Chapter 1

Introduction

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) in vehicles and some of the current efforts for lowering NVH. Further, a summary of the research objectives as well as an outline of the document are provided.

1.1 Introduction

In the past several years, there has been an increased marketplace awareness of noise, vibration, and harshness performance in automobiles. The differentiation between the quality and reliability levels of automobiles has become less pronounced and, as a result, manufacturers have had to demonstrate superiority by focusing on NVH concerns. The current battle began in 1989 when Toyota introduced its Lexus luxury line [1]. The Lexus incorporated groundbreaking techniques for NVH improvements that resulted in vehicles that were substantially quieter than any other car on the market. Lexus had set a new standard for quality and increased customer expectations for both noise and vibration comfort.

The automotive industry is currently spending millions of dollars on NVH work to develop new materials and damping techniques. The new design methods are starting to consider NVH issues throughout the whole design process, not just in the later stages. This involves integrating extensive modeling, simulation, evaluation, and optimization techniques into the design process to insure both noise and vibration comfort. New materials and techniques are also being developed so that the damping treatments are lighter, cheaper, and more effective. For example, the Lexus engineers had developed unique metal panels where asphalt or other sound-insulating materials are layered between two sheets of steel. They also used two-piece oil pans to help cut engine booming, and liquid-filled engine mounts to isolate vibrations.

Some of the current methods used to reduce noise and vibration in vehicles originated in the 1920s. In 1927, Lord Corporation's rubber-to-metal-bonded components were used in General Electric trolley cars, and a few years later in Lincoln and Nash automobiles [2]. Since then, many other methods and techniques have been developed and implemented into vehicles of all kinds. Some of the methods used to control noise, vibration, and harshness include the use of different carpeting treatments, the addition of rubber or asphalt material to car panels, gap sealant, and the injection of expandable foam into body panels. The carpeting treatments include varying types of foam padding combined with different weights of rubber-backed carpet. The overall result of this technique is a mass-spring system that acts as a vibration absorber. The rubber or asphalt materials are attached to various car panels to add damping and mass loading to reduce vibration levels and the rattling sounds from the panels. Sealant is applied to close gaps in order to increase the transmission loss from the engine, wind, and road noise sources to the vehicle interior. Expandable foam injected between panels, such as the dashboard and firewall, helps to add stiffness and vibration absorption.

All of these current methods are effective at reducing sound and vibration levels in a vehicle at higher frequencies. However, some of the treatments become almost ineffective at lower frequencies below 200 Hz. The treatments also add a substantial amount of weight to the vehicle, thus affecting its fuel economy, as well as adding cost.

1.2 Research Objectives

The primary purposes for this study were to:

1. Explore the feasibility of smart damping materials, such as piezoelectric materials, for augmenting and improving the performance benefits of passive damping materials, and

2. Provide a preliminary evaluation of the noise and vibration benefits, and weight savings of smart damping material as compared to conventional damping treatments.

1.3 Approach

To achieve the objectives of the study, a special test rig was constructed and validated in the early stages of the study. Upon validating the test rig and the instrumentation that was set up for data collection and processing, a series of tests were performed. The tests were intended to establish a baseline for the test rig and compare the performance of smart damping materials with a number of passive interior automotive treatments. Further, in order to evaluate the effect of smart damping materials on the sound transmission loss, a series of tests were conducted at a standardized transmission loss test facility, according to the SAE J1400 test specifications. The tests evaluate the transmission loss for smart damping materials for an undamped and a damped plate.

1.4 Outline

Background information for this study, provided in Chapter 2, includes an explanation of piezoceramic materials, possible applications of piezoceramics, and a literature review on related research. This chapter also includes a detailed description of the shunt circuit design and the methodology for PZT attachment.

Chapter 3 focuses on the test setup for the structural vibration tests. This chapter includes justification and explanation of the test rig. Test rig construction and validation tests are discussed as well as the test instrumentation.

Baseline testing for the test plate is described in Chapter 4. This chapter discusses how the smart damping test plate was constructed. A finite element analysis is presented and validated with laser vibrometer measurements, followed by the placement strategy of the piezoceramic material.

The experimental results from the test rig are presented in Chapter 5. A summary of the test results is used to evaluate the effectiveness of the smart damping.

Chapter 6 discusses the transmission loss tests performed and presents the test results evaluating the effectiveness of smart damping techniques on increasing transmission loss.

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