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A STUDY OF THE TRANSMISSION OF NOISE AND VIBRATION IN AN ALUMINIUM MOTOR VESSEL

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ABSTRACT

This paper describes an investigation of the noise problem in an aluminium motor vessel. The problem was due to the high noise level in the work deck area which exceeded operational health and safety (OH&S) requirements by 9 dB at cruising speed. It was identified in this paper that the deck noise was due to contributions from three sources. These sources were: (i) the radiated noise due to vibration of the deck structure, (ii) the noise transmitted from the engine room to the deck and (iii) the noise transmitted from the exhaust vent to the deck. Various control measures for reducing the deck noise are discussed and preliminary results on deck noise measurements of the modified vessel are presented

INTRODUCTION

The study of noise and vibration in ships has received considerable attention in the past few decades as a result of stringent ship noise legislation introduced by many countries. Such legislation aims to provide a safe and comfortable working environment for crew members by specifying a maximum allowable sound pressure level in various ship compartments.

Due to the special operational requirements for military vessels such as the maximum speed and range, high power propulsion machinery is sometimes installed in these vessels which may give rise to noise and vibration problems. These paper describes a program of work to reduce the deck noise of a military vessel.

BACKGROUND

An investigation on shipboard noise and vibration was conducted on an aluminium motor vessel operated by the military. The vessel is 20 m long and powered by two Detroit V12 92 turbo-charged marine diesel engines each develops 650 kW at 2300 rev/min. Each engine is coupled to a four-blade propeller through a 1.971:1 reduction gearbox. The gross tonnage of the vessel is approximately 32 tonnes.

The engines are mounted on deep engine beds that are welded to the hull and to the rear and forward bulkheads of the engine room. Stiff engine mounts are used at the rear to ensure an accurate alignment with the propeller shaft while compliant isolators are used as the front engine mounts. The work deck which carries military personnel is located above the engine room. Under normal operating conditions, it was found that the acoustical environment in the work deck was quite unsatisfactory. Speech communication was very difficult due to the high noise level in the deck area which was found to have a maximum of 94 dB(A) at an engine speed of 2000 rev/min. This exceeds the OH&S requirements according to AS 2254 [1] by 9 dB. It was thus necessary to identify the noise sources quantitatively and develop control strategy to reduce the deck noise level.

MEASUREMENTS AND ANALYSIS

From a preliminary study of the noise and vibration problem, it was identified that the deck noise was due to contributions from three sources. These sources were: the radiated noise due to vibrations of the deck structure (referred to as structure-borne noise for the purpose of this paper), the noise transmitted to the deck as a result of the sound field established in the engine room (referred to as air-borne noise) and the noise propagated from the exhaust outlet vent to the deck.

Having established the noise sources, it was then necessary to quantify the contribution of each of these sources to the deck noise level so that appropriate control measures can be taken. As a first step, an artificial noise source was placed in the engine room with the propulsion system not operating. The transmission loss of the air-borne noise between the engine room and the deck was then determined from sound pressure level (SPL) measurements in these two locations. The noise transmitted from the engine room to the deck can be determined by subtracting the engine room noise (at an operating condition of 2000 rev/min engine speed) with the transmission loss through the air-borne path. Secondly, the experiment was repeated with the artificial noise source placed at the exhaust outlet vent, again with the propulsion system not operating, in order to determine the transmission loss between the exhaust outlet and the deck. Thirdly, the spatially averaged mean square velocity of the deck structure at operating conditions was measured in order to determine the radiated noise from the work deck. The above information, together with the SPLs at the engine room and exhaust outlet measured at operating conditions, enable the contributions of the noise sources on the deck noise level to be determined. Figure 1 shows the deck noise level due to contributions from these three sources. To facilitate the calculation of the 'A' weighted noise level, the SPL presented in this paper is expressed in terms of the frequency band level.

It can be seen from Figure 1 that the structure-borne noise contributes significantly to the deck noise level throughout the entire frequency range of interest, while the exhaust noise and air-borne noise make a significant contribution at a frequency range of 100 - 200 Hz and 400 - 630 Hz respectively. The exhaust noise at 200 Hz is associated with the firing frequency of the engine and has a strong effect on the structure-borne noise.

