Investigation of modal transfer path in Vehicles using FFT Analyzer

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Abstract :*Automotive are subjected to vibratory loads due to engine and road excitations. Automotive seatings are subjected to random vibrations occurring at various frequency range, hence, it is important to verify vibration transfer paths and alter design for better ergonomic performance. A simple seating system, prototype model mounted on chassis will be manufactured for investigation of vibrations and trace its path. Finite element analysis will be used to perform modal analysis to extract resonant modes and natural frequencies. A pneumatics-based excitation system will be mounted below the prototype to simulate running vehicle. Stiffness, alterations will be done with the help of structural ribs, anti-vibration mounts, etc. Comparative analysis will be done between FEA and experimental results for validation purpose. Results and conclusion will be discussed and suitable future scope will be suggested.*

Keywords :Transfer path , Vibration, Path , Finite Element Analysis , Modal Analysis

1. INTRODUCTION:

Noise and vibration are important characteristics in modern life. For example, we experience noise and vibration every day when we drive to work, and they are important causes for component failures in airplanes and space vehicles. Therefore, it is important for us to understand how noise and vibration are transmitted and to find ways to reduce them.

Traditionally, noise and vibration problems are analyzed using the *Modal Analysis* approach. Vibration modes (or normal modes) are intrinsic ways a structure can sustain motion and carry energy. Each mode is typically associated with acharacteristic frequency and vibration shape, both of which provide important clues to the understanding of the dynamic behaviour of the structure. Mathematically, the response of a structure can be expressed as a sum of contributions from its normal modes. This provides a convenient way to solve noise and vibration problems, since, in many cases, engineers can reduce the problems to a few dominant modes and seek to solve the problems by changing the modal frequencies or the mode shapes. However, in cases when there are too many modes, tens or thousands, that are contributing in similar amounts to the problem, this approach breaks down because it is not practical to track and change so many modes as a way to solve the problem. This typically happens in high frequency situations (> 100 Hz in the automotive industry).

Transfer Path Analysis (TPA) was developed as an alternative to the *Modal Analysis* approach for solving noise and vibration problems. It is a technique used to understand a noise or vibration response by breaking it down to contributions from internal or external load paths to identify which paths are dominating the response. Once the dominant paths are identified, the problem is reduced to understanding how to minimize the contribution of these paths. In comparison, the focus of this approach is on the transfer paths, as opposed to normal modes with the *Modal Analysis* approach. If one can define a limited set of transfer paths, TPA can be a more practical approach than *Modal Analysis* in solving high frequency problems.

Since its initial development in the early '90s, TPA has been widely used as an effective tool for solving noise and vibration problems using experimentally obtained data. In general, however, this approach has not been broadly used as an analytical tool employing CAE-based data, even though there are a number of advantages to using CAE-generated for TPA. For example, it is easy to calculate forces directly in CAE, while direct measurement of forces is typically not possible. It is also easy to calculate transfer functions from rotational inputs, while the same is difficult to do in testing. Given these advantages, analytically based TPA could be used much more often in practical problem-solving if a good CAE post-processing tool were made available. A HyperWorks TPA tool has been developed to meet this need.

Steps involved in using the HyperWorks TPA tool

- Define transfer paths/attachment points and control volume. Then calculate attachment forces of the system in the assembled state.
- Calculate Transfer Functions (TF) of the responding structure in an isolated state.
- Perform TPA analysis and visualize results.

$$P_t = \Sigma_{paths} [P_i] = \Sigma_{paths} [(P/F)_i * F_i]$$

Define transfer paths/attachment points and control volume

Some of the key considerations for defining the transfer paths are:

- The transfer paths should be complete, and capture all force transfer from the source to the receiver.
- The transfer paths are physically meaningful for understanding and controlling the response in which the user is interested.
- The number of transfer paths should not be too large; it needs to be manageable

Transfer path analysis (TPA) is a test-based or simulation-based procedure which allows you to trace the flow of vibro-acoustic energy from a source, through a set of known structure- and air-borne transfer pathways, to a given receiver location. Figure 1 schematically shows the impact of a source to an operator.

