Workshop on Radiation Effects in Superconducting Magnet Materials 2015 (RESMM'15)

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Correlation between the dpa number and Tc in Nb3Sn wires for HL-LHC

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Content :

The thermal stability of the Nb3Sn quadrupole magnets in the High Luminosity LHC Upgrade (HL-LHC) accelerator at CERN during operation up to 4'000 fb-1 is an important issue. After introducing a W shield, the radiation load (by high energy neutrons, protons, pions, and especially electrons, positrons, and gammas) on the innermost windings of the quadrupoles will be considerably reduced, and a total dpa value of 2.4 x 10-4 has been calculated, mostly due to the hadronic shower component [1]. An experimental study was performed about the corresponding effects of this radiation load on the superconducting properties of the Nb3Sn magnets. In order to get a better picture of the irradiation effects caused by the multiple high energy sources in HL-LHC, a comparative study was undertaken involving both, high energy protons (60 MeV and 24 GeV) [2] and 1 MeV neutrons [3]. Both types of irradiation were carried out on the same Ta and Ti added multifilamentary Nb3Sn wires.
Several properties were found to exhibit a similar behavior up to 1.4 x 10^21p/m2 (steady loss zone of proton irradiation) and up 1.8 x 10^22n/m2: a) the value of Tc decreases linearly, b) Bc2 increases by 5 and 3%, respectively, c) Jc increases by a factor of 2 and 1.5, respectively, reaching the remarkably high values of the order of 11.0 x 10^3A/mm2 at 4.2 K / 10 T, d) the enhancement of Jc can in both cases described by a quantitative two-force model [2,3], with a strong enhancement of the point pinning contribution.
A calculation of the dpa values based on the FLUKA code shows that for both proton and neutron irradiation, the variation of Tc with the dpa value in the dpa range between 1 x 10-4 and 1.4 x 10-3 is very similar. This "universal" behavior of Tc vs. dpa can be used for predicting the decrease of Tc in the HL-LHC quadrupoles: using the total dpa value given above, a first estimation of ΔTc yields a value of ~ 0.3 K.

(1) A. Lechner, L. Esposito, F. Cerutti, A. Ferrari, G. Steele, N.V. Shetty, N. Mokhov et al., presented at the RESMM'14 in Wroclaw (Poland).
(2) T. Spina, C. Scheuerlein, D. Richter, B. Bordini, L. Bottura, A. Ballarino, R. FIükiger, ASC 2014, Published in Applied Superconductivity, IEEE Transactions on (Volume:25 , Issue: 3)
(3) T. Baumgartner, M. Eisterer, H.W. Weber, R. FIükiger, C. Scheuerlein, L.

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