# Magnetically Induced Displacement Force on Medical Devices

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## Introduction

Medical devices undergo a series of evaluations in order to determine their performance and level of safety in a magnetic resonance (MR) environment. The standard of focus for this work is ASTM F2052-15 which is a standard that specifies the requirements for measuring the magnetically-induced displacement of a device due to the spatial gradient fields in the MRI scanner bore [1]. This test entails suspending the device from a string near the entrance of the MRI bore and measuring the angle of deflection. The deflection angle measurements are then used to calculate the force imparted on the device by the magnetic fields. Evaluating the performance of medical devices in the MR environment is a costly endeavor, both in time and resources. This work aims to build a COMSOL-based model that simulates the deflection of a medical device in a representative magnetic field and calculates the deflection force applied to the device by the spatial gradient fields. This is a proof of study using only one material and is meant to indicate that a more comprehensive model can be developed.

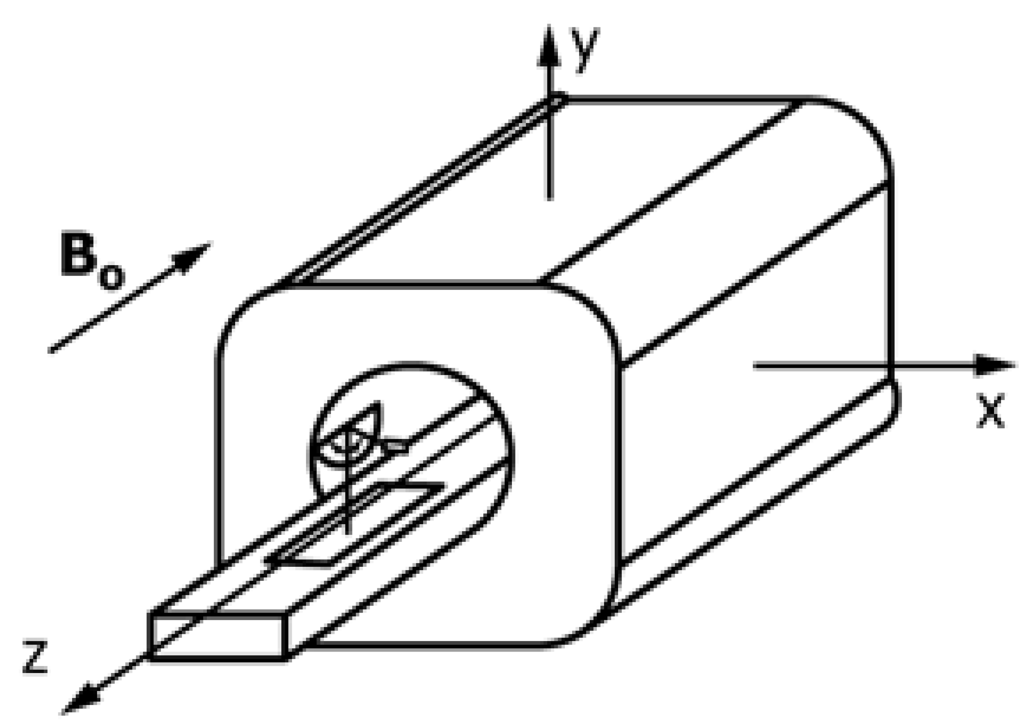


**Figure 1**. Experimental test set up as described in ASTM F2052-15 [1] where $B_o$ represents the magnetic field.

## Computational Methods

A fixture was designed to hold an AlphaLab 3-Axis Gaussmeter probe, which then captured magnetic field information at known locations within the static magnetic field within the bore of a Siemens Magnetom 3T Scanner. The fixture was placed at set Z locations relative to the isocenter within the bore, and the gaussmeter probe collected Bx, By, and Bz data at every fixture location. The fixture was then translated along the z-axis of the bore and measurements were repeated. This measurement method resulted in a point cloud of magnetic field strength measurements that was later imported into COMSOL as an interpolation function.

Computationally, the geometry for the model reflects the test sample and fixture used to validate testing across different scanners. One end of the nylon post is fixed in the X,Y, and Z directions but is allowed to rotate freely.

Within the model, a gravitational force and a magnetic induction force were applied to the sample. The magnetic susceptibility of the materials in the model was taken from literature [2], while the volume was defined as a constant based on the experimental test sample. The magnetic field and magnetic flux values were derived from the measurements taken using the gaussmeter probe. Using the calculated magnetic induction force, a simulated deflection angle was determined using Equation 2 below. The calculated deflection angle was then compared with results that were measured experimentally.

$$|F_m| = \frac{VX}{\mu_0}\left|\vec{B}_0\right|\left[\nabla\left|\vec{B}_0\right|\right] \quad \text{(eq. 1)}$$

(eq. 2)

$$|F_m| = \rho V g \cdot \tan(\alpha)$$

## Results

The results below demonstrate the validity of the measurements made within the MRI scanner bore. Figure 2 shows the magnetic field strength data that was imported into COMSOL in the form of slices in the XY plane moving along the Z axis. Vector arrows show the direction of the magnetic field as it moves into the bore.