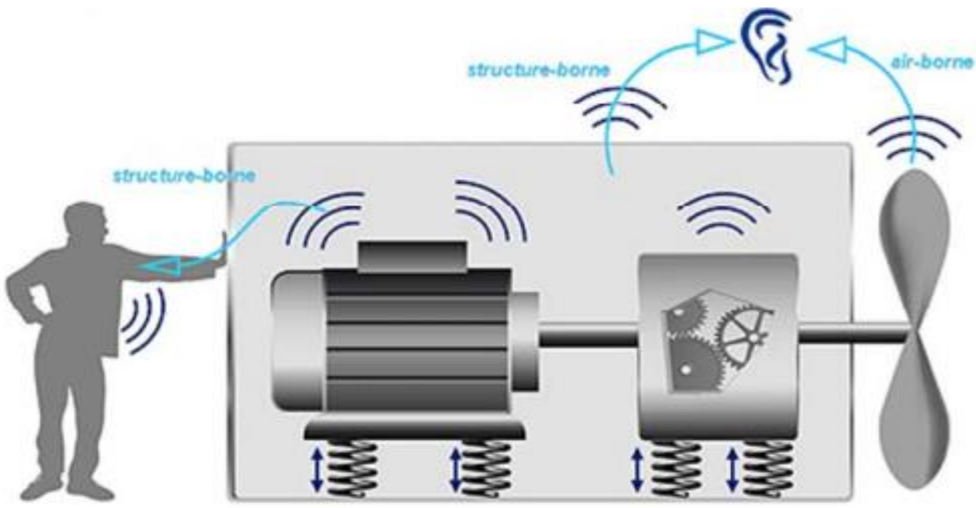


Figure 1: Transfer path analysis quantifies and visualizes the strengths of selected sources and their contribution via multiple transmission paths to a selected receiver signal

The goal is to evaluate the contribution along each transfer path from the source to the receiver, so that one can identify the components along that path that need to be modified to solve a specific problem and perhaps to optimize the design by choosing desirable characteristics for these components. Performing a transfer path analysis is a worthwhile exercise, because the insights it gives lead directly to faster troubleshooting, better product refinement and a more methodical approach to vibro-acoustic design.

TPA is just one step in the NVH optimization process. The first step in this process is the problem identification. It consists of performing preliminary measurements aimed at defining optimal test conditions for data acquisition and at identifying critical frequency ranges of the noise spectra. This step is followed by an operational deflection shape analysis. Once this has been realized, a full TPA analysis can be performed on the identified possible paths. After the TPA is complete, structural modal analysis or acoustic modal analysis help find root causes of possible noise and vibration issues and solve them. TPA can be applied to solve vibro-acoustics issues in many manufacturing industries. Performing TPA on a car engine helps reduce interior noise, driving wheel and seats vibration and thus improve driver's and passenger's comfort. Road noise disturbances in a vehicle can be minimized using the multireference TPA technique. Nowadays, TPA is even employed to complement pass-by noise engineering methods such as to reduce the overall vehicle's pass-by noise. TPA methods have also successfully been applied to printers to reduce sound power levels, as well as to household appliances such as refrigerators, washing machines or dish washers. TPA is a systematic method that can be used for all types of structures, large or small, such as boats and ships, wind turbines or even full aircrafts.

What is transfer path analysis In complicated structures involving many sub-assemblies (such as an automobile, aircraft or submarine) the vibro-acoustic sensations that are experienced by an observer at any one location may easily have been caused by a vibration source some way off. For example, the energy from a source in a car is transmitted into the passenger cavity by a number of different routes: from the engine mountings, the exhaust system connection points and indirectly even via the drive shafts and the wheel suspension. Airborne contributions from the intake or exhaust system, for instance, may be important as well. Some of these paths are important, some are not. Some transfer paths may cause interference at certain frequencies such that the observer does not notice anything significant – until he moves position. Transfer path analysis is used to assess the structure- and airborne energy paths between excitation source(s) and receiver location(s). This is reflected in figure 2 which describes the so-called Source-Transfer-Receiver model, where an operational force (i.e. an engine) is multiplied with a transfer function leading to response at the receiver location (i.e. driver's ear). Transfer path analysis is a systematic method to understand the relation between multiple sources of noise and vibration and their effect on perceived user comfort and health.

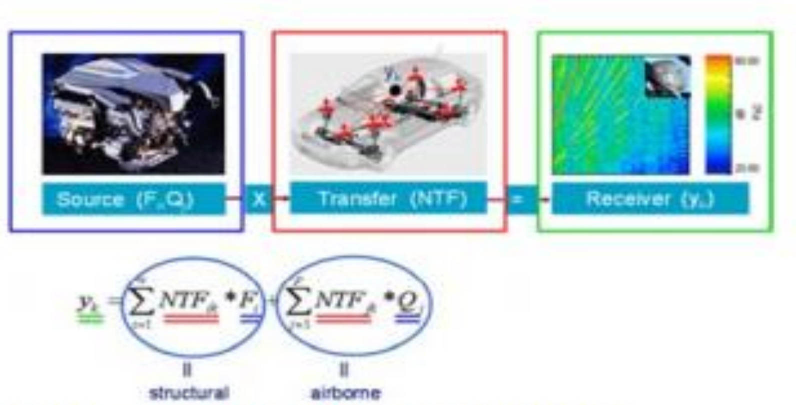


Figure 2: The Source-Transfer-Receiver model

Transfer Path Analysis creates a mathematical model of the structure under test that allows :

• The quantification of source strengths

• The ranking of contributions of the different sources along the different paths for every target receiver position

• What-if simulation of design changes by modifying the forces with new connection stiffness or changing transfer functions by eliminating resonances.

