Characterization of graphite nodules in nodular cast iron using pulse-echo and pitch-catch ultrasonic grain noise

Olivia J. Cook,[1] Rachael M. Krugh,[2] Andrew Gavens,[3] Andrea P. Arguelles, [1] Christopher M. Kube[1]
[1]Department of Engineering Science and Mechanics, The Pennsylvania State University, University Park, PA
[2]Department of Aerospace Engineering, The Pennsylvania State University, University Park, PA
[3]Knolls Atomic Power**,** Niskayuna, NY

In naval applications, nodular cast iron stands out for its superior properties in extreme environments, combining strength, flexibility, and adaptability. Its microstructure is characterized by large graphite nodules embedded in a polycrystalline ferrite matrix. While contributing to the material performance, the nodules can also become crack initiation sites and must be monitored when the loading mode can cause fatigue. Nondestructive inspection by ultrasonic testing (UT) presents an opportunity to characterize the health of components in service. Still, more research is needed to understand the graphite nodules' scattering contribution, as grain noise can obscure signatures of flaws. Knowledge about the typical incoherent scattering seen from nodular cast iron can enable inspection techniques to identify anomalies with greater specificity and sensitivity. Due to the increased complexity of the nodular cast iron compared to single-phase polycrystals, a single parameter, like the correlation length of the matrix grain structure, is insufficient to describe the statistics of the microstructure. Thus, multiple independent measurements may be necessary to characterize test pieces fully. Prior work has explored normal incidence ultrasound for measurement of attenuation and backscatter in nodular cast iron, but other scattering-based methods have not yet been explored. This study evaluates the feasibility of measurement configurations that utilize multiple transducers and oblique incidence, such as mode-converted and shear-to-shear scattering, to characterize the nodular parameters such as size, number density, and distribution. Using an immersion system and custom 3D-printed fixtures, different transducer configurations and frequencies are tested on nodular cast iron specimens to evaluate the scattering strength and identify optimal measurements sensitive to nodules. The scattering contribution of the graphite phase is assessed by comparing the scattering response to a control sample of plain iron, where the response is only due to scattering within a single ferrite phase. These measurements progress toward decoupling the nodule response from the matrix response and ultimately improve the robustness of ultrasonic inspection in this material system.