Numerical Study of Shear Horizontal Electromagnetic Acoustic Transducers for Generation of Ultrasonic Guided Waves

L. Cheng[1], A. Mohimi[1], M. Kogia[1], V. Kappatos[1], C. Selcuk[1], T.-H. Gan[1]

[1]Brunel Innovation Centre, Brunel University, Uxbridge, UK

Abstract

Absorber tubes are one of the most critical components of parabolic trough Concentrated Solar Plants (CSPs). In absorber tubes, the working fluid that flows inside them absorbs the heat of the concentrated sunlight and transfers it to a heat exchanger, where the conventional process for electricity generation starts. Due to the high temperatures these tubes perform at, it is very likely for them to get damaged and unable to operate functionally; therefore, the monitoring of their structural health via Non Destructive Testing (NDT) techniques is regarded as essential for preventing them from being significantly defective.

Ultrasonic guided wave method is one of the best candidates which is more reliable to the tubes at high temperature. This paper reports simulation and modelling results for development of Electromagnetic Acoustic Transducers (EMATs). The theoretical concerns and developments of numerical model using COMSOL Multiphysics® are firstly reported. Then the proposed strategy to configure and optimize EMAT transducers is outlined, which includes selection of wave mode and wave length, optimization of central frequency and phase velocity via dispersion curves and design of coil and magnet for EMAT transducers along with numerical simulation results. The outcome from each step is reported.

The numerical modelling of EMAT transducers carried out can be used for assisting experimental development of EMAT transducers and transducer arrays. The numerical model will be refined along with experimental studies for optimization and design of EMAT transducers for high temperature condition.

To focus the energy to cover the inspection of the whole sample up to several meters, Shear Horizontal (SH) mode SH0 is determined as the best options for this application. Through dispersion curves, SH EMAT working at 256.7kHz with a 12 mm wavelength is determined for 3mm-thick plate made of stainless steel 316L. Then Periodic Permanent Magnet (PPM) and race track coil are selected for the EMAT transducers. The configuration of EMAT developed in COMSOL Multiphysics®, is shown in Fig 1, where a Hanning window centerd at 256.7 kHz with five cycles is used for excitation of the coil.

Three physics interfaces are used for simulating the EMAT: (i) 'Magnetic fields', (ii) 'Magnetic

fields, No currents' and (iii) 'Solid mechanics'. These three interfaces are used to model the static magnetic field, eddy currents and ultrasounds generated in the test sample, respectively.

The direction of magnetic flux density and eddy current density in the steel plate generated from magnets and coils respectively at 9 μs, is shown in Fig 2. The ultrasound waveform at a distance of 75 mm away from the EMAT transducer on the central line of the EMAT along the y axis, is represented in Fig 3. The displacement on the surface of the sample at 100 us is illustrated in Fig 4.

The results show that the ultrasound is concentrated in x and y direction, whereas the displacement in other directions is relatively small, which can be extended for the monitoring on both the length and circumference of the CSP absorber tubes.

Figures used in the abstract

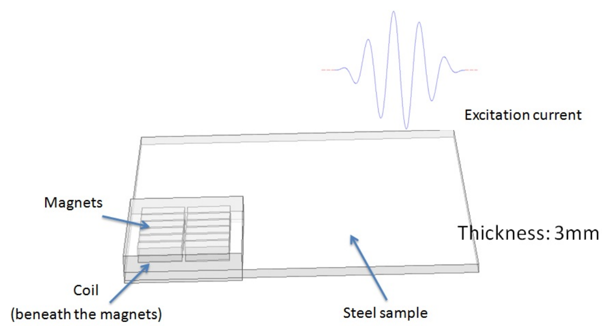

Figure 1: Configuration of EMAT transducer

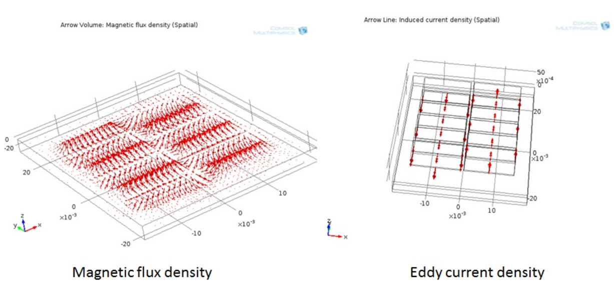

Figure 2: magnetic flux density and eddy current density at 9 us

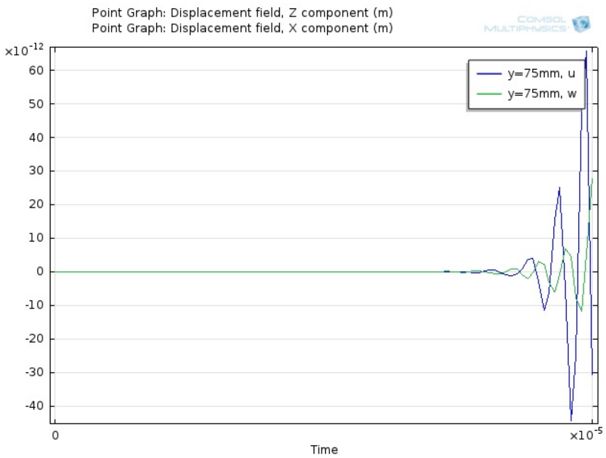

Figure 3: Displacement in x and z direction at a location 75mm away from the EMAT

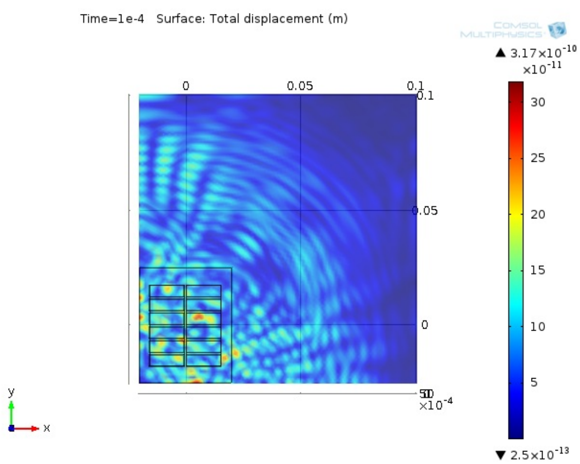

Figure 4: Total displacement at 100us