ULTRASONIC INSPECTION OF RUBBER SONAR DOME WINDOWS

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ABSTRACT

By using a rubber window acoustically matched to sea water, the Sonar system on a destroyer can be made considerably more sensitive. However, if the layered construction of the window develops delaminations while in service, the hydrodynamic characteristics of the structure may become modified and acoustic noise can be generated during high-speed operations. In order to inspect for these delaminations while the ship is tied up to its dock, a pulse-echo ultrasonic scan performed by a diver using a sea-water coupled transducer would appear to be ideal. However, the choice of acoustic parameters suitable for inspecting rubber were unknown. Laboratory studies showed that by utilizing very short time duration pulses whose center frequencies lie between 0.5 and 1.0 Mhz, it was possible to detect water-filled pockets within 0.2 inches of the outer surface of the window. A prototype instrument suitable for shipboard and dry dock operation has now been constructed. This instrument features optimized pulse excitation of low-frequency broad band transducers when attached to 50 to 100 feet of coaxial cable. A signal light is also incorporated to provide the diver with information on the condition of the rubber window under his transducer.

INTRODUCTION

When Sonar systems were first added to the Navy's surface fleet, the acoustic energy was usually coupled to the sea water through the steel hull of the vessel. For anti-submarine warfare from a destroyer, this procedure proved to be sufficiently lossy that a submarine could escape detection. To alleviate this situation, a region of the steel hull is now replaced by a rubber window in which the rubber has been chosen to be a good acoustic impedance match to sea water to make the structure as transparent to sound waves as possible. Figure 1 shows a photograph of a modern destroyer in dry dock and the bulbous Sonar Dome structure under the bow of the ship can be easily seen. Although not clearly delineated in the photograph, this bulb is nearly surrounded by a rubber strip approximately 8 feet high and 80 feet in circumference. It is constructed in a manner similar to an automobile tire with steel reinforcing wires embedded in it.

THE PROBLEM

The outer layer of the rubber window is approximately 1/4 inch thick and has a somewhat different chemical composition than the rest of the window structure so that it will repel barnacles. Since it lies on the surface of the dome, any defects such as a disbond under the layer could interact with the hydrodynamic flow past the window and cause turbulence or cavitation which, in turn, could act as a source of unwanted noise in the Sonar receivers. In order to have an instrument for detecting disbonds or other discontinuities near the outer surface of the window, the Science Center was asked to investigate the possibility of using ultrasonic pulse-echo techniques. Laboratory studies showed that special electronic circuits coupled to conventional, broad-band piezoelectric transducers would detect near-surface flaws if the frequency were between 0.5 and 1.0 MHz and the total pulse durations were less than 6 μsec.

Figure 1. Photograph of a destroyer in dry dock The round bulb below the bow contains the Sonar "antenna" and the Sonar window is a rubber strip around this bulb.

THE INSTRUMENT

Once the electronic and acoustic specifications had been defined, the Albuquerque Development Laboratory was asked to construct a complete instrument package suitable for operation by Navy personnel at dockside or in drydock. Figure 2 shows a photograph of the completed instrument as well as the transducer holder. It can be operated either from a self-contained battery pack or from 110 volt, 60 cycle AC sources. The CRT displays the RF

Figure 2. Photograph of the battery operated, portable instrument for inspection of rubber Sonar Windows.

signal reflected by the Sonar Dome on an expanded time base so that an echo from an inhomogeneity near the Dome surface can be time resolved from the echo from the front surface itself. A gating circuit is available to separate out those signals that arrive after the front surface echo and to activate an alarm if they exceed a preset level. This alarm consists of three parts: (1) a speaker that generates an audible noise signal; (2) the region of time comprising the gate duration appears on the CRT display as an intermittent square wave superimposed on the signal; and (3) a red light on the transducer package that is held on the Sonar Dome becomes activated. The latter alarm is of particular utility, because it alerts the diver scanning the transducer over the dome that he is in the region of a suspected defect. In the usual mode of operation, the person scanning the transducer over the rubber window area will be a professional diver while the person viewing the CRT display will be one who is trained in ultrasonic inspection techniques and will be stationed on a dock or surface vessel some distance away from the Sonar Dome itself. Once a suspect area is located, the diver and the inspector can communicate over a separate audio communication link to make detailed comparisons of the conditions of the signal that activated the light on the transducer package and to establish the location of the transducer on the dome.

