Modelling of Ultrasonic Transducers and Ultrasonic Wave Propagation for Commercial Applications Using Finite Elements with Experimental Visualization of Waves for Validation

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Abstract

Finite element (FE) modelling of ultrasonic propagation using COMSOL Multiphysics® simulations, or indeed any other FE software, inevitably involves large computations because two or three dimensional time-stepping models are needed to predict the behaviour of these kinds of travelling mechanical waves. COMOSL models can be used to create video of waves in these models, which is both attractive and informative. Unfortunately, for time-stepping solutions, it is possible for numerical instabilities to grow sufficiently large to dominate the solution so that the eventual FE prediction does not match physical behavior if the solver is not set up properly. Any design of transducer that is based upon such poorly set up FE models alone is unlikely to perform as expected and will almost certainly result in delayed and costly development. It is valuable, if not essential, therefore, to have independent experimental observations of wave propagation that can give a good degree of validation of FE predictions.

One approach to providing experimental validation is to use receiver transducers, such as hydrophones (in water) and microphones (in air), to sample the ultrasonic wave at a point (or integrated over some region) but the disadvantage is that receiver signals do not provide views of the propagation path that can be directly compared with FE software videos.

However, another approach to validation, which is less well-known but highly effective, is to render visible ultrasonic waves in transparent materials using a combination of stroboscopic illumination and contrast enhancement, for example: polarized light or schlieren or shadowgraph techniques, and by these means create videos and still images that can be compared directly with COMSOL videos and still images. The combination of FE modelling with successful experimental visualization provides a high degree of confidence in the FE models and allows rapid development of complex ultrasonic transducers to proceed efficiently and cost-effectively. Examples of video and still images of FE predictions and examples of experimental visualization of ultrasonic waves propagating from transducers are presented and compared to illustrate the usefulness of this kind of validation.