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Propagation of ultrasonic fields using quasi-Monte Carlo integration for precise attenuation measurements

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ABSTRACT

Measuring ultrasonic wave attenuation due to grain scattering in polycrystals remains a complicated experimental procedure to perform. This is especially true, if one wants to obtain the ultrasonic attenuation as a function of direction of propagation. Nevertheless, a double-through transmission immersion setup can be used to experimentally measure the attenuation profile and by combining this dataset with simultaneously information about the polycrystal wave speed, it is hoped that a better description of the grain sizes and texture is achieved. However, to obtain an accurate value for the attenuation, appropriate diffraction corrections need to be employed, which makes it imperative that we resort to numerical models, able to predict how transducer beams propagate through interfaces.

As a means to attain this goal, in this work we will discuss models for wave field propagation through interfaces generated by finite piston transducers. First, the focus is given to two different methodologies: the Rayleigh-Sommerfeld diffraction integral and a ray tracing model. By introducing a quasi-Monte Carlo integration scheme when evaluating some of the necessary computations, both algorithms are made much more computationally efficient than their regular mesh-based counterparts, such as the finite element method (FEM).

Afterwards, a direct comparison between these two models is made and their relative performance and applicability is analysed for several different case studies. It is found that the Rayleigh-Sommerfeld integral-based formulation performs better for a larger amount of field points in the system. On the contrary, the ray tracing model is far more efficient if a larger number of through-transmission interfaces are present.

Subsequently, the ray tracing methodology is adapted to incorporate anisotropy in its formulation. In turn, this will make our numerical formulation capable of incorporating our double-through transmission experimental setup, which could lead to more precise measurements of grain scattering attenuation. As a concluding remark, it is hoped that by creating this model, capable of efficiently calculating diffraction correction coefficients for ultrasonic systems with interfaces, applications requiring the inspection of single or multi-layered anisotropic materials can obtain improved results.