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SOUND TRANSMISSION THROUGH SHIP STRUCTURES USING STATISTICAL ENERGY ANALYSIS

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1. INTRODUCTION

The application of Statistical Energy Analysis (SEA) to the study of sound transmission through ship structures has been of considerable interest as a technique that can be used at the design stage to predict the noise levels in new vessels. Plunt [1] performed the first significant assessment of SEA as applied to ship structures. More recent studies have been reported by Kang [2] and Hynna [3]. These studies have demonstrated the value of SEA but through necessity have simplified the general problem by omitting the effects of water and simplifying structural coupling. Other techniques have been proposed for predicting structure-borne noise levels e.g. the analytical method by Nilsson [4] and semi-empirical methods by Plunt [5] and Buiten [6] based upon measurements taken from actual vessels.

The objective of this study is to examine in more detail structure borne sound transmission in ships and to include the effects of fluid loading with the aim of improving SEA models. This involves examining the interaction between the water and the structure, coupling between fluid loaded plates and the effects of ribs and stiffeners. The optimum method of modelling in-plane waves will also be studied.

In order to provide a realistic test structure a large tank was constructed as shown in Fig 1. This can be filled with water to apply fluid loading to the structure. It is large enough to provide realism under laboratory conditions.

2. THEORY

The main difference between a ship and a building or aircraft is the fluid loading on the ship hull.

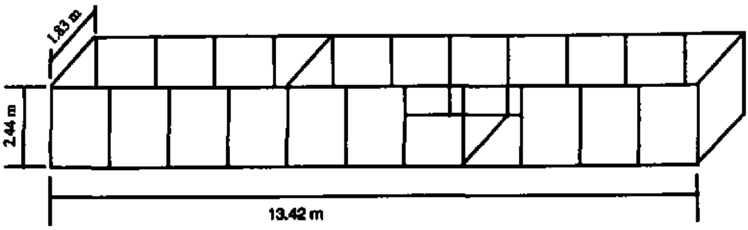

Fig 1. Laboratory Tank Structure

The bending wave equation for a fluid loaded plate has to take account of the fluid loading. The solution to the bending wave equation becomes a fifth order equation in terms of the bending wave number [7]. Using an approximate solution to the fluid loaded bending wave equation it can be seen in Fig 2 that the fluid loaded plate wave numbers are larger than the unloaded plate wave numbers. However, the error introduced by

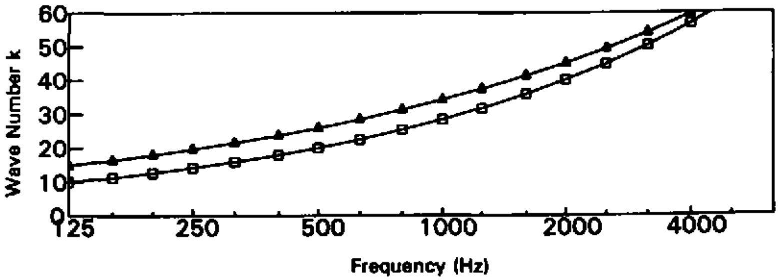

Fig 2. Bending Wave Numbers:Fluid Loaded Plate Δ Unloaded Plate □

neglecting them is less than 2 dB across the frequency range of interest. There will also be a reduction in the group velocity of fluid loaded plates but this is also small. This would suggest that the structure-structure coupling will be more or less unchanged as a result of fluid loading unless there is some non-resonant coupling through the structure.

The speed of sound in the fluid is typically 1500 ms^{-1} and this increases the critical frequency of fluid loaded plates (from 2.1 KHz to 40 KHz for a 6mm plate). Although the fluid loaded plates have a low radiation efficiency, the acoustic impedance of the water is significantly higher than that of air and this offsets the decrease in the radiation efficiency. The coupling loss factor from the structure to the fluid used the standard equation for the coupling between a plate and an acoustic volume with the appropriate changes for fluid desity and wave speed.

