Further Exploration of Ultimate Limits of Flux Pinning in Nb_3Sn

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***Abstract* – Envisioned magnets for high-energy physics would demand unprecedented flux-pinning performance from Nb_3Sn conductors. Accordingly, recent research has questioned whether the native pinning by the grain-boundary network in modern conductors, with ~100 nm grain size, is able to attain the needed performance. One set of experiments has augmented grain-boundary pinning with intragranular damage clusters created by irradiation, which has a side-effect of increasing electron scattering and the upper critical field. A second group of experiments has sought to reduce grain size to < 50 nm by addition of zirconia and rare-earth oxide nanoparticles, which could also function as point pins. In both cases, the shape of the bulk pinning-force curve is improved for high-field applications, where the peak of the curve shifts from 20% to >30% of the irreversibility field. Stimulated by these efforts, we envision two experiments using thin films of Nb_3Sn, possibly obtained by deposition of Nb onto bronze, which could extend understanding further. Past work found that grain size could be varied from > 200 to < 20 nm for deposition at different temperatures, where the Nb_3Sn forms in-situ. These changes lead to a shift of the pinning-force curve peak toward higher field like the effects seen in present-day experiments. Coupling these films with subsequent exposure to proton irradiation allows a systematic variation of each potential pinning center to understand the balance of grain-boundary vs cluster pinning. It also achieves pinning conditions at the extreme of both methods. In the second experiment, gradients in pinning-center distribution could be realized by forcing Nb-Sn reactions to occur along thermal gradients and by using the diverging portion of an irradiation beam. Among the interesting physics questions posed by a gradient configuration are whether asymmetric critical states can be formed, whether field-cooled configurations with non-zero macroscopic current exist, and what the arrangement of pinned flux lines becomes.**

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