Chapter 6

Closure

6.1 Salient Feature of the Thesis

The present study provides a methodology for calculating of total sound power radiated due to a moving load on a floating platform (ship or airport). The ship has been modeled as a beam while the floating airport has been modeled as a one dimensional plate to simplify the formulation. The effect of external factors such as loss factor, mean flow, inplane loading on the total sound power radiated has been analyzed additionally. A GUI has been developed to undertake all the above analysis by varying the input parameters.

6.2 Contribution of the Thesis

The following are the contributions of this study:-

- An expression for total sound power due to the presence of a moving load on Rayleigh beam, Shear beam and Euler-Bernoulli beam has been developed. It is observed that the sound radiation from a Timoshenko beam is lower and increases with the Shear beam, Rayleigh beam to the Euler-Bernoulli beam in that order and is attributed to the inclusion or otherwise of the rotary and shear factors.
• The effect of **varying loss factor** (structural damping) on such floating beams has been evaluated. It is noticed that increased vibrational levels (due to structural damping) lead directly to increased sound radiation. It is interesting to note that the curves appear to have the same basic shape. As the structural damping decreases, the amount of steady-state vibrational energy in the beam increases. What is most interesting is that the curves shift up by an amount which is directly proportional to the change in the loss factor.

• The methodology has been extended to a floating airport and the **sound power generated by the landing / takeoff of airplanes** has been investigated. The concept of sound generated from the floating airport is important due to the effect the sound has on the ecology and the marine life below the airport.

• The floating airport has been evaluated for generated sound power in the **presence of a current** in the fluid along with the moving load. The relative difference of sound power due to the presence of mean flow is limited to 1dB, a small magnitude, however cannot be neglected when acting along with other types of loading.

• The **effect of inplane loading** in the sound power produced by a moving load on the structure has been analysed. The effect of increasing tensile loading shows an increased sound power from the structure while increased compressive loading shows reduced sound power.

• The **structural deflections** due to the moving load on a floating airport is studied. The effect of a point loading and distributed loading is considered to study this deflection.

• A **GUI** for undertaking the above analysis for both a ship model and a floating airport model has been developed for making the calculation procedure user friendly and speed up the user’s work especially for non-technical people.

The study undertaken herein develops a methodology for understanding the total sound power produced by a floating structure, namely a ship modeled as a beam and a floating
airport modeled as a one dimensional plate due to moving loads. This study shall allow researchers to calculate sound produced by moving loads on such structures and hence reduce sound from such structures.

6.3 Brief Overview of the Research Work Pursued

The content of the thesis is divided into six chapters for ease of explanation and the problems investigated.

Chapter 1, gives a basic introduction and the motivation behind the present study. The available literature relevant to the present study is reviewed thoroughly followed by a brief introduction of the research work pursued in this thesis. The basic physical equations, boundary conditions associated with acoustic problems associated with fluids and moving loads and the preliminary mathematical tools relevant to the thesis are discussed.

In Chapter 2, the generalized expression for the total sound power due to a moving load on a ship (modeled as a beam) as given by Keltie and Peng (1988) is formulated in detail for the various beam types, viz. Rayleigh beam, Shear beam and the Euler-Bernoulli beam.

Studies of sound generated from floating airfields due to the traveling load of starting, landing or taxiing planes is a natural extension of the ship (modeled as a floating beam) studied in the previous chapter. A dynamic analysis of a three-dimensional runway with time varying loading during take-off however would be exceeding difficult. In Chapter 3, this analysis is made simpler by assuming that the runway behaves as a simple, infinitely long beam floating on water and supported by buoyancy. The model is assumed to be a one dimensional plate, described by the Timoshenko-Mindlin plate equation. The understanding of radiated sound power as established in chapter 2 has been extended to model a floating airport. The sound generated and platform response in frequency domain
by the landing / taking-off of an airplane from such an airport, which would be akin to a moving load, has been analysed in section 2 of the chapter. Acoustic analysis in the presence of a mean flow or current complicates the analysis of a floating airport by modifying the effect of the moving load. The effect of mean flow on the response of a fluid-loaded structure has been studied in Section 3. Even though a VLFS is structurally very long, the longitudinal strength does not play an important role in their design. The most severe type of loading for the bottom plate occurs when the structure is subjected to the combined action of uniformly distributed hydrostatic lateral loading and compression due to hogging. Similarly for the deck plate, maximum loading occurs when the structure is subjected to compression and tension due to sagging and hogging respectively. The inplane loading plays an important role for such structures during berthing, plate connections at ends, initial deformation and corrosion to name a few and hence needs to be accounted for. This effect of inplane loading has been studied in section 4 by extending the formulation developed in section 2.

