A Temperature-Stable Permanent Magnet Halbach Design For MRI Applications

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Abstract

The development of low-cost portable NMR/MRI scanners requires the use of different equipments from those that current MRI scanners use. This might be the use of a permanent magnet instead of superconducting magnet for the main field, a different cooling system, different magnet structure, etc. This project proposes a bipolar Haibach array consisting of rare-earth permanent magnets to produce the main field of an NMR/MRI scanner. A problem of this setup is the changes in room temperature which can alter the magnetic field produced by the magnet and impact MRI/NMR image quality (due to resonance frequency shifts). The goal of this project is to find the right materials and magnet design that keeps the temperature of the magnets as stable as possible.

Through the use of COMSOL®, we simulated change in the main field as a function of the room temperature in a time-dependent study via coupling of Heat Transfer and Magnetic Field. The results from the simulations improved our understanding regarding permanent magnet Halbach designs that are stable under temperature fluctuations.

Materials such as aluminum, acrylic plastic, and ABS were used for mitigating temperature fluctuations due to temperature changes in the environment and were incorporated into the simulation such that the best ones were chosen for a steady magnetic field throughout temperature fluctuations of the environment. Heat Transfer solver was used to simulate the temperature distribution in the magnet and to fed that data to the Magnetic Field solver, to see the effects of the temperature on the main magnetic field of the magnet. What we saw was that, given a +/-10 degree difference in temperature between the magnet and the room temperature, the resulting change in the magnetic field was significantly worse (~-1.56E-4 Tesla). Therefore, by deciding to thermal insulate the magnet we saw that the change in magnetic field was significantly less (~1.1E-5 Tesla).

The suggested material for the magnet structure was ABS because it gave us the best results and it's easily 3D printed. The magnets were of two different types, Samarium Cobalt and Neodymium Magnet. For the thermal insulator was used the Foam 101kPa material provided in COMSOL® Material Library. The main field produced in the center of the magnet which is about 0.9 T, is shown in a cross-section surface of the magnet design.

In the future we expect to add further details of a complete MRI scanner such as gradient and RF coil and see how the temperature and the heating from those equipments affect the magnetic field and the quality of the image reconstruction. Through the use of CAD geometry we expect to 3D print the results that are feasible for the scanner and physically test them. So far the conclusions of this simulation is that with the use of thermally insulating foam we can achieve relatively stable magnetic field in the main magnet, which gives us hope in the development of portable stable low-field and low-cost permanent magnet MRI systems.