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# Singing Propellers

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**Abstract.** The causes of singing of propellers of ship and the characteristics of noise produced are discussed with data from a case study. Five frequencies of singing were observed at 50 Hz, 152 Hz, 250 Hz, 340 Hz, and 458 Hz depending on the state of the propeller. The marine fouling has profound influence both on frequencies and noise levels of singing. The airborne noise produced by the singing propellers has deleterious effects on human habitability and working efficiency and may even cause damage to hearing. Some remedial measures for elimination of singing are suggested.

## 1. Introduction

The singing propellers contribute to both underwater noise and airborne noise of ships. The reduction of underwater noise of ships is necessary to keep the warships operationally efficient and to avoid detection by enemy submarines from a long range. The reduction of airborne noise is necessary to improve audio communications, to provide good habitability conditions for the ship's crew, to eliminate human fatigue on exposure to noise and to improve working efficiency and to avoid damage to hearing.

A propeller is said to be singing when it generates noise in a very narrow band of frequencies or almost at discrete frequencies with a typical waxing and waning characteristic. It is spread over a wide range of ship's speed or in other words, shaft revolutions (RPM). A propeller may sing at more than one frequency. The singing occurs in low frequency region of a few hundred hertz and the noise due to singing propellers may spread over a frequency range of ten. The pitch of the continuous singing may be identified with one or other of the torsional vibrations of the blades and the pitch of the most favoured partial tone changes with RPM but the noise is composite of two or three lines occurring together. The singing of ten occurs below the cavitation speed and its elimination would require special techniques that are different from those used for reducing propeller cavitation. The causes of singing and the characteristics of noise produced by singing propellers are discussed in this paper.

*Relaxation Oscillation*

The singing propeller is a form of 'relaxation oscillation'. These oscillations are produced whenever a system receives regular impulses sufficiently detached to allow it to oscillate in one or other of its degrees of freedom but ofcourse, with diminishing amplitude between impulses.

## 2. Causes of Singing

One obvious cause for the vibrating of the blade may be the vortices produced in the water as in the air-screw case. Another may be the incipient cavities which are shed from the blades. The natural blade vibrations are excited by eddy shedding in the vicinity of the blade trailing edge; thus producing singing. This happens at low speeds if the water contains air in solution which is outgassed when the water suffers a sudden drop in pressure as happens when it passes over the edges of the blades where the curvature changes abruptly. Some model propellers which sang in water under atmospheric pressure ceased to do so when the air pressure above the water was reduced to one quarter.

The case of vortices regularly produced in water before they reach the propeller, such as those produced at the stern post, is quite the same as that of the vortices shed from the blade. But, whereas the vortices shed by the blade pass as a spiral screw into the wake by virtue of the slipstream, those from the hull and its fixtures tend, for a time atleast, to preserve their position without twist. The net result is that the propeller is, at certain speeds, acted on by vibrating forces coperiodic with the revolutions.

## 3. Case Study

Studies on the phenomenon of singing propellers in a ship were carried-out on three different occasions, before docking, immediately after undocking and three months after undocking. The physical condition of the propellers with reference to marine fouling from organisms like barnacles was different in the three cases.

Airborne noise was measured with the help of a sound level meter in the propeller shaft tunnel in the lower deck to establish the properties of the singing propellers. The noise level increased as one moved towards aft in the shaft tunnel i.e. towards the propeller. The maximum difference in the noise levels at the aft and at forward ends of the shaft tunnel was about 10 db. At each plummer block bearing, the noise level was measured and it was the same as that in the surroundings. These observations clearly indicate that the noise originated not at any one of the plummer block bearings but from outside the shaft tunnel at the aft end. This leaves only two possibilities for the source of noise viz., stern tube bearings or propeller. The other characteristics of the noise, explained in the following paragraphs, clearly indicate that the sourc eis only the singing propellers.

## 4. Characteristics of Noise

The noise levels were measured in the shaft tunnel at different RPM of both starboard and port shafts. The noise waxes and wanes periodically. Its cycle of waxing and waning is coperiodic with the revolution of the propeller shaft. Between waxing and waning, there is a difference in overall noise level of 5 to 8 db depending on the state of the propeller at the time of measurement.

The variation of noise level on the starboard side with frequency around the prominent frequencies of singing is given in Figs. 1 — 3 for the measurements taken during predocking, immediately after undocking and three months after undocking trials respectively. The variation of noise level with RPM of port and starboard shafts, as measured during the three months after undocking trials, is given in Fig. 4. The comparison of overall noise levels at different places in the ship for different times is given in Table 1 and the frequencies of singing observed at different times are given in Table 2.

