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Understanding mechanical behaviour of Nb₃Sn superconducting magnet coils by combined neutron diffraction and macroscopic stress strain measurements

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Reliable mechanical materials data are required for predicting the strain and stress state evolution during assembly, thermal cycling and powering of superconducting magnets. The ingredients for thermomechanical modelling of linear elastic and isotropic magnet materials behaviour are often available. However, taking into account anisotropic mechanical properties, the yielding and flowing of fully annealed Cu, the brittleness of Nb₃Sn, and the non-linear and irreversible thermal expansion of the Nb₃Sn conductor during reaction heat treatment is particularly challenging. The Nb₃Sn conductor block Young's modulus anisotropy and mechanical behaviour are explained based on in-situ neutron diffraction loading strain measurements at the MLZ Stress-Spec diffractometer. It is shown that the conductor block behaves like a fibre reinforced composite, with iso-strain and iso-stress in the conductor constituents under axial and transverse loading, respectively. The potential of different coil characterisation methods, notably digital image analysis and indentation hardness maps in metallographic coil cross sections, and residual strain mapping of collared coil assemblies by neutron diffraction, are compared.

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