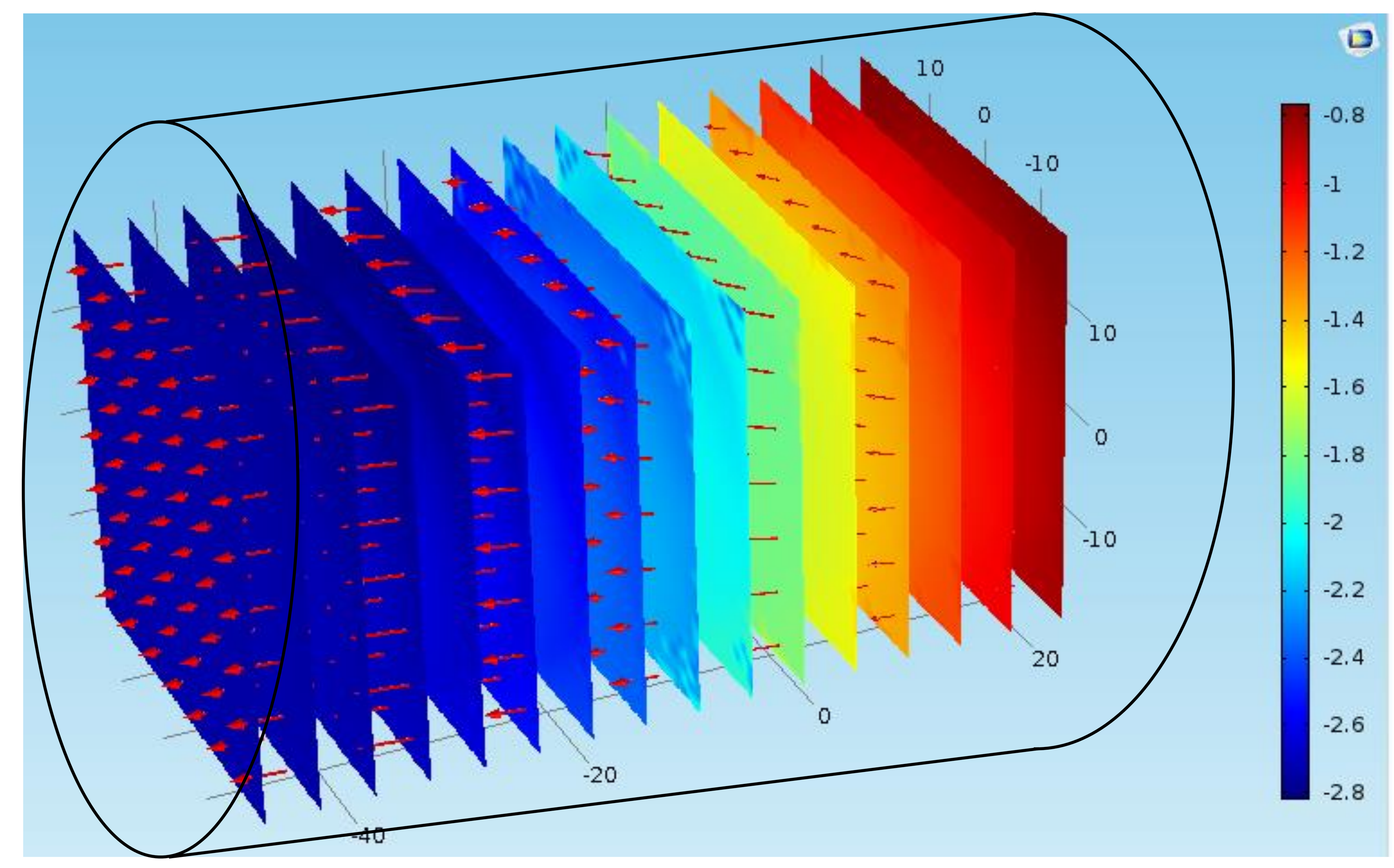


**Figure 2**. Map of magnetic field strength measurements organized in XY planar slices along the Z-axis of the MRI bore.

A brief comparison was conducted between the experimental data and the model's results for the one material analyzed. The experimental data showed a 0.07 N magnetically induced displacement force resulting in a 77º displacement angle. The COMSOL model predicted a 0.08 N displacement force with a 78.7º calculated angular displacement. There is a fifteen percent error in the displacement force, and a two percent difference in angular displacement. Percent error was defined as the difference between the experimental and COMSOL calculated values, divided by the experimental value.

## Conclusions

The results of the model show promise in being able to predict forces and deflections. Only one material was used in this proof of concept model, leaving areas of improvement in the robustness of the model. Further validation work evaluating multiple materials with varying magnetic properties is necessary for a extensive model. Once the model is assess for sensitivity, an uncertainty assessment will be conducted to more fully characterize the errors developed above.

Ultimately, the model will be used to asses more complex geometries and composite materials and their impact on the ability for the model to predict magnetically induced displacement force in simulated tissue interfaces.

## References

1. ASTM F2052-15, Standard Test Method for Measurement of Magnetically Induced Displacement Force on Medical Devices in the Magnetic Resonance Environment, ASTM International, West Conshohocken, PA, 2015, www.astm.org
2. *Magnetic Circuits (II)Example 3* (n.d.): 24. University of Central Florida. Web.

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