Because the CRT display is expected to be at least 100 feet away from the transducer, special transmitter and receiver circuits had to be developed to insure that there would be no degradation of the signal between the transducer and the display. To meet this requirement, very compact transmitter and preamlifier circuits were designed to fit into the small container housing the transducer. Thus the long, waterproof cable connecting the instrument with the diver held probe need only transmit DC power supply voltages and the preamplified RF signals detected by the transducer. The remote transmitter-circuit consists of a carefully chosen transistor switch designed to discharge a capacitor into the transducer with a time constant tailored to the desired center frequency of operation. The preamplifier consists of high gain, low noise amplifier stages designed to recover quickly from the transmitted burst, as well as to present an optimum impedance to the transducer at the input and to the long cable at the output.

OPERATION

Delivery of the final instrument and acceptance tests on the Sonar Window of a destroyer are scheduled for October of 1979, so only laboratory simulations of the actual operation of the instrument are available at this time. Figure 3(a) shows the RF signal

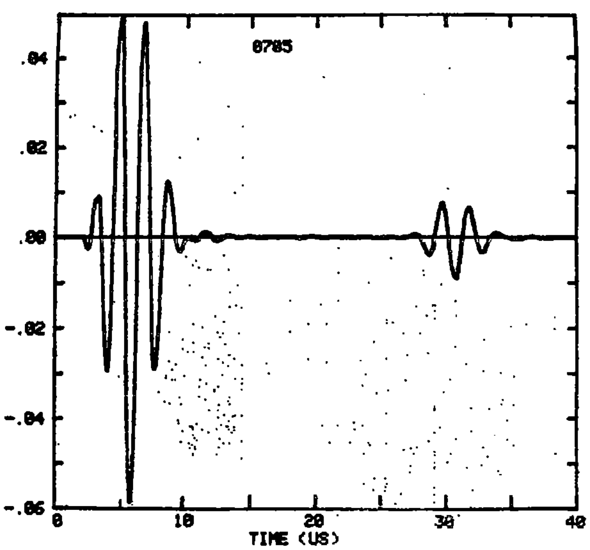

Figure 3(a). Example of the RF w[illegible]orm observed on the CRT [illegible] a good Dome display for the case of a defect free test sample of the rubber window structure. The large signal on the left is the reflection from the front surface of the sample. That is, the reflection from the sea water to rubber window interface. The small signal on the right of the trace is from a layer of steel reinforcing wires buried in the test rubber sample, approximately 1/2 inch below the surface. Its amplitude is reduced because of attenuation of the sound in the rubber. Figure 3(b) shows the signal observed when the acoustic path between the rubber surface and the steel reinforcing wires is interrupted by a water-filled disbond. Clearly the thin layer of water in the disbond causes a reflection of ultrasonic energy which can be detected by the ultrasonic pulse-echo technique. By adjusting the signal gate to coincide in time with this disbond echo and setting the alarm trigger level to be activated by a signal of that amplitude, the instrument alarm system could be initiated whenever the transducer was scanned over the disbonded region of the sample.

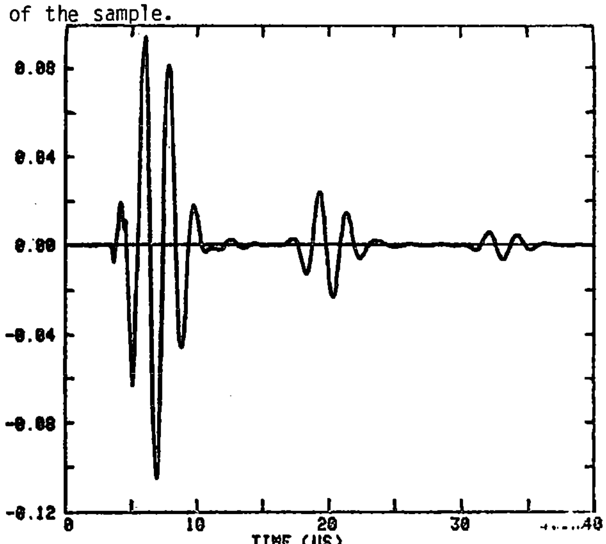

Figure 3(b). Example of the RF waveform observed on the CRT in the region of a disbond.

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