 4.2 K, + 7 % as compared to standard HT, in non-copper part J_c ~ 2670 A/mm^2!! New world record for a PIT strand!
- High RRR data for virgin strands: RRR ~ 220

SEM examinations

- Such examinations showed that, despite the 7 % increase in I_c, 320 h @ 625 ^oC sample presents slightly less reacted Nb_3Sn than standard HT sample.
- 320 h @ 625 ^oC sample has indeed higher quality Nb_3Sn with a higher Sn content (24.7

at. % Sn versus 24.2 at. %) and a lower mean fine grain size (~ 160 nm versus ~ 180 nm).

- However, reducing reaction temperature did not reduce coarse grain area which remains ~ 30 % of the total reacted Nb_3Sn region.

PERSPECTIVES

Measurements are currently underway at Nijmegen University to confirm the excellent critical current results for 320 h @ 625 ^{o}C and to assess the cabling degradation on both I_c and RRR. An additional heat treatment will be shortly launched at 625 ^{o}C but with duration longer than 320 hours in order to assess the critical current limits of the B215 PIT strand.

ACKNOWLEGMENTS

Many thanks to: E. Barisone, A. Bonasia, Z. Charifoulline, S. Geminian, P. Jacquot, G. Jesse, D. Leroy, S. Mathot, D. Richter, J.-L. Servais (CERN), B. Seeber (Geneva University), S. Wessel (Twente University).

REFERENCES

[1] A. Devred et al., Supercond. Sci. Technol. 19 (2006) S67-83.

[2] T. Boutboul et al., “Nb_3Sn conductor development and characterization for NED”, J. Phys.: Conf. Ser. 97 (2008) 012211.

[3] A. Devred, T. Boutboul and L. Oberli, “Status of NED conductor development”, IEEE/CSC & ESAS European Superconductivity News Forum (2007), ST5.