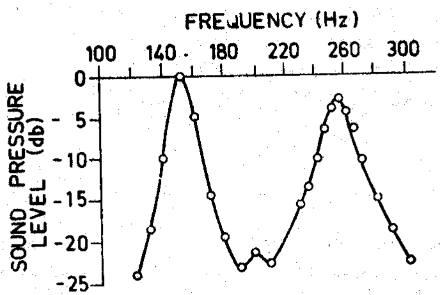


**Figure 1.** Relative values of noise levels around the prominent frequencies of singing (pre-docking tests)

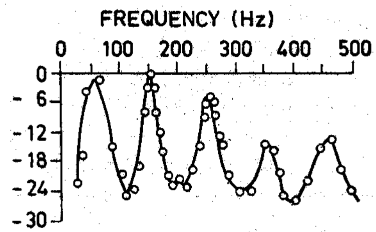


**Figure 2.** Relative values of noise levels around the prominent frequencies of singing (tests immediately after undocking).

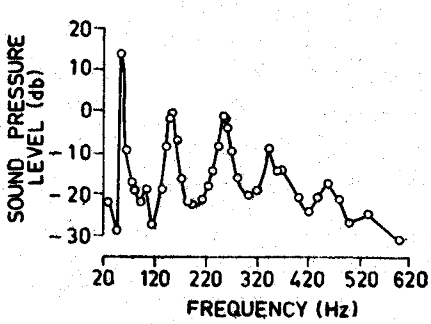


**Figure 3.** Relative values of noise levels around the prominent frequencies of singing (three months after undocking tests).

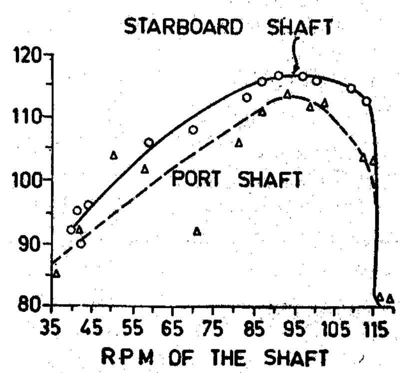


**Figure 4.** Variation of noise levels (sound pressure level db re 0.0002 microbar) with RPM of port and starboard shafts).

**Table 1.** Comparison of overall noise levels due to singing propellers at different places at different times

| Sl. No. | Place of observation | Pre-docking tests | | Immediately after undocking tests | | Three months after undocking tests | |
|---|---|---|---|---|---|---|---|
| | | Max. noise level db* | Singing range of RPM | Max. noise level db* | Singing range of RPM | Max. noise level db* | Singing range of RPM |
| 1. | Shaft tunnel (Port Side) | 103 | 70 – 115 | 112 | 70 – 120 | 114 | 42 – 116 |
| 2. | Shaft Tunnel (Starboard side) | 112 | 70 – 115 | 117 | 70 – 127 | 117 | 44 – 116 |
| 3. | Site towards the aft of the ship on the deck above the starboard shaft tunnel | 86 | — | 96 | — | 94 | — |
| 4. | Site towards the aft of the ship on the deck above the port shaft tunnel | 92 | — | 99 | — | 94 | — |

*db re 2 × $10^{-4}$ microbar

**Table 2.** Different frequencies of singing at different times

| Sl. No. | Description | Frequencies of singing in Hertz: Pre-docking | Immediately after undocking | Three months after undocking |
|---|---|---|---|---|
| 1. | Prominent frequencies of singing for starboard propeller | 150 & 255 | 55, 150 & 250 | 50, 152 & 250 |
| 2. | Less prominent frequencies of singing for starboard propeller | — | 352 & 458 | 340 & 458 |

## 5. Discussion

*Frequencies of Singing*

During the pre-docking tests, there were two prominent frequencies of singing, at 150 Hz and 255 Hz (Fig. 1). During the docking, the propellers were cleaned and in the trials after undocking, three prominent frequencies of singing were recorded at 55 Hz, 150 Hz and 250 Hz (Fig. 2). Also, there were two minor resonances at 352 Hz and 458 Hz. It is quite possible that the prominent resonance at 55 Hz was suppressed during the earlier investigations by deposition of some marine organisms like barnacles on the blades of the propellers. In the tests conducted three months after undocking, three prominent frequencies were noticed at 50 Hz, 152 Hz and 250 Hz as shown in Fig. 3. Also, a less prominent resonance occurred at 348 Hz, 8 db below the level at 152 Hz and another minor resonance at 458 Hz, 16 db below the level at 152 Hz. The three preminent frequencies of singing as well as the two less prominent ones are similar to those observed during the tests conducted immediately after undocking. But the noise level at 50 Hz is inexplicably high by about 15 db relative to those at the other two frequencies. The incidence of higher noise levels during these tests compared to those measured immediately after undocking is perhaps attributable to the constant sailing of the ship for a period of 15 days immediately preceding these measurements.

*Effect of Marine Fouling*

It is interesting to note that, when the ship's screws were considerably fouled with barnacles, no such waxing and waning sound characteristic of a singing propeller was heard for any speed of the ship and for any acceleration. However, the peculiar noise showed itself as soon as the marine fouling was cleared.