The deck noise levels due to the three noise sources are compared with the measured values in Figure 2. It can be seen that the agreement is very good up to a frequency of approximately 2000 Hz, beyond which the combined noise levels overestimate the measured values by approximately 8 dB. Further investigation of the experimental results reveals that the mean square velocity of the deck decreases with frequency and beyond 2000 Hz, the mean square velocity is of the same order of magnitude as the resolution of the accelerometers. Thus the structure-borne noise results are not valid beyond 2000 Hz. However, since the air-borne noise and exhaust noise have very little contribution to the deck noise beyond 2000 Hz, it can be assumed that the deck noise beyond this frequency is solely caused by the vibration of the deck.

Figure 3 shows the 'A' weighted band levels of the sound pressure at the work deck. A combination of all band levels gives a noise level of 94 dB(A). To reduce the noise level to 85 dB(A), the band levels have to be reduced, particularly in the 200 Hz and 500 Hz bands. Referring back to Figure 1 which shows the contribution of the three noise sources to the deck noise, it is evident that all of the three sources; namely, the air-borne noise, structure-borne noise and exhaust noise, have to be reduced in order to achieve a deck noise level of below 85 dB(A).

CONTROL MEASURES

Structure-borne noise

The structure-borne noise may be controlled either by introducing damping to the hull structure or reducing the source level of vibration (for example, using compliant engine mounts) and the effect of these measures on deck noise reduction is discussed here.

To study the effect of damping on the response of the deck structure, a statistical energy analysis (SEA) model of the ship structure was developed. The structural elements of the model consist of a 3.2 mm viscoelastic layer together with a 3 mm aluminium constraining layer added onto the bulkheads, deck and the hull plates (assume 70% of coverage), the SEA model predicts a reduction in deck response of approximately 3 dB as shown in Figure 4. This is a modest reduction of structural response considering the amount of damping treatment added on to the structure. The reason for this is probably due to the relatively high initial damping of the structural elements such that further addition of damping treatment would not cause a significant reduction of the structural response.

Another way of controlling the structure-borne noise is to reduce the source level. This can be achieved by using compliant engine mounts to isolate the input excitation from the engines. Results of measurements on the response of the engine mounts indicate that by increasing the compliance of the rear engine mounts to the same level as that of the front mounts, a significant reduction in deck response can be achieved. It should be noted that the use of compliant engine mounts will require the installation of a flexible coupling between the gear box and the propeller shaft.

Exhaust noise

The influence of exhaust noise on the deck noise level is mainly concentrated in the low frequency region (below 200 Hz) and it is straight forward to incorporate a reactive muffler to the exhaust system to give an attenuation of the order of 10 dB or more in this frequency range. However, analysis shows that the required chamber size would probably be too large to fit into the engine room.

An alternative approach is to line the exhaust jacket with a suitable sound absorbing porous material. It is estimated that by lining the vertical surfaces of the exhaust jacket with 50 mm thick sound absorbing material, the exhaust noise can be attenuated by approximately 1.6 dB per metre length of jacket at 200 Hz, giving a total of 8 dB attenuation for 5 m length of lining. However, due to the close proximity of the exhaust outlet to the sea level, the use of sound absorbing material in the exhaust jacket is not considered to be a preferred option.

Another alternative method to reduce the exhaust noise is proposed by the engine manufacturer by using a through hull exhaust system as shown in Figure 5. This system directs the exhaust gas through the eductor to flow under the hull and exit at the rear of the boat. It should be noted that there is an element of 'trial and error' in the design of a suitable through hull exhaust system for noise reduction.

Air-borne noise

As a result of the sound field established in the engine room, noise is transmitted to the deck level through the air-borne path. To reduce the noise level in the engine room, acoustic enclosures may be used to control the direct field while sound absorbing linings may be applied to the room surfaces to control the reverberant field. The close proximity of the main engines to the room surfaces suggests that the direct field has a significant effect on the engine room noise. However, the use of acoustic enclosure is not a practical solution due to operational and maintenance requirements. Also, given the strong influence of the direct field, it is unlikely that the use of sound absorbing lining will have a significant effect on noise attenuation in the engine room.

