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3D X-Ray Micro-Tomography as a Tool for Non-Destructive Characterization of Multi-Filamentary Superconducting Wires

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Practical superconducting cables used in large-scale applications (e.g. magnets for fusion reactor) consist in superconducting filaments embedded in a normal-conducting matrix. The common technique to reduce the eddy-current losses is to twist the wire and the filaments during the manufacture. This also reduces the time-independent proximity effect between the filaments and its associated loss. Currently, the only method for measuring the twist-pitch consists in evidencing the twisted structure by etching techniques. This method has two main drawbacks: it is destructive and does not permit the visualization of the Nb3Sn filaments. Here we demonstrate that X-ray micro-tomography overcome these drawbacks and permit a 3D non-destructive quantitative visualization of the multi-filamentary wire. This enables the determination of the number of inter-filament contacts on unite lengths. By post-processing the reconstructed volume data - nonlinear anisotropic diffusion filtering, intensity-based segmentation, contour filtering - one can derive an improved 3D model of the multi-filamentary structure. This model is used in the determination of the twist-pitch parameter by a method based on the monitoring the displacement of the centroid of each filament, while navigating inside the superconducting wire. The examination and analysis methods reported in this paper are validated by experimental results for Nb3Sn multi-filamentary wires for ITER. The high-resolution X-ray micro-tomography facility constructed at the Association EURATOM-MEdC (Romania), with European Community support, was used for the examination of the superconducting samples. The setup of the experiments enabled us to reach a fine spatial resolution of only few microns per image voxel. The results provided by the tomographic examination can be used to develop a more complex model of the multi-filamentary superconducting wire in order to explain the role of the internal wire structure on the superconducting transport properties and to optimize the fabrication process in terms of the hysteresis losses, critical current and the Cu/non-Cu ratio.