Vibration Induced Eddy Current and Its Effect on Image Quality for MRI System

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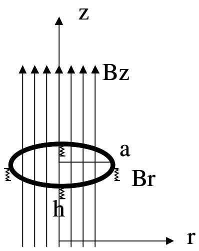
Introduction

During normal operation, MRI systems experience vibration from different external sources, e.g. refrigeration unit, environmental ground vibration and gradient coil pulse. Moving conductors within the MRI system will generate eddy currents, disturbing the homogenous magnetic field and affecting image quality (so called "ghosting"). The more conductive the material is, the more eddy currents will be generated. However, in addition to mechanical damping stiffness, the eddy currents will generate magnetic damping and stiffness which prevents the conductor from moving. Furthermore, the higher damping might over dampen the vibration. As a result, it is not necessarily true that the more conductive conductor will generate more field instability or image quality. In this study, vibration induced magnetic field fluctuation was investigated on a system with a single degree of freedom to illustrate the behavior. The methodology was then extended to a 3 dimensional MRI system by using FEM/BEM. Experimentally simulated results are presented, showing general agreement between experimental results and simulation for the 1.5T MRI system

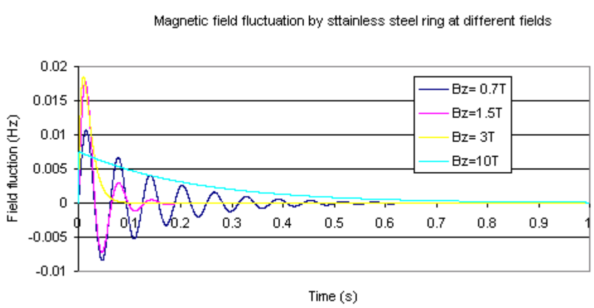
Methods and Illustration

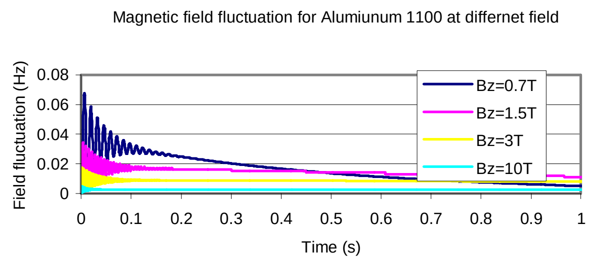
Consider a ring with cross section is of **A** and radius **a** supported on a spring under magnetic field Br and Bz. The area enclosed by its centerline is **S**. The center of ring is located on (0,h) as shown at the left while the equation of motion and electric circuit equation is shown at the right.



$$\frac{d}{dt}\begin{Bmatrix} w\\ \dot{w}\\ I\end{Bmatrix} = -\begin{bmatrix} 0 & -1 & 0\\ \frac{k}{m} & \frac{c}{m} & -2\pi a\frac{B_r}{m}\\ 0 & \frac{S}{L}\frac{dB_z}{dz} & \frac{R}{L}\end{bmatrix}\begin{Bmatrix} w\\ \dot{w}\\ I\end{Bmatrix} + \begin{Bmatrix} 0\\ F/m\\ 0\end{Bmatrix}$$

where **w** stands for displacement, **k** for stiffness, **m** for mass, **c** for viscous damping, **F** for applied force, **I** for current, **L** for inductance and **t** for time. The above equation has been solved by assuming the initial condition $\{w \;\; \dot{w} \;\; I\} = \{1\,\mu m \;\; 0 \;\; 0\}$. The field fluctuation shown below was obtained by integrating the current using the Biot-Savart Law.





For a stainless steel ring in low magnetic fields, the field fluctuation exhibits ringing behavior, while it is over damped for higher magnetic fields. Also, the field fluctuation decays very fast for highly conductive material, e.g. aluminum 1100. For complicated structures, numerical simulation (FEM/BEM) has been developed to implement the methodology in both time domain (transient analysis) and frequency domain (harmonic analysis).

Results and Conclusions

Vibration from the refrigeration unit attached to a 1.5T whole body MRI system was simulated in the following figure using the coupled mechanical, electromagnetic simulation in frequency domain as illustrated above. The field instability (or fluctuation) experimental measurement is attached for comparison. It is observed that there is general agreement between the simulation and experimental data.