MSEAS Seminar Series

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Acoustic Scattering of Spherical Directional Waves by Smooth and Statistically Rough Solid Elastic Cylinders

Abstract: Realistic sonars radiate spherically spreading waves and have directivity. Therefore, they insonify a target over a finite number of Fresnel zones and span a continuum of oblique incident angles, even when the center of the beam is at normal incidence. These effects strongly influence both the overall scattered pressure levels and resonances. For example, because of the spreading of the beam and associated oblique insonification within the beam, normal modes associated with axially propagating guided waves are excited that would not have otherwise existed for an idealized incident plane wave. This thesis analyzes acoustic scattering by solid elastic cylinders insonified by realistic sonars both theoretically and experimentally. A theoretical model to predict scattering by arbitrary-length cylinders is derived based on the apparent volume flow accounting for the above-mentioned practical sonar properties, namely, spherical spreading and directionality. The formulation is first bench-marked against the formally exact T-matrix solution and tested against previously published laboratory data for finite cylinders. It is found that the formulation outperforms the T-matrix solution in predicting laboratory observations at near-normal incidence. Laboratory experiments are then conducted on arbitrary length smooth cylinders insonified by a directional sonar, with a small number of Fresnel zone excited, to evaluate the theory for monostatic as well as bistatic geometries. The formulation is found to outperform the classical scattering models in predicting the new measurements. For example, resonances associated with axially propagating guided waves excited at broadside incidence observed in the experiments are predicted by the proposed formulation but not by the classical models. The measurements are found to agree well with predictions in terms of overall scattering levels and resonance locations. However, the resonance shapes exhibit inconsistent agreement with data. In addition to testing the predictions, the bistatic laboratory observations presented herein substantiate the significant effects on scattering due to the properties of the incident field from practical sonars. The comparison between theoretical and experimental results is then extended for the more complex case involving statistically rough elastic cylinders with one-dimensional Gaussian roughness. The roughness is found to have a considerable impact on all aspects of scattering—overall levels as well as locations and shapes of resonances. General agreement is found between the theoretically predicted and measured ensemble averaged scattered pressure. Both the theory and data reveal two main observations in the ensemble-averaged scattered field: overall scattered pressure levels are seen to decrease, and resonance effects are diminished compared to the corresponding case of smooth cylinders. Effect of various statistical properties of the rough cylinder, namely, different root mean square (RMS) roughness for fixed correlation length and different correlation lengths for fixed RMS roughness on the scattered field are investigated. Finally, the fluctuations of the scattered field are analyzed using the derived formulation.

Friday, Dec. 6, 2024

4:15 PM EST; Rm. 5-314

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