*RPM of Shaft*

The characteristic noise of singing was always heard during a definite range of the ship's speeds. During the pre-docking tests, it was heard between 70 and 115 RPM on both port and starboad shafts with the maximum overall noise level occurring at 98 RPM on starboard shaft and at 92 RPM on port shaft. The singing range of shaft RPM increased, as can be expected, after cleaning the propellers during docking and extended from 70 to 127 RPM on the starboard shaft and upto 120 RPM on the port shaft as measured during the immediately after undocking tests. In the tests conducted three months after undocking, it was observed that the range of RPM further extended to the lower side possibly because of constant sailing at high speeds preceding the tests. The noise occurred at speeds between 44 and 116 RPM on the starboard shaft and between 42 and 116 RPM on the port shaft as given in Fig. 4.

*Maximum Overall Noise Level*

The maximum overall airborne noise level measured in the shaft tunnel followed the same pattern as explained above increasing from the pre-docking tests to the three months after undocking tests as shown in Table 1. The maximum overall noise levels were 103 db and 112 db in the shaft tunnels on the port side and the starboard side respectively in the pre-docking tests. This increased to 112 db and 117 db during the measurements immediately after undocking and to 114 db and 117 db during the measurements three months after undocking.

The speed at which the maximum overall noise level was observed changed in the three tests. Also, a change of pattern was noticed between the pre-docking and post-docking trials due to cleaning of the propeller blades. Whereas the maximum overall level occurred at 98 RPM on starboard shaft and at 92 RPM on port shaft during the pre-docking trials, the level was constant over a long range of 85 to 103 RPM on starboard shaft during the post docking trials. The port shaft, however, gave peak noise at 98 RPM. This pattern repeated during the trials three months after undocking, with a peak noise level at 93 RPM on the port shaft and with a constant maximum noise level over a range of 87 to 105 RPM on the starboard shaft.

*Effect of Ship's Sailing*

During the pre-docking trials, when the propeller blades were not cleaned of the marine fouling, the effect of ship's sailing at high speeds was studied by measuring the noise levels on two consecutive days. After the measurements on the first day, the ship sailed at high speeds for a long time and the measurements were repeated on the second day. An increase in the maximum overall noise level from 106 db to 112 db on the starboard side and from 98 db to 103 db on the port side in the shaft tunnel was observed. This confirms that the singing of propellers is affected by the sailing of ship and the consequent change in the quantity and pattern of deposit of marine organisms on the propeller blades.

*Effect on Inhabitability*

The airborne noise produced by the singing propellers has been found to have a profound effect on the habitability of the crew and their working efficiency. The noise due to singing, being in a narrow band, causes more damage than a noise of equal intensity in wide band. It may, therefore, impair hearing of ship's crew and even cause permanent damage to hearing if a particular limit is exceeded. The maximum noise level in the octave band that should not be exceeded to avoid permanent damage to hearing after long exposure is only about 90 db. In some locations of the ship, this limit was exceeded. Noise measured in some locations is given in Table 1. When the ship was sailing, the crew were constantly subjected to this noise menace and were deprived of their rest even during their non-working hours. This causes exhaustion besides hearing problems and thus has a telling effect on working efficiency and habitability conditions of the crew.

*Prevention of Singing*

The singing of propellers can be prevented or reduced to a large extent by proper care at the time of design of the propeller. The point of importance is to alter the frequency of eddy shedding so that the resonant vibrations of the blades can be prevented. It may however be mentioned that the problem of singing propeller may sometimes prove itself to be beyond the simplified design considerations. It has been reported that there have been cases of identical ships fitted with propellers of identical design and in one case, singing has taken place but not in the other.

A fine trailing edge helps to a large extent in changing the frequency of eddy shedding but care should be taken to see that it is not damaged or rounded off during cleaning. Lead filled grooves on the blades also help prevent the excitation of resonant vibrations if reduction in strength of the propeller is acceptable. Alternatively, new materials are to be developed which have better damping characteristics than the existing propeller materials. These modifications do not affect propulsive qualities or cavitational effect on the propellers.

## 6. Conclusion

The singing of propellers is a phenomenon of resonant vibrations of blades excited by eddy shedding. The airborne noise produced by singing propellers has a waxing and waning characteristic and this cycle of waxing and waning may be coperiodic with the revolutions of the propeller shaft.

More than one prominent frequency of singing can occur on the same propeller and the noise is essentially a narrow band noise around these prominent frequencies of singing.

Marine fouling has a highly significant effect on the characteristics of singing and it may even totally suppress the singing sometimes.

The airborne noise produced by singing propellers adversely affects habitability conditions of the ship's crew, its working efficiency and also human hearing.

Modifications to trailing edge and lead filled grooves on the propeller blades are two important remedial measures to eliminate singing of propellers.

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