3D Simulation of Metal Detector Data using Finite Elements

J. Lange*[1], T. Hanstein[2], and S. L. Helwig[1]

[1] Institue of Geophysics and Meteorology, University of Cologne, Germany

[2] HarbourDom GmbH, Cologne, Germany

The German project network "HuMin/MD Metal detectors for Humanitarian Demining: Development potentials for data analysis and measurement techniques" funded by the German Federal Ministry of Education and Research (BMBF) evaluates the potential of new mathematical methods that work with measuring data from commercial off-the-shelf metal detectors. The network consists of eleven institutes working on 3D-imaging, signal analysis, research on the soil influence and the measurement technique (http://www.humin-md.de).

Our approach is the inversion of the signal by using fast semi-analytical simulations for simple-shaped objects. For testing of the inversion and to study which components of a mine are important for the measured signal, we did 3D simulations using the commercial finite elements modeling program comsol multiphysics. The first and easiest simulations were models with axial symmetry. By using an axial symmetry boundary condition the problem gets 2D and therefore reduces the number of finite elements a lot. The receiver and transmitter had the same coil diameter with a metal sphere about 10 cm underneath embedded in air or a homogeneous ground. Comsol multiphysics offers the possibility to refine the mesh locally, so a small discretisation inside the metal sphere was possible to take the small skin depth into account. We compared the solutions in time and frequency domain with analytical ones to study which parameters like number of elements or size of the model space are the best regarding quality and runtime of the solution. With this axially symmetric simulations it was possible to look at the effect of mutual inductance or to compare the signal amplitude for different objects and metals in time and frequency domain.

3D simulations for non axial symmetric models were only done in frequency domain so far. We were interested in profiles above the object, like they are measured when moving the detector over a mine. Comsol Multiphysics does not support a local mesh refinement in 3D, so mesh generation gets more difficult. Although it is possible to preset the maximum element size within an object, the huge contrast of finite elements of half a millimeter inside the object, because of the small skin depth and much bigger elements at the border of the model space overstrains the mesh generator for some models. Splitting the geometry into two model spaces, one small around the object and a bigger one including the coils and afterward connecting them trough identity boundary conditions eased meshing a lot. Our hole model space was 2 m x 2 m x 4 m. The minimum element size within the metal parts was 0.5 mm. The comparison to an analytical solution for a metal sphere showed good matching. For other objects like cylinders we checked our solution with the 3D axial symmetry solution for the object position at the axis of the coils. Our current research is the simulation of a striker above a detonator capsule with a very thin wall thickness of one mm. The simulation of the spring is still to difficult, but laboratory measurements show that their influence on signal the is negligible.