Having developed the general expressions for the ship (in chapter 2) and floating airport (in chapter 3), one needs to validate the model. This is done by using the published results for a Timoshenko beam by Keltie and Peng (1988). Once the model has been validated, a Graphical User Interface for undertaking numerical calculations using these mathematical formulations is developed and discussed in Chapter 4. The GUI has been generated to make the calculation procedure user friendly and speed up the user’s work especially for non-technical people.

The GUI developed in chapter 4 has been used to undertake numerical analysis to understand the total sound power radiated due to a moving load on a ship (modeled as a beam) and a floating airport (modeled as a plate) in Chapter 5. Using the beam model to represent the ship, we first analyse the total sound power produced by a Timoshenko beam, a Rayleigh beam, a Shear beam and an Euler-Bernoulli beam. We then compare them to understand which beam type produces the maximum sound power and the reasons associated with it in section 5.5. This is followed by the calculation and analysis of
the total sound power from a Timoshenko beam due to varying loss factor in section 5.6. Having analysed the beam model, the plate model is used to undertake the numerical analysis of the total sound power from a floating airport due to a landing / taking off of an airplane. The analysis is carried out for aluminium and steel and the effect of the material on the total sound power is studied in section 5.7. The same plate model is then extended by modifying the governing equation Equation (3.3) to Equation (3.21) to incorporate the effect of mean flow and the numerical results of the total sound power are obtained and analysed in section 5.8. Another extension is obtained by incorporating the inplane loading to the plate model to get Equation (3.35). This is analysed numerically next in section 5.9 to understand the effect of compressive and tensile inplane loads on the floating airport. The numerical analysis terminates with the structural response of the floating airport due to airplane landing / taking off modeled as a point and a harmonic moving load in section 5.10.

Finally, Chapter 6, summarizes the work done in the thesis followed by the future scope of research. Major contributions made in the thesis are also highlighted in this chapter.

Additional information used and derived is enumerated in the Appendices for clarity of the methods described in the chapters and as a starting point for future researchers working in this area.

- Appendix A : Time Averages of Products.
- Appendix B : Detailed derivation for the non-dimensionalized sound power.

### 6.4 Scope of Future Work

The study undertaken herein develops a methodology for understanding the total sound power produced by a floating platform due to moving loads. It hence allows development of procedures to reduce sound from structures. The following are the possible areas of
extension of this work

- The present analysis has been undertaken assuming a one dimensional plate for ease of formulation. The work can be extended to a two dimensional / three dimensional plate to model a floating airport.

- The structural material considered in the present study is isotropic. Further study could be undertaken for orthotropic material and cater for composite structures.

- The moving load type considered in the present study is a point / line load. More complicated loads such as platoon loads, circular loads, multiple loads etc. can be looked at to represent a variety of loads.

- This is an extremely difficult problem to tackle. What has been done as part of this thesis study is based on sound principles and are considered valuable as a first attempt to tackle a tough problem. However to validate these results the following may be considered as possible areas of extension of this work:
  
  - Laboratory testing with a scaled down model using relevant scaling laws and laws of similitude.
  
  - Field testing by deploying hydrophones around the floating platform, recording the acoustic pressure and comparing the results obtained with those recorded using these hydrophones.
  
  - Numerical modeling using other standard Finite Element packages (Abaqus/Ansys etc).

6.5 Concluding remarks

6.5.1 Marine noise problem

Sound becomes noise when it is too loud, unexpected, contains unwanted tones (e.g. a whine, whistle, or hum), or is unpleasant. Sound only has to be unwanted for it to be noise, not necessarily just loud.
Acoustic pressure level takes into account the surroundings and the distance of the source as discussed in section 1.9.3. Available information in regards to the hearing curves for select fishes have been discussed in Figure 1.1 as a graph between frequency (Hz) and threshold (dB re 1 μ Pa). By calculating the acoustic power from a floating airport due to landing / taking off of an airplane one infers that the sound power produced by the landing / taking off of an airplane from a floating airport has a direct co-relation to the hearing threshold of the fishes and hence should be treated as a noise problem. Accordingly the effect of sound produced by the aircraft landing / taking off on a floating airport needs to be factored into while undertaking the design of such a floating airport for safer marine environment and hence the need for the present study.

6.5.2 Present study

We notice that the initial work of Keltie and Peng (1988) is for a harmonic line force moving along an infinite beam at a constant subsonic speed undertaken for a Timoshenko beam filled with an acoustic medium (water, air etc).

