INCREASING THE DEPTH CAPABILITY OF BARREL STAVE PROJECTORS

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1. Introduction

The Barrel Stave Projector (BSP), an underwater acoustic transducer, has been under development at DREA since the mid-eighties[1]. It is a flextensional transducer where the driving element is a stack of piezoelectric ceramic rings. The extensional vibrations of the ceramic stack are coupled to a concave shell that vibrates in flexure. The leverage action of the shell amplifies the motion of the stack. To operate in the low frequency regime (<2 kHz) it is necessary to reduce the hoop stiffness of the shell by forming the shell from staves separated by small gaps, 1 mm wide or less. The shell is covered by a neoprene boot to waterproof the transducer.

All flextensional transducers with air-backed shells have a common problem - their performance is very depth dependent not to mention the higher tendency of being crushed when submerged to great depths.

2. The pressure compensation system

In the BSP the volume behind the shell is usually occupied by air at atmospheric pressure. As the projector is lowered to progressively greater depths, the hydrostatic pressure on the outside of the shell increases. This may cause the rubber outerlayer to be pushed in the gaps between the staves and/or a deformation of the shape of the stave. Either of these mechanisms would cause a change in acoustic performance of the projector. When the differential pressure across the shell exceeds a certain threshold, the flexural mode of the staves becomes clamped. To overcome this, the BSP can be filled with a fluid to equalize the interior with the exterior ambient pressure. The compressibility of the fluid used must be about the same as air or better to maintain the performance of the projector. Otherwise the driver's force is expended more in compressing the interior fluid than generating the exterior water motion to produce radiation. Pressurized air is the natural choice. The added air inside the projector will still have some side effects on the performance of the projector. The compliance of the pressurized air is given by: $C=V/\rho_{air}c^2$ where V is the volume of air in the projector, ρ_{air} is the density and c is the sound speed in air. The density is related to the pressure P and temperature T by: $\rho_{air} = \rho_0(T_0/T)(P/P_0)$ where ρ_0 is the density at absolute temperature T_0 and pressure P_0. As the depth is increased, ρ_{air} will increase causing the compliance to decrease or the stiffness to increase and causing an increase in resonance frequency.

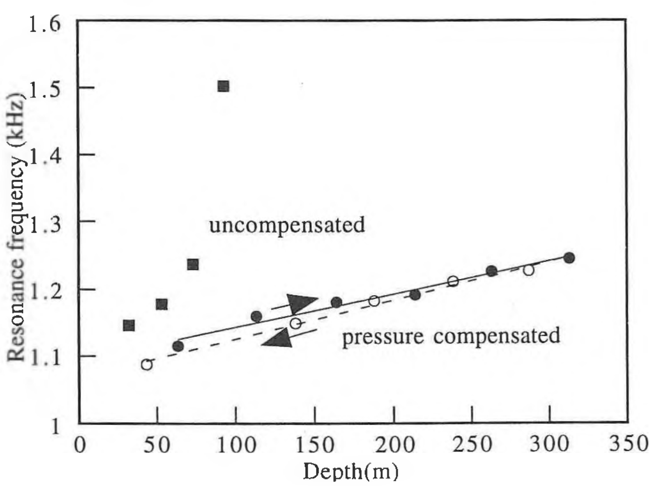

Figure 1 *The resonance frequency as a function of depth for a Barrel Stave Projector with and without pressure compensation.*

3. Calibration and Results

Several Sparton of Canada BSP Model 03BA1100[2] were refurbished to accommodate an active pressure compensation system. The system is essentially modified scuba gear as used by divers. High pressure tubing connects the air bottles to a dual-stage regulator which in turn is linked to the BSP via Tygon™ tubing. The projector has been equipped with a spigot on the bottom end plate. This end plate also has a channel milled out to allow the pressurized air to fill the area between the ceramic stack and the staves.

The transmitting voltage response and the admittance were measured for several Barrel Stave projectors without any compensation at various depths. The dependence of the resonance frequency, f_R, on depth is shown by the filled squares in Figure 1 for one of the projectors tested. As the depth increases f_R increases quickly. In fact at the deeper depths the lowest mode is no longer the flexural mode of the shell but the higher frequency longitudinal mode of the stack. For the BSP this dependency had previously been observed[3].

The same measurements were repeated with the projector equipped with pressure compensation. The second curve in Figure 1 shows the dependence of f_R on depth. The arrows indicate whether the projector was lowered to deeper depths or brought back up. The flexural mode of the projector remains active but increases at a rate of 0.57Hz/m as the depth is increased. This frequency increase is due to the increase of the density of air inside the projector. As the BSP is moved to shallower depths, f_R decreases at a rate of 0.43Hz/m. The difference in the rate of change of f_R is attributed to the inherent hysteresis of the regulator. The peak of the transmitting voltage response changes very little as the depth is increased. All the projectors tested showed a rate of change of f_R between 0.4 and 0.6Hz/m.

4. Conclusions

For many applications underwater acoustic projectors are required to work in the low frequency regime and at great depths. The Barrel Stave Projector is a compact high power low frequency projector and we have shown that by pressure compensating it with compressed air it can also be used in deep water applications.

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1 D.F. Jones and G.W. McMahon, "The Design and Performance Analysis of Barrel Stave Projectors", DREA Informal Report, 1987.

2 C. Duck, J. Ellis, D. Hoare, D. Holcombe, S. Lo and J. Surry, "Barrel Stave Transducers", Technical Report DREA/CR/91/430, Defence Research Establishment Atlantic, 1991.

3 D.F. Jones and M.B. Moffett, "Water Depth and Drive Voltage Dependence of the Acoustic Parameters of a Barrel Stave Flextensional Projector", JASA, vol. 94, p.2305, 1993.