Finite Element Model for Simulating the Inspection of Steel Tubes Using Electromagnetic Acoustic Transducers

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Background: Electromagnetic acoustic transducers (EMATs) based guided wave technology received considerable attention for inspecting tubes, with the purpose of ensuring the safety and reliability of industrial processes. Here, we develop a finite element model based on COMSOL Multiphysics software for simulating the receiving process using EMATs. The simulating results are then used to optimize the structure of the transducer.

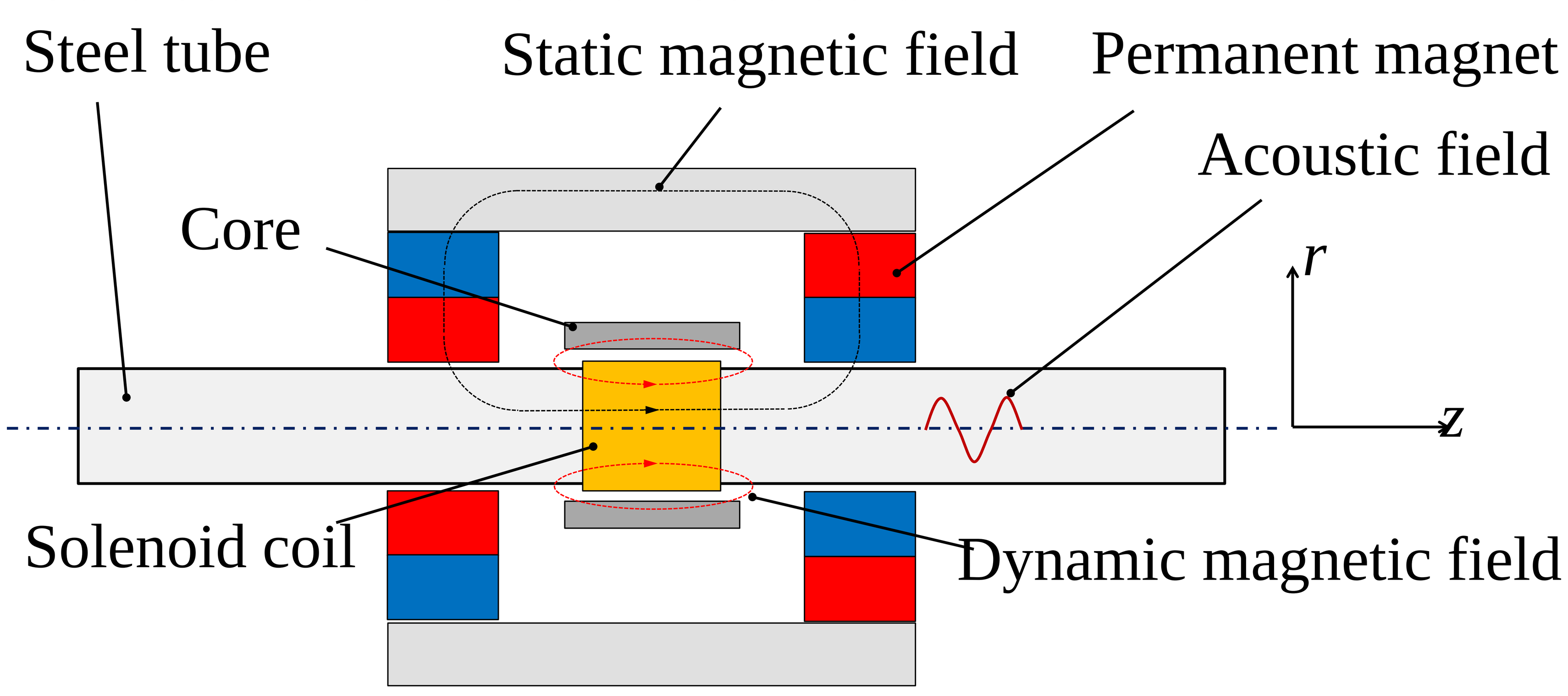

Fig 1. Schematic illustration of the EMAT

Model: The static magnetic field and the dynamic magnetic field are simulated by magnetic field interface. The elastic waves generated by the coupling process [1] between two fields are calculated by a solid mechanics interface.

Elastic field $$\rho\frac{\partial^2\mathbf{u}}{\partial t}-\nabla\cdot\sigma=\mathbf{F}_V$$

Coupling process $$\nabla\times(\nu\nabla\times\mathbf{A})-\sigma\frac{\partial\mathbf{A}}{\partial t}=\mathbf{J}_L+\mathbf{J}_{mz}+\mathbf{J}_{ms}$$

Magnetic field $$\sigma_m\frac{\partial\mathbf{A}}{\partial t}+\nabla\times\mathbf{H}=\mathbf{J}_e \qquad \mathbf{B}=\nabla\times\mathbf{A}$$

