Proposal

Analysis of Parallel Vibration Paths with Potential Application to Vehicle Noise Reduction

Submitted to

The Engineering Honors Committee

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Abstract

In a vehicle, noise is transmitted from the source to the receiver through many structural paths. This research will compare frequency domain results obtained with the two, competing experimental procedures, the Transfer Path Analysis method and the Path Disconnect method. A two-plate system will be used to replicate some dynamic, sub-system characteristics of a vehicle. Further exploration using this system will be done to experimentally and analytically evaluate what causes path dominance in a system. Finally, the issues with structure borne noise will be explored in the time domain since many transient noise problems are encountered in a vehicle.

Introduction

The purpose of this research is to determine the role of parallel structural paths from a vibration source to a receiver and to examine the critical factors that dictate the contribution from each path. In real-life there are many parallel paths that the structure borne noise can take. For instance, when considering a vehicle, the engine vibration transmits noise through connections such as mounts, joints, and the suspension system to a vehicle occupant [1]. This is illustrated in Figure 1 which shows a laboratory system with a source transmitting noise through three paths to the receiver. To reduce the noise heard by the occupant, it is important to be able to identify the dominant paths in order to modify or redesign the system. For example, engine mounts can be selected in terms of their stiffness (k) and damping values (c) to reduce the effect of that structural path.

There are two experimental methods for determining the contribution through each path [3]. Both use accelerometers to determine the vibration, a measure of noise, at the output receiver. The first method is the Path-Disconnect method [2]. Each path is

removed from the system singly and the reduction in transmitted noise is measured. The second method is Transfer Path Analysis (TPA) which involves measuring the Frequency Response Functions of the system [3]. Unlike the path disconnect method, TPA allows all structural connections to remain attached and for the system to operate under standard operating conditions. It accounts for the interactions between the paths in transmission from the source to the receiver.

In this research, the Path-Disconnect method and TPA results for a simplified, yet meaningful, system shown in Figure 2 will be compared in order to determine if the path disconnect method, which is much simpler than TPA, is valid and under what circumstances. The TPA data will also be used to look at what parameters of the structural paths result in variation in the amount of structure-borne noise transmitted. Properties such as bolted connection to the structure, natural frequencies of the transmitting path, location of the paths relative to the source, moments generated at paths not located the center of gravity, and geometry of the path will be considered.

Noise radiation in the time domain is increasingly becoming more important because all structural paths do not transmit vibrations at the same rate. Further, nonlinear paths seem to transmit impulsive events such as clunk or stick-slip events very efficiently in vehicles [2]. Most of the previous research has been done in the frequency domain. Using the simplified experimental system, a new time domain method will be investigated.

Objectives

In this research the major objectives are as follows:

- Evaluate the contributions of parallel structural paths using the system shown in Figure 2, given an impulse excitation on the top plate.
- Analyze the validity of using Path Disconnect methods when compared with Transfer Path Analysis.
- Explore how to analyze path contributions in the time domain and to correlate results with those found using frequency domain methods.

Methodology

In order to complete this research, a simplified experimental system shown in Figure 2 will be utilized. The system consists of two metal plates which can be connected using plastic or steel connectors. The top plate is 0.25" thick and represents the source which is more rigid and has been found to only have a few modes at low frequencies. The bottom plate is 0.125" thick and has more natural frequencies at low frequencies. The structural transmission paths are represented by rods of steel and plastic are connected with screws to both plates. Two lengths of the rods are available for testing in 3" and 6" lengths. The rods can be rearranged or removed completely. For all experiments, only impulsive force inputs will be considered.

First, data will be acquired using the Path Disconnect method. Eight accelerometers will be connected to a data acquisition system, one on each corner of both plates. The 'X' in Figure 2 represents the excitation point which will be hit with an impact hammer. Individual paths will be disconnected and the reduction in vibration will be measured to find the path's contribution. Next, the contribution of each path in the

frequency domain will be found using Transfer Path Analysis. The acceleration and input force will be measured to find the transfer functions for each accelerometer. This yields data similar to Figure 3 [4]. Using this data, the receiver frequency spectrum can be found by the following [3]:

$$a(\omega) = \sum_{i=1}^{\#paths} \frac{a(\omega)}{F_i(\omega)} \cdot F_i(\omega)$$

$a(\omega)$ = Receiver spectrum as a function of frequency/rpm
$\frac{a(\omega)}{F(\omega)}$ = accelerance= Transfer Function between the receiver and the input force at path i
$F(\omega)$ = operation force at transfer path i

The data from the Path Disconnect method will be correlated with data taken from the Transfer Path Analysis and the validity of the path disconnect method for the simplified system with be evaluated.

Next, the Transfer Path Analysis method will be used to further explore the simplified system. In addition to testing with the plastic and steel rods, other rods will be machined to provide different test conditions. Potential options include aluminum or rubber rods or using rods of varying cross sections. Experimenting will allow the characteristics that cause structural transmission to be better understood. More understanding will allow for new materials or geometries of the rods to be created in order to test the theories.

The final aspect of the research will be to correlate the frequency data obtained with the time domain data. Transient data will be taken for the simplified system with steel and plastic rods. The goal will be to develop a model of how transient sources transmit in the two-plate system.