The preceding discussion suggests that it is difficult to reduce the source level (i.e., the engine room noise) and that leaves the transmission path to be considered as a means of reducing the air-borne noise. It is observed that the air intake to the engine room is drawn from two sources; namely, the intake vents which are incorporated into the bulwark (see Figure 6) and the inlet stacks on the port and starboard side. The bulwark vents are located in close proximity to the work deck and it is estimated that by blocking off these vents, a significant reduction in air-borne noise is possible at a frequency of 500 Hz. Of course, the reduction in air intake has to be compensated by increasing the size of the inlet stacks.

MODIFICATIONS

After a series of discussion between the client, the boat builder and the engine manufacturer, the following course of action was taken:

a) The stiff engine mounts were replaced with more compliant mounts. Flexible couplings are used to connect the propeller shaft to the gearbox of the two engines.

b) Through hull exhaust systems are installed.

c) The engine room inlet vents in the bulwarks are blocked and the inlet stacks are enlarged and fitted with induction fans to compensate for the reduction in air intake.

d) The work deck area is carpeted.

Noise measurements were conducted on the modified vessel and the deck noise before and after the modifications is shown in Figure 7. The overall noise level of the modified vessel is now 89.4 dB(A) which still exceeds the OH&S requirements by 4.4 dB. Preliminary analysis shows that further reduction in the exhaust noise (particularly at a frequency of around 200 Hz) and structure-borne noise are necessary in order to achieve the target of 85 dB(A).

CONCLUSIONS

The noise sources that contribute to the deck noise of a motor vessel have been identified and control measures to reduced the deck noise to within OH&S requirements have been discussed. Modifications on the engine mounts as well as the inlet and exhaust systems resulted in a noise reduction of 4.6 dB. This is below the target value of 9 dB due to the higher than expected structure-borne noise and exhaust noise. Work is currently underway to investigate the appropriate control measures for further reduction of the deck noise.

REFERENCES

1. AS 2254-1988. Recommended noise levels for various areas of occupancy in vessels and offshore platforms.

2. Sawley, R. J., 1969. The evaluation of a shipboard noise and vibration problem using Statistical energy analysis. *ASME Symposium on Stochastic Process in Dynamical Problems, Los Angeles.*

