IOP Publishing Superconductor Science and Technology

Supercond. Sci. Technol. 32 (2019) 034004 (9pp) https://doi.org/10.1088/1361-6668/aaf99e

Passive magnetic shielding by machinable MgB_2 bulks: measurements and numerical simulations

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Received 26 October 2018, revised 7 December 2018
Accepted for publication 14 December 2018
Published 7 February 2019

Abstract

We report on a combined experimental and modelling approach towards the design and fabrication of efficient bulk shields for low-frequency magnetic fields. To this aim, MgB_2 is a promising material when its growing technique allows the fabrication of suitably shaped products and a realistic numerical modelling can be exploited to guide the shield design. Here, we report the shielding properties of an MgB_2 tube grown by a novel technique that produces fully machinable bulks, which can match specific shape requirements. Despite a height/radius aspect ratio of only 1.75, shielding factors higher than 175 and 55 were measured at temperature $T = 20$ K and in axially-applied magnetic fields $\mu_0 H_{appl} = 0.1$ and 1.0 T, respectively, by means of cryogenic Hall probes placed on the tube's axis. The magnetic behaviour of the superconductor was then modelled as follows: first we used a two-step procedure to reconstruct the macroscopic critical current density dependence on magnetic field, $J_c(B)$, at different temperatures from the local magnetic induction cycles measured by the Hall probes. Next, using these $J_c(B)$ characteristics, by means of finite-element calculations we reproduced the experimental cycles remarkably well at all the investigated temperatures and positions along the tube's axis. Finally, this validated model was exploited to study the influence both of the tube's wall thickness and of a cap addition on the shield performance. In the latter case, assuming the working temperature of 25 K, shielding factors of 10^5 and 10^4 are predicted in axial applied fields $\mu_0 H_{appl} = 0.1$ and 1.0 T, respectively.

Keywords: magnetic shielding, MgB_2, bulk superconductors, numerical modelling, machinable bulks

(Some figures may appear in colour only in the online journal)

1. Introduction

The ability to shield an external magnetic field or to act as a permanent magnet are two superconducting bulk applications that have attracted remarkable interest in the last few years. Different shaped vessels made out of superconducting compounds such as cuprate superconductors [1, 2] and MgB_2 [3, 4] have been proved to mitigate magnetic fields larger than 1 Tesla. Besides, it has been shown that magnetic fields exceeding 3 T can be trapped by $REBa_2Cu_3O_{7-x}$ (RE = rare earth) [5, 6] and MgB_2 [7–10] disks or disk-stacks.

