Chapter 1

Background

This chapter provides an introduction to the research that was conducted throughout the course of this study. An introduction is given on noise, vibration, and harshness (NVH) prediction of structures, followed by the results of a literature search. Further, a summary of the research objective as well as an outline of the remaining chapters are provided.

1.1 Introduction

Noise, vibration, and harshness (NVH) in structures have received increased attention in recent years. The emphasis on improving customer satisfaction and brand image has affected such industries as automotive and aviation. Customer awareness and sensitivity to noise and vibration have been raised through increasing television advertisement, in which the vehicle noise and vibration performance is used as the main market differentiation. This awareness has caused the transportation industry to regard NVH as an important criterion for improving market shares.

One industry that tends to be in the forefront of the technology to reduce NVH is the automobile industry. The battle for quick improvements in products has led to the use of analytical techniques for prediction and control of NVH. In the past, experimentation was the only method of evaluating the effect of various elements on noise and vibrations. Although it is an effective evaluation tool, experimentation is often expensive and time consuming. Therefore, analytical methods that can provide an estimate of noise and vibration in a complex structure, such as a vehicle body, are needed to help with performing the noise and vibration design iterations more quickly and with less cost.

Technologies that have become an essential part of the design process are Computer Aided Design (CAD) and Finite Element Analysis (FEA). Using these tools, one can make design changes and evaluate their effects with considerably less effort. One potential problem with FEA models is the need for limitless resources as the structure complexities increase. For instance, for vehicles, the shear number of elements required to model the structure can become so large that a full-scale model cannot be run without significant computational capability. Alternatively, sub-assemblies are often modeled and individually run to estimate the behavior of the complete structure. Correctly estimating the boundary conditions between different elements, however, can be difficult to model and also can result in modeling errors.

Therefore, alternative modeling methods that can provide relatively accurate predictions without the need for large finite element models are desired. This study investigates a method that combines experimental and analytical modeling for predicting structural vibrations. The method is applied to a complex structure such as a locomotive cab, and the accuracy of the results is evaluated.

1.2 Literature Review

An extensive literature search in the area of vehicle vibration prediction and testing was conducted. The databases INSPEC™, a leading source for literature for physics, electronics, and engineering research, and AppSciTechAb™, another source for applied science and technology literature, were used to complete the search. The keywords used to carry out the search, along with the number of "hits" for each keyword, are shown in Fig. 1.1.

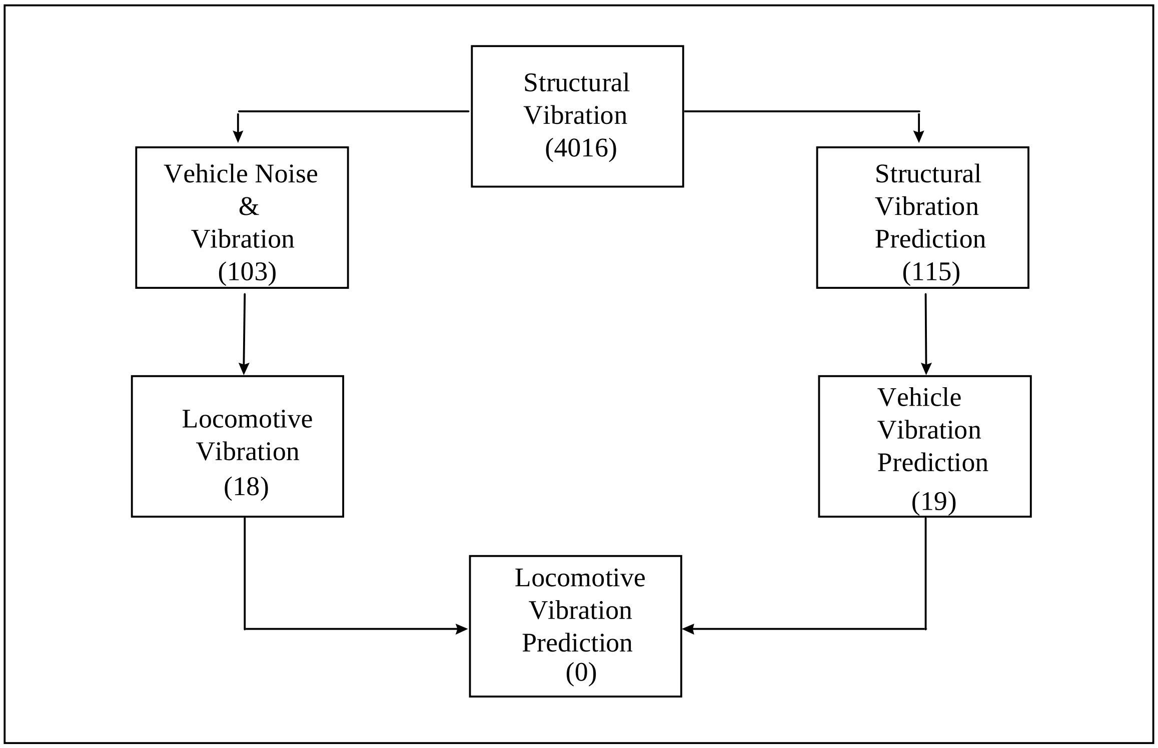

Figure 1.1 Literature Search Flow Chart

This literature search resulted in a large number of articles in general areas such as "structural vibration," "vehicle noise and vibration," and "structural vibration prediction." The number of articles, however, quickly reduced for narrower search topics, as shown in Fig. 1.1. A summary of some of the search areas is provided next.