3. Beranek, L. L., 1971. *Noise and Vibration Control.* McGraw-Hill

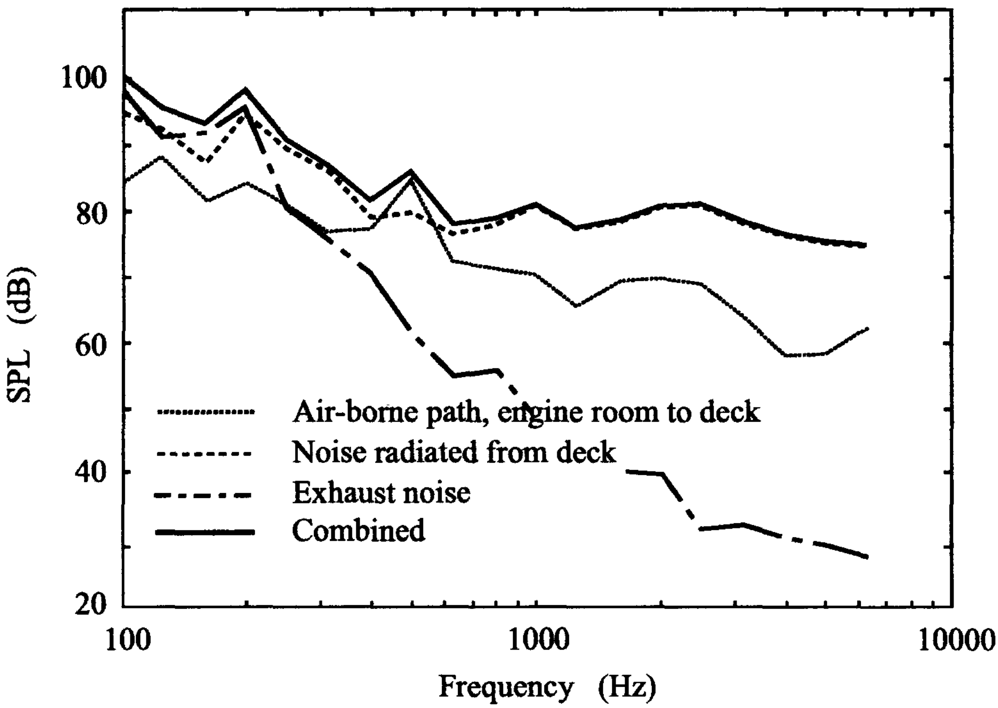

Figure 1. SPL at deck due to air-borne noise, structure-borne noise and exhaust noise.

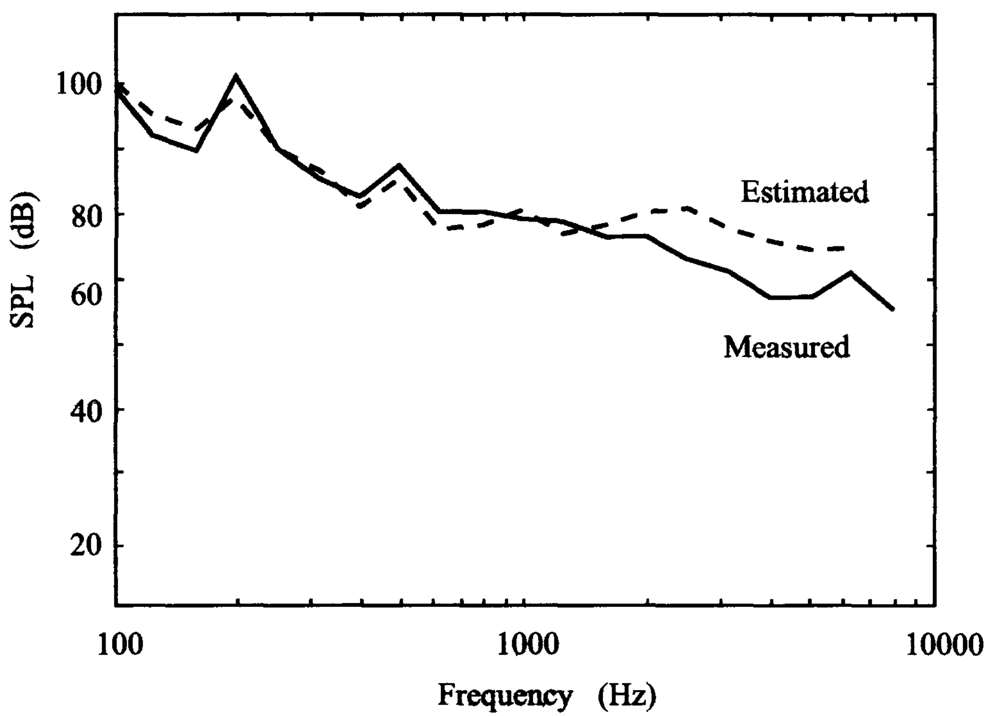

Figure 2. Comparison between measured and estimated deck noise.

