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Classification of cylindrical shells filled with gas, liquid and solid materials using acoustic resonance spectra

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1. Introduction

Detection and classification of cylindrical targets using acoustical method have been studied by many investigators.[1),2),3)] In many cases, detection and classification process dependent target's geometrical specifications. But there are many unnecessary objects in the actual ocean or river conditions and these objects may have very similar geometrical specification with the targets which we want to detect. Specially, there are many artificial structures or products which have cylindrical shape (pipe, sea main, metal bar, Etc.). So, for classifying these objects, we need to consider another acoustical characteristic except geometrical specification. In this study, target's resonance property is considered. Acoustic resonance scattering is particularly dependent boundary conditions between target and inside material. Using this property, we can classify cylindrical shells shape targets filled with different materials which have same geometric properties (radius, thickness). Used target samples are air filled cylindrical shell, water filled cylindrical shell and solid aluminum circular bar. These targets inside materials represent gas, liquid and solid. Through this study, we try to classify cylindrical shells which have different inside material.

2. Experimental Measurements

Our purpose is to classify cylindrical targets which have same geometrical specification according to different inside materials. We used three cylindrical shell samples, each samples are filled with different materials. The insides materials are aluminum, air, water. These materials have large difference of density, sound speed. Each samples have same geometrical specifications which are L=30 cm, a=10 mm, b=8 mm (b/a=0.8). Other specification is showed **Table 1**. In this experiment, we used 1MHz broadband acoustic transducer. The wavelength of 1 MHz wave is about 1.5 mm, which is longer than thickness of aluminum tube and shorter than radius of aluminum tube. The cylindrical targets placed in laboratory water tank. The water tank is filled with degased water. **Fig. 1** shows experimental settings. Olympus V302 immersion type transducer is used, which has 1 MHz center frequency and broadband frequency range. Transducer is 50 cm away from cylindrical target. This value is longer than Rayleigh distance which is satisfied plane wave condition. Acoustic signal is generated by pulser/receiver (Olympus 5072PR). Pulser/receiver send short pulse to transducer and it can insonify resonance frequency acoustic wave. One transducer is used as transmitter and receiver (monostatic method). Transmitting signal is perpendicularly incident to cylindrical target's axis. After acoustic signal incident to cylindrical target, specular echo and elastic echo is received by same transducer. The backscattered signal is recorded by digital oscilloscope and moved to personal computer to process computational work.

Table. 1 properties of cylindrical shells

		Cylinder A	Cylinder B	Cylinder C
Outer diameter (mm)		12.2	12.7	12.7
Inner diameter (mm)		-	11	11
Inside material		Aluminum	Air	Water
Inside material property	Density (kg/m^3)	2762	1.2	998
	Sound speed (m/s)	6223	343	1475

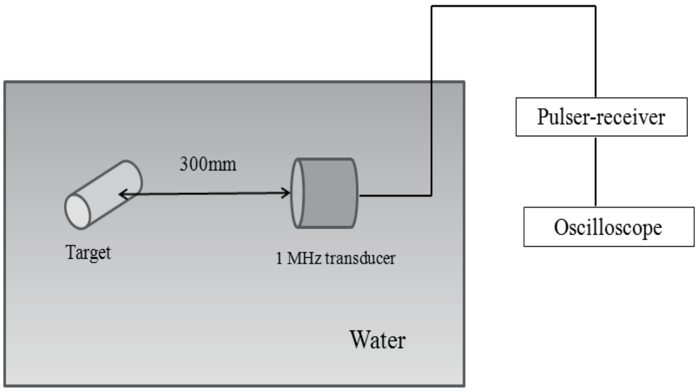

Fig. 1 Experimental setting

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3. Results and Discussion

Figures 2, 3 and **4** show average of specular echo spectrum amplitude and elastic echo spectrum amplitude. Incident sound wave creates modes caused by shell thickness (difference between outer diameter and inner diameter of cylindrical shells.). Each target's modes have different acoustic resonance scattering properties caused by boundary conditions between target shell material and target inside material. According to these reasons, modes contribute amplitude of resonance scattering amplitude for frequency domain. Experimental results show how different the target's resonance spectrum by inside materials.