1.2.1 Structural Vibration Prediction

Technological advances in devices such as personal computers, analyzers, and signal conditioners have made it possible to analyze very complex structures more accurately. The majority of the articles in this area address structural vibration prediction through the use of modern computers [1-5]. They reflect the vast number of studies that have been conducted in the past years in vibration prediction using analytical and experimental methods. In the past ten years, the industry has begun to take advantage of fast computers to develop sophisticated models that can predict system behavior relatively accurately. Before then, analytical prediction of structural vibration through the use of computers was not a common practice.

The studies by Eisinger et al. [1], Hiramatsu et al. [2], and Suhardjo et al. [3] provide methods for the prediction, estimation, and measurement of vibrations in complex structures. Eisinger et al. illustrate a process for estimating acoustic vibration in steam generator tube banks based on flow and acoustic parameters. Hiramatsu et al.'s study deals with the prediction and control of vibration and structure-borne noise generated by various types of machinery and equipment installed in buildings. Finally, Suhardjo et al. present a method for controlling civil engineering structures under earthquake conditions.

In another study, Bodruzzaman et al. [4] review a process for the estimation of natural frequencies of aircraft structures subjected to random vibration for health monitoring applications. Knowing that the growth of structural damage reduces the stiffness of a structure and decreases the natural frequency of a specimen, an on-line health monitoring process that is conventionally used to monitor and predict the natural frequencies cannot be used. Instead, an estimation approach such as the forward-backward linear prediction (FBLP) method is adopted to identify all the prominent frequencies in a certain bandwidth.

Finally, a study by Steel [5] predicts the structural vibration transmission through a motor vehicle using statistical energy analysis. A vehicle constructed from glass fiber-reinforced plastic panels was used to collect vibration transmissions. The collected data was later used to compare with predicted results. The results presented conclude that relatively simple predictive techniques can be used to model structural vibration transmission in a motor vehicle.

1.2.2 Vehicle Vibration Prediction

Among the nineteen articles found in vehicle vibration prediction, only four studies were related to this study [6-9]. A study by Jones [6] deals with the prediction of ground vibrations from freight trains that give rise to disturbance and possible damage to lineside residents. A theoretical model of the generation and propagation of vibration was created to establish the influence of parameters of the track and rolling stock. Comparing the results of the model to actual experimental results proved that the model approximations were close enough to indicate locations along a track at which high levels of vibrations would be generated.

Another study by Lu and Harwood [7] deals with the prediction of torsional vibration on mass transit vehicles. Similar to the study by Jones, Lu and Harwood investigate torsional vibration, caused by loss of adhesion, by forming a simulation. The results of the simulation are also corroborated by experimental results.

Finally, studies by Riley and Bodie [8] and Nelson [9] discuss a strategy for controlling and modeling vehicle vibration and noise. Hardware, using well-known principles of filter theory, is implemented within concept vehicles to compare results with those calculated by the model.

1.2.3 Locomotive Vibration

The studies found in locomotive vibrations were quite limited [10-13]. None of the studies addressed locomotive vibration prediction. Johnsson's study [10] discusses the use of a laser to measure the relative displacement between the locomotive wheel and rail for the examination of surface quality and surface vibration. The noise and heat generated at the wheel-rail interface as a measure of the operational health of the locomotive is the subject of Dolezal's study [11].

Another paper by Chudzikiewicz et al. [12] presents the conception and the process of building a model of a simulator of the cabin on an electric locomotive. The simulator is intended for training electric locomotive operators, and therefore needs to function as it does in a real electric locomotive. The main concept of the study was to show how an excitation input can be developed for the simulator to resemble actual field input to the cab. A functional model of an excitation using frequencies obtained from spectral analysis of recorded field data was created to be used to drive servo-motors on a simulator.

Finally, a study by Sekine and Murase [13] discusses the simulation of vibrational response characteristics of a structural model of a locomotive from the dynamic characteristics of its sub-components. The simulation is used to predict the vibration levels in the lateral direction, which have the most serious influence on riding comfort and vehicle stability. The results of the simulation are compared to actual vibration testing. The results prove that the model can be used to predict locomotive vibrations at the design stage.

1.3 Research Objective

The primary purpose of this study is to be able to predict the vibration isolation effect of various mounting systems in a realistic structure, such as a locomotive cab. The approach includes first creating an analytical formulation for the vibration approximations. The formulation will be used to generate vibration approximations at discrete locations, both inside and outside of the cab. Finally, in order to validate the analytical approximations, experimental results are compared with the analytical predictions using simulated field input to the cab.

1.4 Outline

The theory and mechanics of vibration prediction as they are used in this study are explained in Chapter 2. A previous approach to vibration prediction, along with its deficiencies, is also discussed in Chapter 2. A new approach to vibration prediction is introduced as an alternative to the previous method.

Chapter 3 provides an outline of the locomotive cab setup at the Advanced Vehicle Dynamics Laboratory (AVDL) for vibration testing. It includes the cab installation, the actuation mechanism, and the data acquisition system.

The baseline testing and validation of the cab are discussed in Chapter 4. First, the configuration of the cab in its baseline form is examined. Next, the procedure for creating the baseline input signal to the hydraulic actuator using field data is discussed. Finally, the results of the baseline test along with the validation of the results are presented.

The experimental results and the analytical predictions of the cab vibrations are discussed in Chapters 5 and 6. A comparison between the results is used to validate the vibration prediction technique.

Finally, Chapter 7 summarizes the results of the study and provides recommendations for future research.