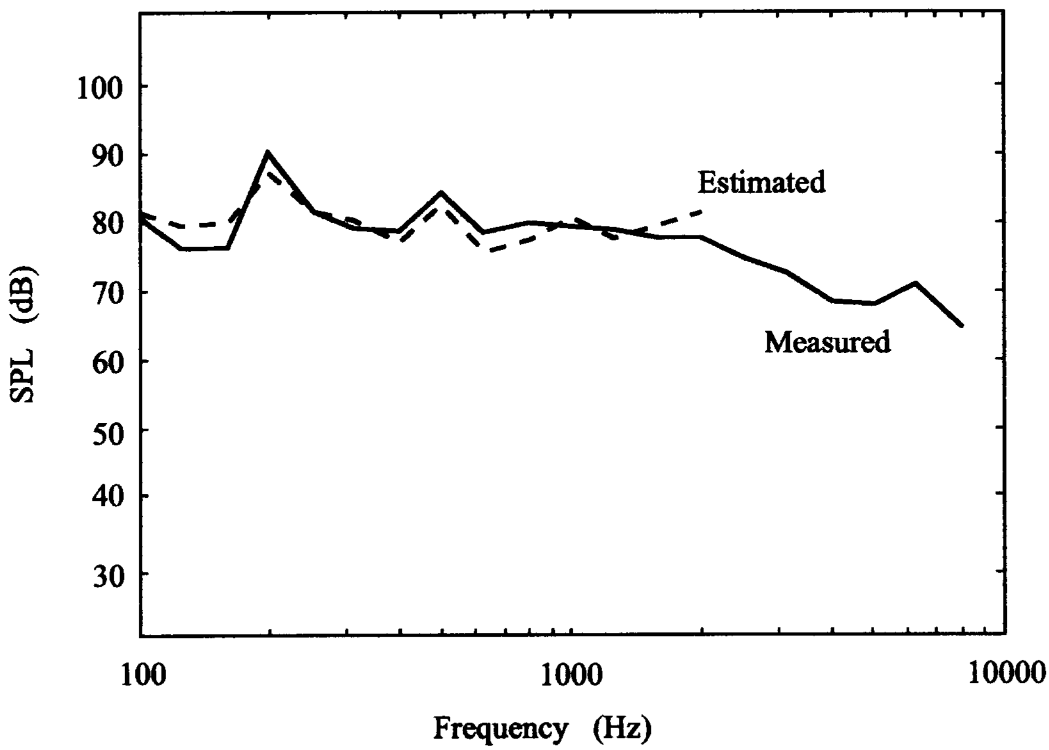

Figure 3. "A" weighted SPL at deck.

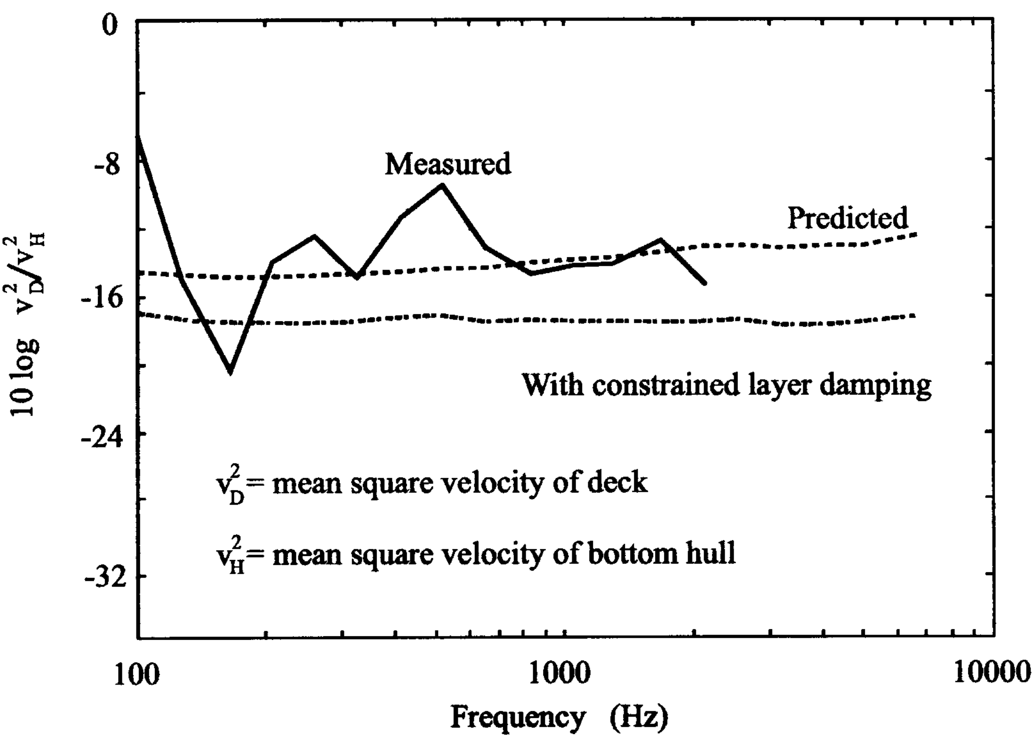

Figure 4. Response of deck structure.