The present study may be considered as an extension of the work of Keltie and Peng (1988). The study is commenced by remodeling the Timoshenko beam as modeled by Keltie and Peng (1988) for validation of the model as discussed in section 5.2 (which can be considered as the only similarity between the two studies).

The study is then extended by modeling a ship as an Euler-Bernoulli, Rayleigh and Shear beam and comparing the results obtained to discuss the performance of the beam model in section 5.5. It is noticed that the Timoshenko model gives the least sound radiation power and is better when compared to other beam types in section 5.5.3.

The effect of the varying loss factor (structural damping) on sound radiation by floating beams has then been evaluated in section 5.6.
This model has then been extended to a floating airport modeled as a one dimensional plate described by the Timoshenko-Mindlin plate in section 5.7. Since the plate can be one, two or three dimensional and since one dimensional plate has been studied here, the study of the two / three dimensional plate has been proposed as a likely extension of the study in section 6.4. Performance of the plate models can however be concluded once the study for two and three dimensional plate is undertaken.

The effect of presence of current and inplane loading on the one dimensional plate model has then been studied in section 5.8 and section 5.9 respectively.

Further structural deflections of the floating airport have been analyzed in section 5.10.

A GUI for undertaking the above studies for both a ship (beam model) and a floating airport (plate model) has been developed for making the calculation procedure more user friendly and speed up the user’s work especially for non-technical people. This GUI has been discussed in Chapter 4.

### 6.5.3 Frequency Independent results

Results obtained in this study have been expressed as a wave number ratio ($\gamma$) against the total sound power (dB re 1 $\mu$ Pa), where wave number ratio ($\gamma$) is the ratio between the acoustic wave number ($K_0$) and the free bending wave number ($K_B$).

By doing so, the dependence on type of sound and structure have been removed hence making the results more versatile. If we were to make the results frequency dependent, then for varying structures, the analysis shall become more cumbersome.

Notwithstanding, for a floating airport with the structural parameters under reference, the relationship between the wave number ratio ($\gamma$), angular frequency ($\omega$) and frequency (Hz) has been discussed in Table 5.3.
6.5.4 Conclusion

Effect of loss factor, shear effect and rotatory inertia on radiated sound power from a ship (modeled as a beam) subjected to a moving load has been investigated. It is concluded that a Timoshenko beam gives the least sound radiation power when compared to the other beam types. The correction for shear effect and rotatory inertia yield results within 4 – 5% more accurate than classical beam theory. As the structural damping (loss factor) decreases, vibrational levels increase thus causing an increase in the sound vibrations. The shift of the curves are proportional to the change in the loss factor.

Sound produced by an airplane taking off from a floating runway has been investigated for different structural materials, presence of mean flow and inplane loading independently assuming a one-dimensional plate in lieu of a three dimensional runway with time varying loading. The sound generated at various speeds of convective loading has been calculated and as expected an increase in sound is observed with increasing Mach number. No pronounced peaks are observed in the sound power curves due to the denser medium of water wherein the energy drain is faster disallowing peak formation. Changing of structural material from steel to Aluminium has an effect of higher sound power from steel as compared to Aluminium. Presence of current does not alter the sound produced prominently and the change is seen to be in the range of 1dB. Though the need to study effect of mean flow (current) may be considered irrelevant in light of the fact that such structures are set up in relatively calm waters behind islands or breakwater, however recent interests to have a floating airport in River Thames, UK and studies to widen range of potential setup sites for VLFS emphasizes this need. With increasing compressive inplane loading, the sound power decreases while tensile inplane loading shows a corresponding increase in the sound power magnitude. The change though not very large over the entire range of frequency, cannot be neglected when treated with other components of loading. The observations so made are considered to be analogous to a guitar string which produces greater sound when tightened (under tensile loading) as compared to the dull sound it creates when relatively loose (under compressive loading).
When analyzing the **structural response** of a floating airport subjected to landing / taking off of an airplane, one notices that a number of large spectral responses are visible when the wave number is plotted against the increasing speed of the airplane. These large spectral responses are seen as local peaks emanating from the point of load application and represent the flexural wave propagating in the same direction as the convected loading due to the Doppler Effect with the local peak moving in a curvilinear path with increasing speed of the airplane. Defining the location of these peaks precisely a priori is however not feasible.

The **methodology** discussed herein provides the designer a simple tool for understanding the total sound power radiated from a floating structure subject to a moving load. Such a tool shall help in a better design of a VLFS for a safer marine environment.