Vibro-Acoustic Analysis of Acoustic Liners For MRI Scanners

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Introduction

Magnetic Resonance Imaging (MRI) scanners are popular medical diagnostic devices providing useful information about patients in a non-invasive manner. However, a disadvantage of MRI is the high level of acoustic noise generated during scanning, which is caused by the Lorentz forces acting on the gradient coils bound within an epoxy resin cylinder. As the gradient current switches direction the gradient windings vibrate, leading to the generation of sound waves [1]. Active and passive methods are commonly used for noise control. Due to the frequency limitation of Active Noise Control methods (normally effective only at relatively low frequencies), a passive noise control method using an acoustic liner was investigated by Mechefske *et al.* [2]. To extend their work, this paper shows some simulation results that predict the noise blocking effect of an acoustic liner, which could be used to attenuate the noise propagating into the bore of the MRI scanner (see Figure 1). Vibro-acoustic analysis was conducted to predict the acoustic performance of the liners with different thickness based on the coupling of a finite element (FE) structural model and a boundary element (BE) acoustical model.

Methods and Results

Acoustic liners for a 4 Tesla Varian / Siemens Unity INOVA whole-body MRI system were investigated. Referring to Figure 1, the noise generated by the gradient coil could penetrate through the liner directly. Acoustic waves reflected by the warmbore (the magnet containment vessel) also could transmit through the liner and some sound waves could diffract into the bore of the scanner through the two open ends of the liner. The solid model for the gradient coil and liner is shown in Figure 2. Known forces with varied frequency from 100 Hz to1000 Hz were applied to the structural FE model of the gradient coil with SDRC I-DEAS to generate a velocity distribution for the acoustical BE model with LMS-Sysnoise. The structural modes of the liner with different thickness (15 mm, 25 mm and 35 mm) were calculated and a modal structural damping was also considered. The acoustic liners are made of fiberglass and the properties are: Young's modulus $E = 1.67 \times 10^{10}\ N/m^2$, Poisson's coefficient $\nu = 0.38$ and mass density $\rho = 1835\ kg/m^3$.

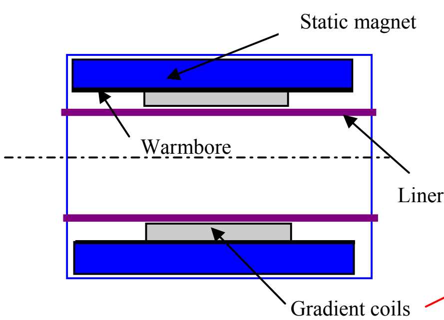

Figure 1. Schematic view of a MRI Scanner with liner (cross-sectional view)

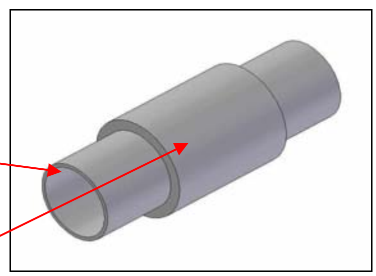

Figure 2. The solid model for the gradient coil and liner

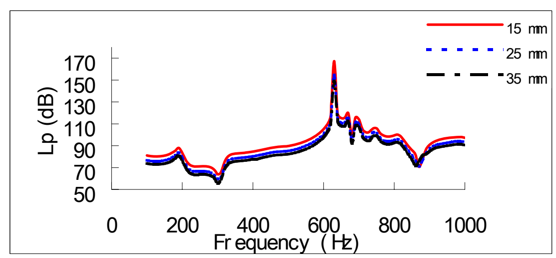

Figure 3. The sound pressure level at the isocenter

By linking the FE and BE models, the sound field inside the liner bore can be predicted. The sound pressure levels (SPL) in units of dB (with a reference of 20 micro pascal) at the isocenter of the models are shown in Figure 3. These results indicate that increasing the liner's thickness can reduce the noise further. It can also be found that the 25 mm liner reduces the noise at 630 Hz by 13 dB compared with the 15 mm liner. The 35 mm liner attenuates the noise by an additional 5 dB compared with the 25 mm liner at the same frequency. The peak at 630 Hz was possibly caused by the structural breathing mode of the liner (See Figure 4). About 3-5 dB more noise is reduced at other frequencies as the thickness of the liner is increased by 10 mm steps.

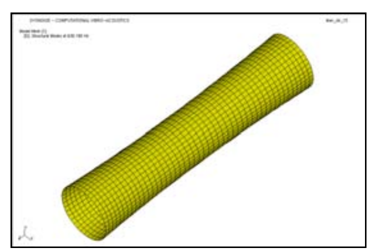

Figure 4. The structural mode of the liner at 630 Hz

Conclusions

FEM and BEM are powerful simulation tools for the vibro-acoustic analysis. The results show that increasing the liner thickness will attenuate more noise. However, the cost of this attenuation will be a much heavier liner and potentially reduced inner radius of the MRI bore.

References

[1]. Price DL, Wilde JPD, Papadaki AM, Curran JS, Kitney RI, "Investigation of acoustic noise on 15 MRI scanners from 0.2 T to 3 T," J. Mag. Reson. Imag. **13**, 293-299 (2001). [2]. Mechefske CK, Geris R, Gati J, Rutt BK, "Acoustic Noise Measurements in a 4T MRI Scanner", MAGMA - Magnetic Resonance Materials in Physics, Biology and Medicine, **13**, 172-176, (2002).