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A FEM/BEM scalar potential formulation for 3D nonlinear magnetostatic analysis in superconducting accelerator magnets, implemented in PITHIA-EM software

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Superconducting magnets used in particle accelerators produce magnetic fields of high precision and uniformity to bend or focus the particle beam. For such magnets, the development of accurate and efficient numerical methods for the evaluation of the magnetic fields is of high importance. This work presents a hybrid Finite/Boundary Element Method (FEM/BEM) scalar potential formulation, implemented in PITHIA-EM software, capable of solving three –dimensional nonlinear magnetic problems in accelerator magnets. The present FEM/BEM formulation combines the advantage of FEM in treating problems with material nonlinearities and the efficiency of BEM in solving problems with high volume to surface ratio. Additionally, it avoids the use of the node –based vector potential formulation, which is characterized by high computational cost in 3D. The proposed formulation overcomes the interfacial jump condition difficulty and cancellation errors appearing in the total and reduced scalar potential formulations. The source magnetic field produced by superconducting coils is calculated with high accuracy via a Biot –Savart integral, allowing for a coarse discretization. The proposed FEM/BEM formulation is employed for the solution of representative 3D nonlinear magnetostatic problems, while the provided accuracy is assessed through comparisons made with corresponding results obtained by well-known commercial FEM packages.

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