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Simple analytical formulae to evaluate the irregular field in solenoid coils with high-temperature superconducting tape wires

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The irregular field due to the screening current in high-temperature superconducting (HTS) tapes can bring about fatal impacts on the spatial and temporal uniformity of the magnetic field in MRI and NMR magnets using HTS tape wires. Although numerical evaluation is necessary to deal with the irregular field, accurate numerical computation of the irregular field in HTS coils requires huge computation costs and highly specialized technique.

Here we propose a simple theoretical evaluation of the irregular field in solenoid coils using HTS tape wires. Such rough but simple evaluation of the irregular field is very useful, especially in the early stage of the magnet design.

We derive a direct relationship between the irregular field in a coil and the magnetization of the tape wires. Assuming the simple distribution of the magnetization of tape wires in a solenoid coil, we derive analytical formulae to evaluate the irregular field in HTS coils. We have confirmed that our simple formulae can roughly and qualitatively evaluate the irregular field by comparing the accurate numerical results. We also propose a scaling law for the irregular field associated with the dimensions of solenoid coils: the ratio $B_{\mathrm{SC}}/B_{\mathrm{TC}}$ of the screening-current-induced irregular field B_{SC} to the transport-current-induced magnetic field B_{TC} is inversely proportional to the coil size.

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Primary authors: Dr MAWATARI, Yasunori (National Institute of Advanced Industrial Science and Technology (AIST)); Dr HIGASHI, Yoichi (National Institute of Advanced Industrial Science and Technology (AIST))

Presenter: Dr MAWATARI, Yasunori (National Institute of Advanced Industrial Science and Technology (AIST))

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