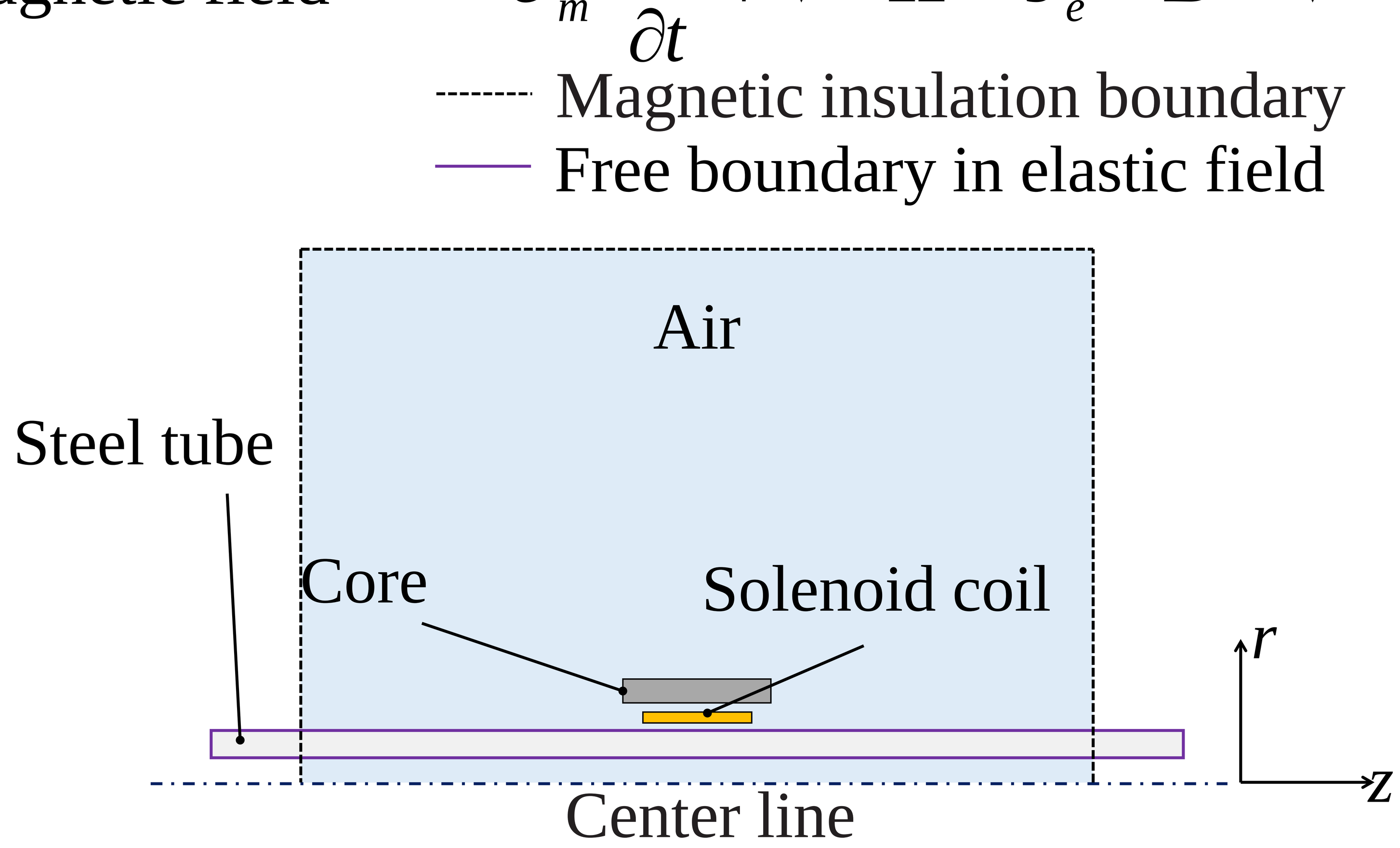

Fig 2. Schematic diagram of the finite element model

Results: Guided waves of L(0,1) mode are generated in the tube at a generation frequency of 30 kHz. The z component of the displacement field (*w*) are shown in Fig. 3. The peak to peak values of induced voltages are investigated against cores with different materials, as shown in Table.1.

