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MECHANICS OF UNDERWATER NOISE

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CHAPTER 8

PROPELLER CAVITATION NOISE

Cavitation of marine propellers is the most prevalent source of underwater sound in the oceans. Furthermore, when it occurs, propeller cavitation is usually the dominant noise source for any single marine vehicle. Submarines and torpedoes often operate deep enough to avoid cavitation. Surface ships, on the other hand, generally have well-developed propeller cavitation, with the result that their entire radiated spectra from as low as 5 Hz to as high as 100 kHz are controlled by this source. The basic phenomena of cavitation and cavitation noise were considered in the previous chapter. Now these concepts are combined with propeller hydrodynamics relations to explain the fundamental characteristics of propeller cavitation noise. Data on surface ship radiated noise and an analysis of the contribution of this source to low-frequency ambient ocean noise are presented in the final two sections.

8.1 Types of Propeller Cavitation

Propeller blades are rotating twisted wings that produce hydrodynamic forces. Depending on operating conditions, they experience cavitation in a number of different places, as illustrated by three typical examples shown in Fig. 8.1. Prominent in these photographs are two types of vortex cavitation: tip-vortex and hub-vortex. Propeller tip-vortex cavitation, shown most clearly in Fig. 8.1(a), is similar to wing-tip cavitation, which was discussed in Section 7.8. Hub vortices such as that shown in Fig. 8.1(c) are formed when the lift is heavy on inboard sections. Vortex cavitation produces noise, but not as much as blade-surface cavitation, which is most clearly visible in Fig. 8.1(b). In this case, the cavitation is occurring on the suction, or back, surface of the blade. When the thrust produced is small or negative, blade-surface cavitation may occur on the driving face of the blade. In addition to two types of vortex cavitation, there are two types of blade-surface cavitation: back and face. Of these, blade-surface cavitation on the suction surface is the most noisy, and hub-vortex cavitation the least.

8.2 Blade-Surface Cavitation Noise

Of the various types of cavitation, blade-surface cavitation on the suction surface produces the highest noise levels. This is because the voids collapse rapidly when they reach a region of positive collapse pressure. Both types of vortex cavitation voids, on the other hand, remain in negative pressure regions for relatively long times, tend to fill with gas as well as vapor and so collapse with less energy release.

Rotating Blade Experiments

Blade-surface cavitation can be made to occur on the surfaces of non-lifting as well as lifting measuring with omnidirectional phones and one-third-octave bandwidths are 1.5 to 2.5 dB for the distant shipping component alone. When data are contaminated by nearby ships, as in Fig. 8.24, standard deviations are much larger.

It is common practice in the underwater sound community to assume a log-normal distribution of ambient noise values. While this offers a reasonable fit to the central distribution, a Gaussian function does not properly represent the tails. Dyer (1973) concluded that the actual distribution is closer to a Rayleigh distribution, which is similar to Gaussian but with truncated tails.

Long-Term Trends

One of the more important conclusions that follows from this analysis of shipping noise is that low-frequency ambient noise levels must have risen significantly in the past quarter century. In the 25 years following 1950, the total number of ships has more than doubled. With increased efficiencies of port handling facilities, the number of ships at sea has increased even more. This factor alone would account for a 3 to 5 dB increase of ambient noise originating from shipping. In addition, as discussed in the previous section, increases of average ship speed, propulsion power and propeller tip speed all lead to the conclusion that the average ship produces at least 6 dB more noise. Combining all these factors, one must conclude that in the past 25 years ambient noise has probably risen about 10 dB in those areas where shipping noise dominates. Furthermore, ship noise must now have become a dominant factor in some areas where it did not previously control. Unfortunately, measurements made at the same location a decade or more apart have not appeared in the literature, so this conclusion cannot be supported with experimental data. However, in view of the nearly tenfold increase of the horsepower of propulsion plants in ships at sea, it would indeed be remarkable if the noise due to ships had not increased close to 10 dB.

This trend is not expected to continue at so rapid a pace. Over the next 25 years, the number of ships may be expected to increase only about 50%, and the noise per ship by only a few dB. Thus, the increase of low-frequency ambient noise levels due to ships may be only about 5 dB during the next quarter century.

REFERENCES

Sections 8.1-8.4

Aleksandrov; I.A., Some cavitation characteristics of ship propellers, *Sov. Phys.-Acoustics, 7*, 67-69, 1961.

Aleksandrov, I.A., Physical nature of the rotation noise of ship propellers in the presence of cavitation, *Sov. Phys.-Acoustics, 8*, 23-28, 1962.

Boswell, R.J., Design, Cavitation Performance, and Open-Water Performance of a Series of Research Skewed Propellers, *N.S.R.D.C. Rept. 3339*, March 1971 (AD 732511).

Burrill, L.C., Sir Charles Parsons and cavitation, *Trans. Inst. Mar. Engin., 63*, 149-167, 1951.

Burrill, L.C., The phenomenon of cavitation, *Int. Shipbuilding Progress, 2*, 503-511, 1955.

Burrill, L.C. and Emerson, A., Propeller cavitation: tests on 16-inch models in the King's College cavitation tunnel, *Northeast Coast. Inst. Engin. and Shipbuilders, 70*, 121, 1953; also, *Int. Shipbuilding Progress, 10*, 119-131, 1963.

Eisenberg. P., On the Mechanism and Prevention of Cavitation, *D.T.M.B. Rept. 712*, July 1950.

Emerson, A. and Sinclair, L., Propeller cavitation: systematic series tests on 5- and 6-bladed model propellers, *Trans. Soc. Naval Arch. and Mar. Engin., 75*, 224-267, 1967.

Flamm, O., The scientific study of naval architecture in Germany, *Trans. Inst. of Naval Arch., 53*, 207-216, 1911.