Timeline

	SP 06	SU 06	AU 06	WI 07	SP 07
Read Literature	X	X			
Take Transfer Path Analysis data using two plate system and current plastic and steel rods as paths		X			
Take data using path disconnect method and compare with Transfer Path Data		X			
Create new paths with other materials and analyze		X	X		
Analyze data to find path contributions		X	X		
Explore transient methods with simplified system			X	X	
Thesis/ Presentation				X	X

Capabilities

For two quarters, I have worked in the NVH department at Honda Research and Development. Working there gave me an understanding of the importance of Transfer Path Analysis. I was able to see how Transfer Path Analysis is used in industry. Combined with my class work, I feel I have a solid back ground in order to do research in this area. I have successfully completed Mechanical Engineering 481, 482, and 571, which has given me an understanding of dealing with data in the frequency domain. This spring I am taking Mechanical Engineering H680 which will give me knowledge of digital signal processing which will be useful in taking and analyzing the data.

I intend to go to graduate school to get my Masters and possibly Ph.D. I would like to work in a research environment this summer and next year in order to ensure that doing research is something I enjoy and also to better understand what is involved in research. The research I do could possibly lead to a Master's thesis or at the least give me direction as to which field of research I would like to pursue. I also want to apply for a National Science Foundation Fellowship next year so having a good technical understanding of a research subject will be important. Doing this research will help reinforce concepts learned in class and at Honda and will give me a taste of what the academic research environment involves.

Figures

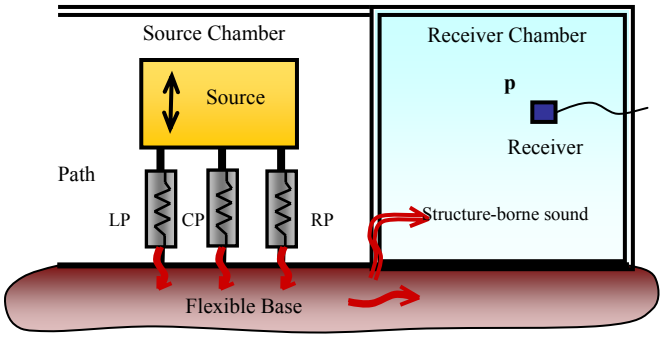

Figure 1: Schematic of Experimental Source-Path-Receiver System [2]

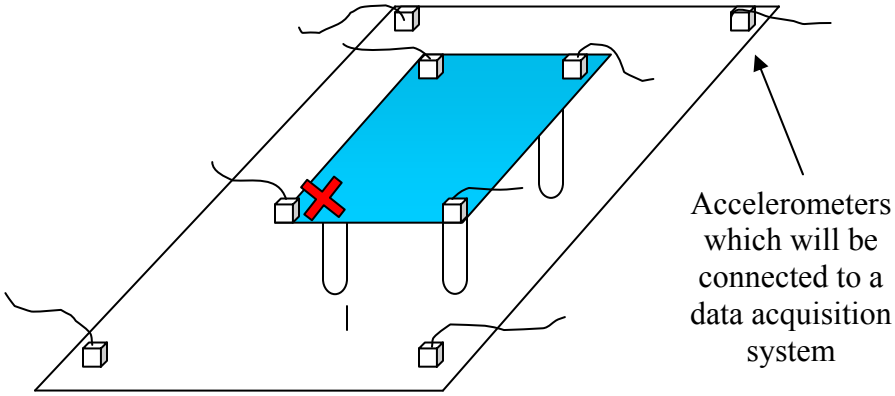

Figure 2: Experimental Setup for Comparison of Path Disconnect and TPA Results (The system will be suspended using a support structure)

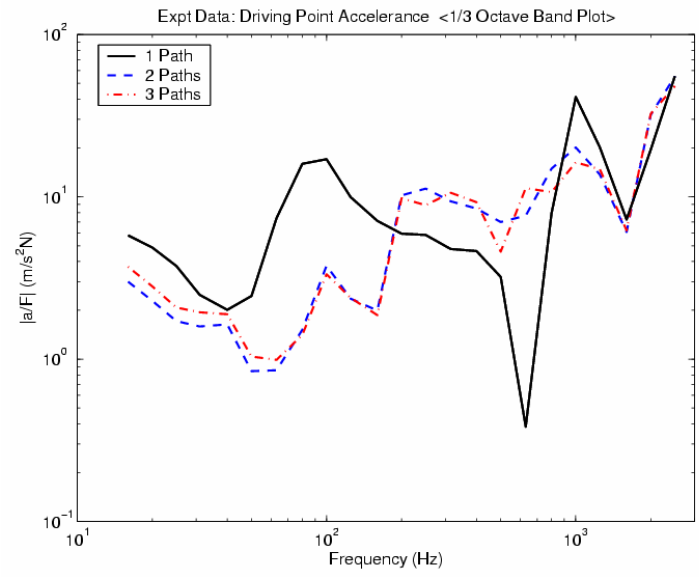

Figure 3: Sample 1/3 Octave Band for Various Path Configurations [4]
The y-axis is accelerance which is the relation between the output acceleration and the input force.

References

[1] Singh, R., S. Kim, and A. Inoue. "Comparative Evaluation of Structure-Borne Noise Transfer Paths in a Laboratory Experiment." Noise Control Engineering Journal (2006).

[2] Singh, R. "Quantification of Parallel Structural Paths Given Transient Sources with Application to the Shift Quality of Automatic Transmissions." Submitted Proposal to Ford Motor Company (2006).

[3] LMS International, Application Notes. *Transfer path analysis: the qualification and quantification of vibro-acoustic transfer paths.* http://www.lmsintl.com/

[4] Inoue, Akira, R. Singh, and G. Fernandes. "Determination of Absolute and Relative Path Measures in a Discrete System by Using Two Analytical Methods." Journal of Sound and Vibration (2006)

[5] Singh, R., S. Kim. "Prediction of Structure-borne Noise Transmission Through Multiple/Multi-Dimensional Transfer Paths." NOVEM Key Note Lecture (2005).