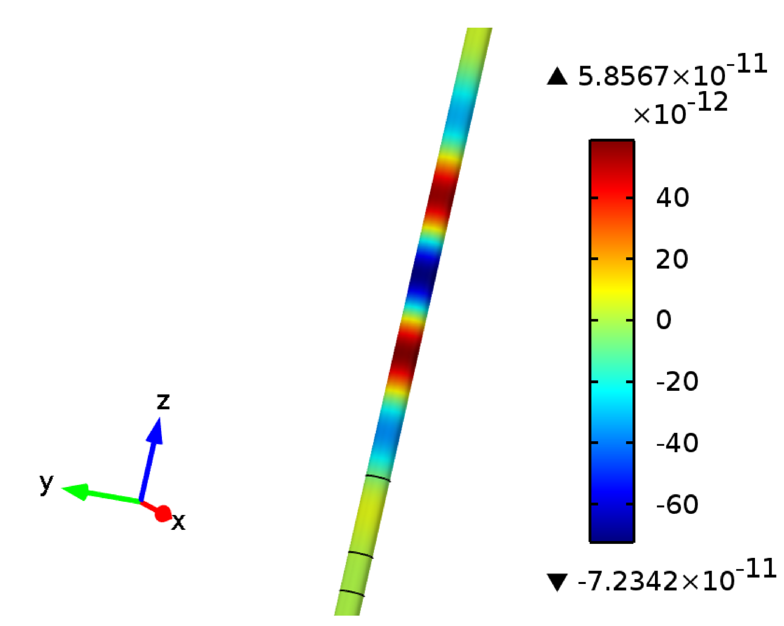

Fig 3. The *z* component of displacement field (*w*)

Material of the core	Equivalent $\mu_r^{(S)}$	$\sigma^{(S)}$ (S/m)
Permalloy	650	1.67e6
Mn-Zn ferrite	400	1
Ni-Zn ferrite	300	2e-3
Air	1	0

Table 1. Materials of cores

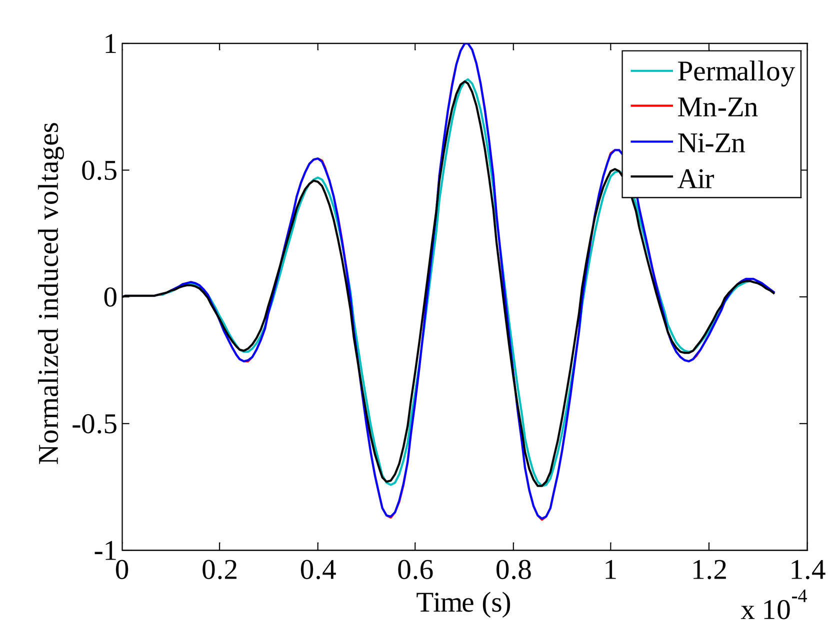

Fig 4. The induced voltages obtained under different cores

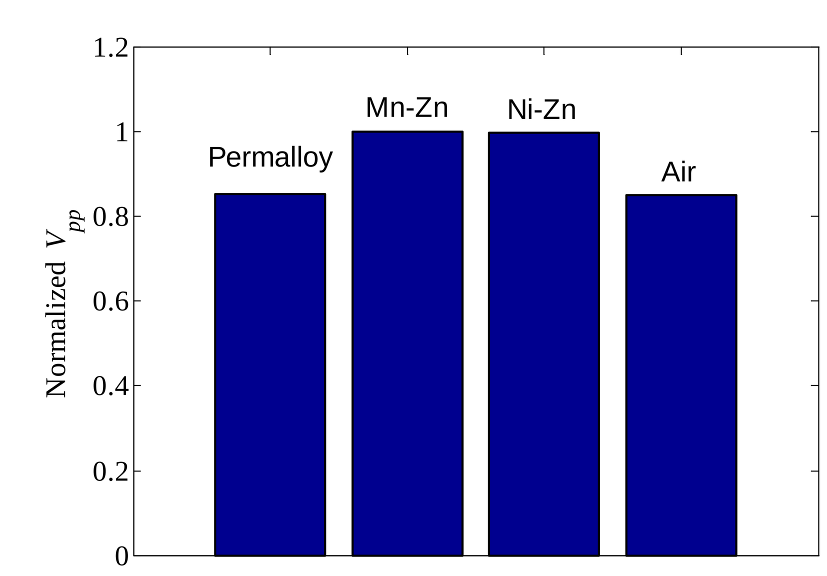

Fig 5. The peak-to-peak values of induced voltages

Conclusions: Both the permeability and the conductivity of the core have significant influence on the receiving efficiency of the EMAT. The final enhancement of receiving efficiency should take two aspects into account at the same time based on FEM. The model proposed here will be helpful for optimizing the structure of the EMAT.

参考文献:

1.Jafari-Shapoorabadi, R.,Konrad, A.,Sinclair, A. N. The governing electrodynamic equations of electromagnetic acoustic transducers. J. Appl. Phys., 97 (10), 10E102 (2005).

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