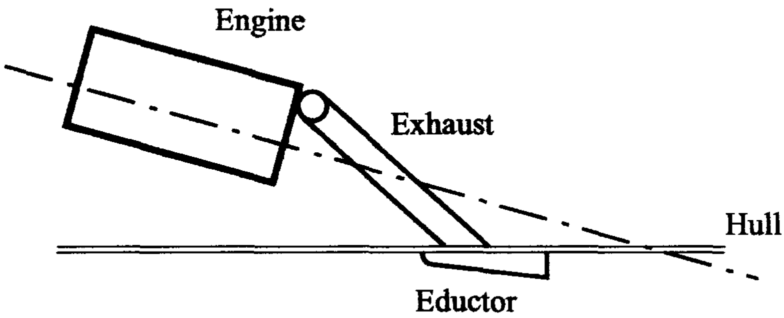

Figure 5. Through hull exhaust system.

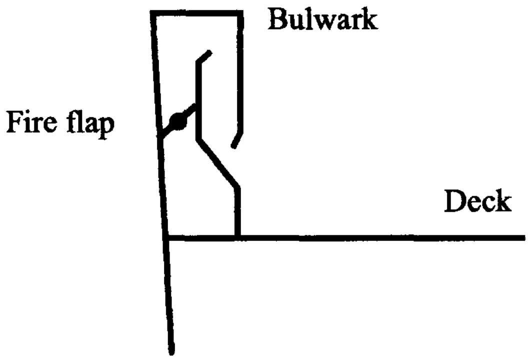

Figure 6. Engine room vent.

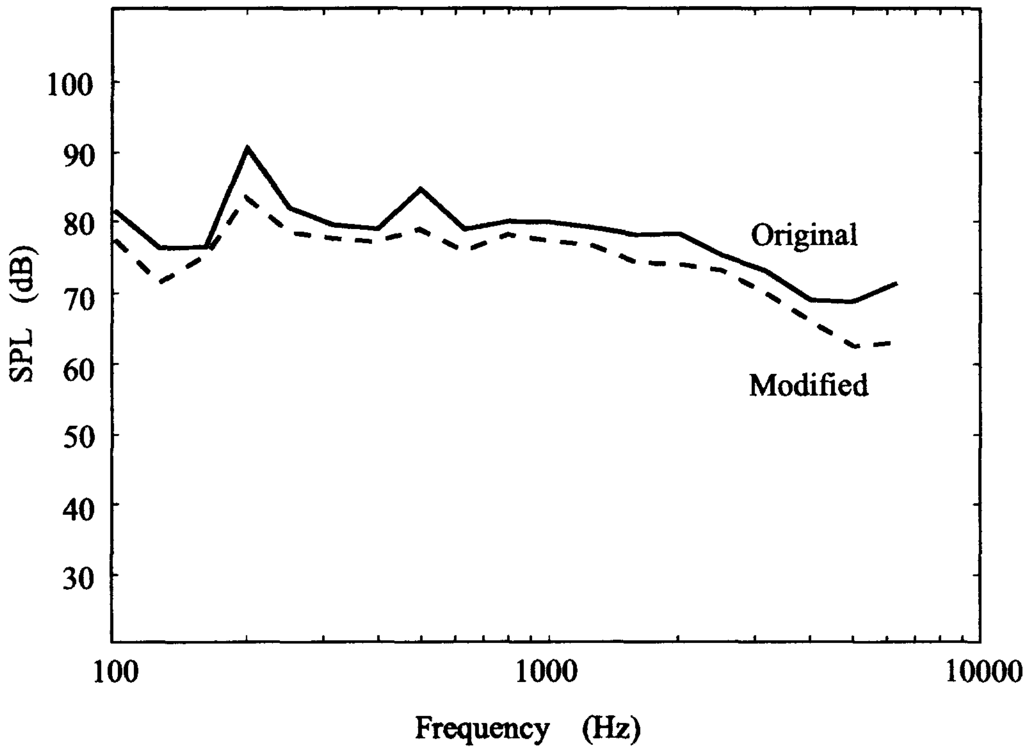

Figure 7. Effect of noise control measures on deck noise.