Magneto-Optical Study of Effect of Deformation of Nb$_3$Sn Multifilamentary Cables

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Introduction

Several factors can degrade the performance of Nb$_3$Sn strands, especially plastic deformation and precompression during cabling and magnet fabrication. Lorentz forces can damage strands during magnet operation at high fields, while at low fields filament deformation can induce magnetic instabilities which can induce quench. To simulate the damage during Rutherford cabling, rolling deformation was applied to single strands so as to produce an easily controlled deformation. Wires were reacted after rolling deformation, allowing the effects of damage to the strand architecture to show themselves in the superconducting properties.

Experimental

Magneto-optical imaging based on the Faraday Effect in ferrimagnetic garnet films was used to analyze trapped superconducting state magnetic flux behavior of the rolled strands. Magnetization and $T_c$ measurements were used to characterize undeformed (round) and deformed strands of RRP (Restack Rod Process) and PIT (Powder-in-Tube) Nb$_3$Sn strands. A Scanning Laser Confocal microscope was used to image the strand cross-sections. Magneto-optical and magnetization measurements were carried out at T=12 K so as to avoid any signal due to the Nb barriers surrounding the Nb$_3$Sn, The 1 mm diameter of virgin round strands were reduced to final thickness 0.5 mm with a few rolling steps.

Results and Discussion

Images show that RRP and PIT strands deform differently, namely PIT configuration has less broken and merged sub-bundles than RRP at the same stage of deformation (Figs. 2a and 3a). However Magneto-Optical images show interesting features, which are not visible by light microscopy. On early deformation (Fig. 1a- 0.8 mm) there are no broken sub-bundles in optical images, but MO clear shows that some sub-bundles are already broken and do not trap magnetic flux well (Fig. 1b). Rolling to 0.6 mm broke down many sub-bundles (Fig. 2a) in RRP strand, which did not trap flux well (Fig. 2b). A variation of Magneto-Optical contrast is quite visible in PIT samples, reflecting non-uniform damage on left site (Fig. 3b).

Conclusion

Magneto-Optical technique can be a powerful tool for the detection of damage during Nb$_3$Sn strand cabling.

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References