Figure 3 shows the loss factor for a loaded and unloaded plate. It can be seen that the radiation loss factor for the fluid loaded plate is significantly higher than that of an unloaded plate and is also higher than the measured internal loss factor. However, it is lower than the total loss factor of the unloaded plate. Fluid loading will increase the total loss factor of the loaded plates by about 2-4 dB

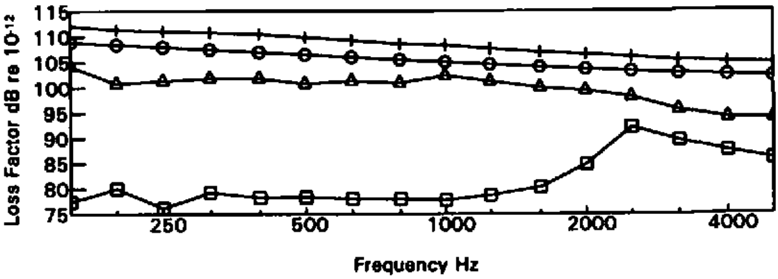

Figure 3. Loss Factors Loaded Plate
Loss Factor Loaded Plate O Loss Factor Unloaded Plate □
Internal Loss Factor Loaded Plate Δ Total Loss Factor Loaded Plate +

3. RESULTS

The measured and predicted energy level differences (in dB) between a directly excited plate and the water are shown in Fig 4. Two results are given for a perspex plate and for a steel plate and it can be seen that there is reasonable agreement is above 500 Hz. Below 500 Hz the SEA model predicts a significantly lower energy level difference in the water than has been measured. This is probably due to the low number of modes in the water as the first cross mode occurs at 420 Hz. Consequently the general SEA requirement for sub-system response to be multi-modal is not achieved at these low frequencies.

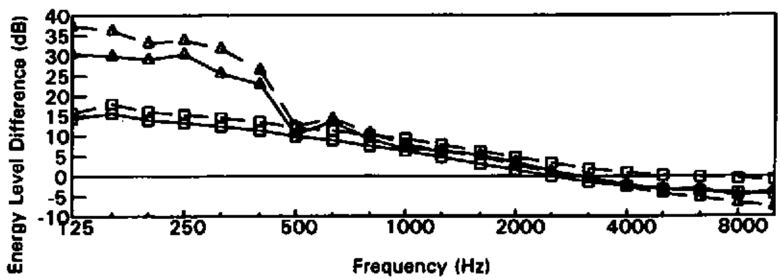

Fig 4. Energy Level Difference: Plate to Water
Measured □ Predicted Δ Perspex ______ Steel - - - - - -

The measured and predicted energy level differences across a tee-junction formed by the bulkhead and side plates are shown in Fig 5. Two cases are shown, the first with the water compartment empty and the second with the compartment full. The measured results show that there is no significant difference between the fluid loaded case and the unloaded case up to the 1600 Hz frequency band. The change in the predicted result is approximately 3 dB due to the increase in the total loss factor arising from the additional radiation damping. The transmission coefficients were computed using an unloaded plate model.

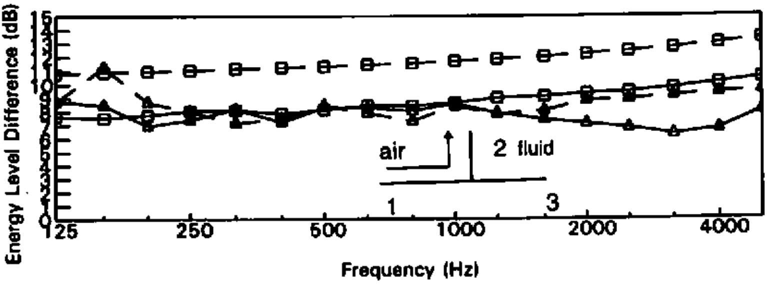

Fig 5. Energy Level Difference: tee Joint from plate 1 to 2
Measured □ ;Predicted Δ ;Fluid Loaded Joint ____ ;Unloaded Joint - - -

4. CONCLUSIONS

The results have shown that the effects of fluid loading on real structures are relatively small and only of the order of a few dB. In small laboratory models the total damping will be smaller and so the effect of fluid damping will be larger.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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