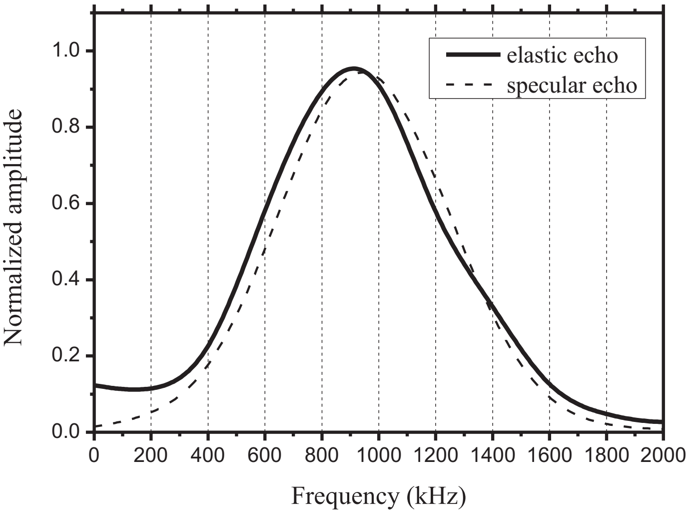

Figure. 2 Backscattering spectrums of solid cylinder

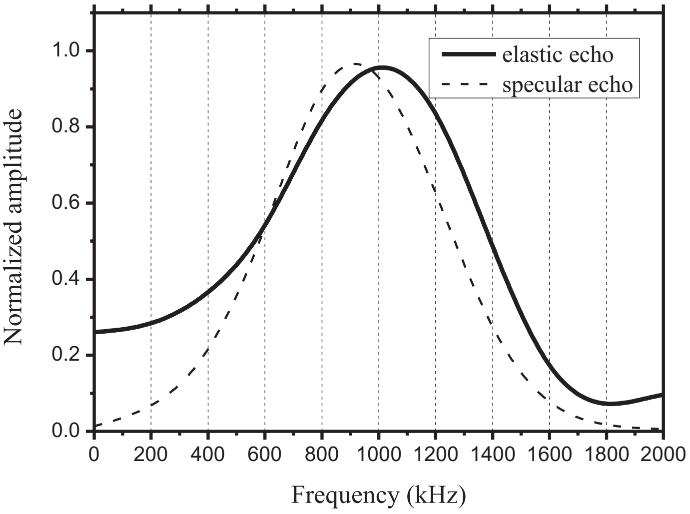

Figure. 3 Backscattering spectrums of air filled cylindrical shell

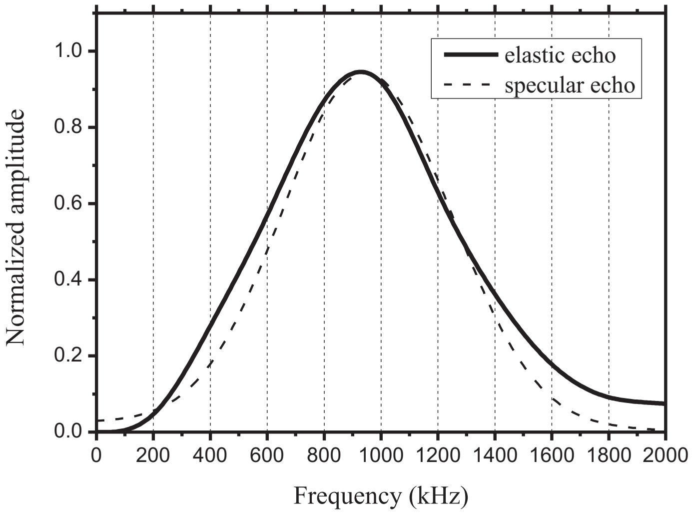

Figure. 4 Backscattering spectrums of water filled cylindrical shell

4. Conclusion

We try to classify cylindrical shells which are filled different inside materials using acoustic resonance spectra. Unless used three samples had very similar geometrical specifications, acoustic resonance spectrums of each sample are different. Inside materials represent gas, liquid and solid. They have large characteristic impedance difference, so the boundary conditions between cylindrical shell materials and inside material are affected by this property. For this reason, inside material contribute acoustic resonance spectra, we can classify used samples by experimental method. Through this study we can find how to classify targets which have similar geometrical specifications using differences of inside materials.

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