# Princeton Plasma Physics Laboratory

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# Modeling of Imperfect $Nb_3Sn$ Superconducting Wires under Transverse Loading


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High field superconducting magnets play a very important role in many large-scale physics experiments, particularly particle colliders and fusion confinement devices such as LHC and ITER. The two most common superconductors used in these applications are NbTi and $Nb_3Sn$. $Nb_3Sn$ wires are favored because of their significantly higher Jc (critical current density) for higher magnetic field applications. The main disadvantage of $Nb_3Sn$ is that the superconducting performance of the wire is highly strain-sensitive and it is very brittle. This strain-sensitivity may be strongly influenced by cracked filaments. Cracks are induced by large stress concentrators that can be traced to the presence of voids in the wire.

We develop 2D and 3D finite element models containing $Nb_3Sn$ wire filament details and implement various experimentally measured distributions of initial voids in a bronze-route wire. We apply compressive transverse loads for various cases of void distributions to simulate the stress and strain response of the bronze-route $Nb_3Sn$ wire. Results from the 2D elastic finite element model show a correlation between the stress concentrations around the voids and the irreversible limits of bronze wires under transverse loads observed in experiments. A temperature dependent bilinear material model is developed for materials that the theory expects to become plastic and is tested on a 3D model of the cool-down process. This study improves our understanding of the effect voids have on the $Nb_3Sn$ wire's mechanical properties, and in so, the connection between the distribution of voids and performance degradation such as the correlation between irreversible strain limit and the void-induced local stress concentrations.

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