AN ACTIVELY SHIELDED 3T MGB2 MRI MAGNET DESIGN

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Introduction: With a threefold increase in helium price over the last 10 years, and nearly a 7% annual increase in the MRI market, a drive towards helium free MRI magnet design is at the forefront of the hardware research. A superior critical current density characteristic of magnesium diboride (MgB_2) at 10-15K temperature has made it a good candidate for conduction cooled magnet design. Different designs are proposed and developed for conduction-cooled magnet using MgB_2 tape [1] and wire [2,3]. Most of these designs deal with low-field (generally 0.5T or less) magnets due to limitations of MgB_2 wire technology. Designing a magnet of higher strength would require a current density on wire that would not exceed the critical field on wire at operating temperature range. A small bore test coil bundle for 3T magnet has been designed and tested recently [3]; however, a complete 3T full body MgB_2 shielded magnet is yet to be built or even designed. An optimized design for 3T main magnet for whole body MRI using the second generation of MgB_2 wire developed by Hyper Tech research, Inc. is presented in this paper.

Theory and Method: An improved functional approach that achieves optimized design by nulling external moments along with a certain series of internal moments of the magnetic fields [4] is used to design an actively shielded magnet. A continuous current distribution is obtained for the magnet design using the aforementioned functional method. A first approximation for the position of discretized coil bundles carrying constant current through $1mm^2$ is achieved from this continuous solution. These discrete bundle positions are then optimized again using the same functional to achieve desired magnet properties. The particular challenge in discretizing MgB_2 is to ensure that the current is limited such that the maximum field on wire of any bundle does not exceed the critical value yet sufficient field homogeneity inside the DSV and a small enough 5-Gauss footprint are maintained.

Results: Figure 1 shows the three-dimensional layout of the newly designed 3T MgB_2 magnet. It has 4 pairs of primary coils and 1 pair of secondary coil. The magnet has an inner and outer diameter of 1.1m and 2.15m and length of 1.8m. These dimensions are similar to typical 3T NbTi magnet [5]. A 45cm DSV is considered. Figure 2 shows the peak-to-peak field homogeneity inside the DSV. The maximum inhomogeneity for the design is 11 ppm. The MgB_2 wire cross-section is considered to be $1mm^2$ and carries 101 Amps current. The highest field on wire is found to be 5.15 Tesla, which is sufficiently below the critical field of more than 6T at 10K. Figure 3 shows the 5-Gauss contour that extends 3.5m radially and 4.4m in axial direction. The highest hoop stress on the wire is approximately 336MPa and the highest for a bundle is 80MPa. Maximum axial force on the bundle is about 7131kN. The total volume of the coil is calculated to be $0.438m^3$.

Discussion: An actively shielded 3T MgB_2 main magnet design is presented that could operate at 10-15K temperature as conduction cooled dry magnet. The 45cm DSV shows a few ppm higher inhomogeneity than a conventional 3T magnet. The 5-Gauss footprint area is about 15% larger than the typical design due to bigger outer diameter of the shield coil of magnet design. The latest manufacturing guidelines available to us indicate that these hoop stresses and axial forces represent technological challenges but not insurmountable ones. The total volume of the wire for the magnet is large due to the lower current level resulting from the critical field-on-wire restriction. This translates into higher inductance and higher energy for the design. Further improvements in wire design are expected in the future that will increase the critical B field by optimizing the copper-MgB_2 ratio. These will reduce the wire volume and energy of the design.

Acknowledgement: The authors are grateful for the support of the Ohio Third Frontier and an NIH grant 5R44CA144415-03**,**
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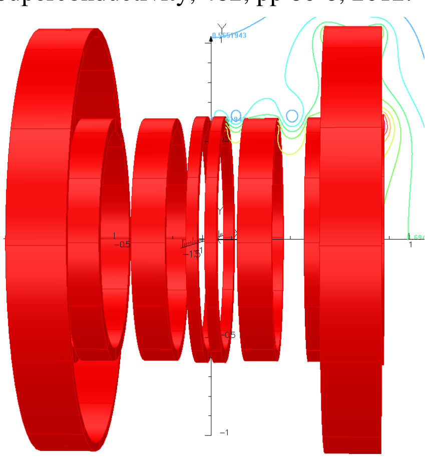

Figure 1

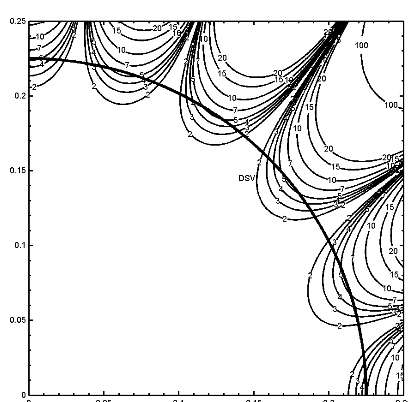

Figure 2

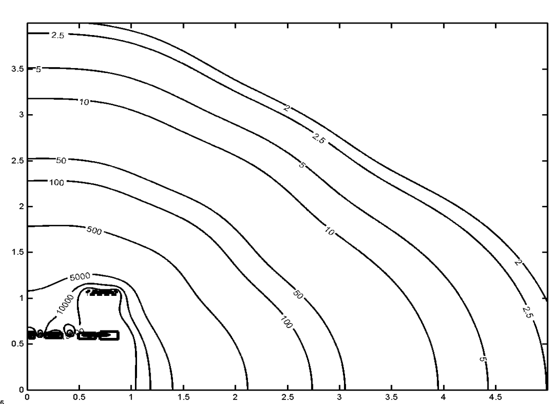

Figure 3