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Optimal Design of a Piezoelectric Transducer for Exciting Guided Wave Ultrasound in Rails

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An existing Ultrasonic Broken Rail Detection System [1] installed in South Africa on a heavy duty railway line is currently being upgraded to include defect detection and location. To accomplish this, an ultrasonic piezoelectric transducer to strongly excite a guided wave mode with energy concentrated in the web (web mode) of a rail is required. A previous study [2] demonstrated that the recently developed SAFE-3D (Semi-Analytical Finite Element – 3 Dimensional) method can effectively predict the guided waves excited by a resonant piezoelectric transducer. In this study, the SAFE-3D model is used in the design optimization of a rail web transducer. A bound-constrained optimization problem was formulated to maximize the energy transmitted by the transducer in the web mode when driven by a pre-defined excitation signal. Dimensions of the transducer components were selected as the three design variables. A Latin hypercube sampled design of experiments that required a total of 500 SAFE-3D analyses in the design space was employed in a response surface-based optimization approach. The Nelder-Mead optimization algorithm was then used to find an optimal transducer design on the constructed response surface. The radial basis function response surface was first verified by comparing a number of predicted responses against the computed SAFE-3D responses. The performance of the optimal transducer predicted by the optimization algorithm on the response surface was also verified to be sufficiently accurate using SAFE-3D. The computational advantages of SAFE-3D in transducer design is noteworthy given we needed to conduct more than 500 analyses. The optimal design was then manufactured and experimental measurements were used to validate the predicted performance. The adopted design method has demonstrated the capability to automate the design of transducers for a particular rail cross-section and frequency range.

References:

1. F. A. Burger, "A Practical Continuous Operating Rail Break Detection System Using Guided Waves," in *18th World Conference on Nondestructive Testing*, (2012).
2. D. A. Ramatlo, C. S. Long, P. W. Loveday and D. N. Wilke, "SAFE-3D analysis of a piezoelectric transducer to excite guided waves in a rail web", *Review of Progress in Quantitative Nondestructive Evaluation*, eds. D. E. Chimenti and L. J. Bond, (American Institute of Physics 1706, Melville, NY) **35**, 020005 (2016).