The comparison of effects of various design modifications can be made in a TPA model. The design work can then focus on the most promising modifications.

2. LITERATURE SURVEY:

[1] Inresearchpaper published on "Experimental and numerical study of Advanced Transfer Path Analysis applied to a box prototype " by ÀngelsAragonès

Advanced Transfer Path Analysis (ATPA) is a technique that allows the characterisation of vibroacoustic systems not only from the point of view of contributions but also topologically by means of the path concept. Some of the aspects addressed in the current research such as the proper characterisation of the less contributing paths remained not proven. ATPA is applied to a cuboid-shaped box. The simplicity of this vibroacoustic system helps to make a detailed analysis of the ATPA method in a more controlled environment than in situ measurements in trains, wind turbines or other mechanical systems with complex geometry, big dimensions and movement.

[2] In the research paper published on "Influences of system uncertainties on the numerical transfer path analysis of engine systems "by A. Acri

Practical mechanical systems operate with some degree of uncertainty. In numerical models uncertainties can result from poorly known or variable parameters, from geometrical approximation, from discretization or numerical errors, from uncertain inputs or from rapidly changing forcing that can be best described in a stochastic framework. Recently, random matrix theory was introduced to take parameter uncertainties into account in numerical modelling problems. In particular in this paper, Wishart random matrix theory is applied on a multi-body dynamic system to generate random variations of the properties of system components

[3]In research paper published on "Transfer path analysis: Current practice, trade-offs and consideration of damping" by Akın Oktav

Current practice of experimental transfer path analysis is discussed in the context of trade-offs between accuracy and time cost. An overview of methods, which propose solutions for structure borne noise, is given, where assumptions, drawbacks and advantages of methods are stated theoretically

[4]Inresearch paper paper published on "Application of the transmissibility concept in transfer path analysis " by P. Gajdatsy

In recent years, there has been a renewed interest in developing faster and simpler transfer path analysis (TPA) methods. A dominant class of these new approaches, often referred to as Operational Path Analysis (OPA), is designed to achieve this goal by using only operational data in conjunction with the application of the transmissibility concept

[5] In research paper published on “Modified transfer path analysis considering transmissibility functions for accurate estimation of vibration source" by Ba-Leum Kim

In this study, we developed a modified transfer path analysis (MTPA) method to more accurately estimate the operational force of the main vibration source in a complicated system subjected to multiple vibration sources, base excitation and several disturbances. In the proposed method, transmissibility functions are adopted to compensate the disturbances due to base excitation or to reject transferred forces from other vibration sources.

[6] In research paper published on “Operational transfer path analysis: Theory, guidelines and tire noise application" by D. de Klerk

The operational transfer path analysis (OTPA) method is the subject of research in this article, which starts with a discussion on its theory. Here clear similarities with the MIMO technique in experimental modal analysis are found. Based on the knowledge of MIMO, one finds that input signals are allowed to be coherent to a certain extend. As coherence can be larger in OTPA in practice, the method is extended with the singular value decomposition method to reduce influences of noise.

[7]Inresearch paper published on “Experimental validation of the direct transmissibility approach to classical transfer path analysis on a mechanical setup " by OriolGuasch

Transmissibility functions have received renewed interest given the important role they play in operational modal analysis and operational transfer path analysis. However, transmissibility’s can also be used in the framework of classical transmission path analysis.

[8]In research paper published on “Component transfer path analysis method with compensation for test bench dynamics " by D. de Klerk

In this article a component transfer path analysis (TPA) procedure is proposed. The method allows one to calculate the total system response resulting from a subcomponent’s source excitation. It is based on the knowledge of the frequency response functions (FRFs) of the total system and on a measurement of the stand-alone subcomponent on a test bench. As the true source excitation, for example an engines combustion, is not measurable, equivalent forces at the subcomponent interface are found.

[9]Inresearch paper published on “Reliability analysis of random vibration transmission path systems " by Wei Zhao

The vibration transmission path systems are generally composed of the vibration source, the vibration transfer path and the vibration receiving structure. The transfer path is the medium of the vibration transmission. Therefore, the uncertainty of path parameters influences the system reliability greatly. In order to avoid the resonance failure, the transmission reliability analysis and the reliability sensitivity analysis are both very important

[10] In research paper published on “General framework for transfer path analysis: History, theory and classification of techniques" by Maarten V. van der Seijsa

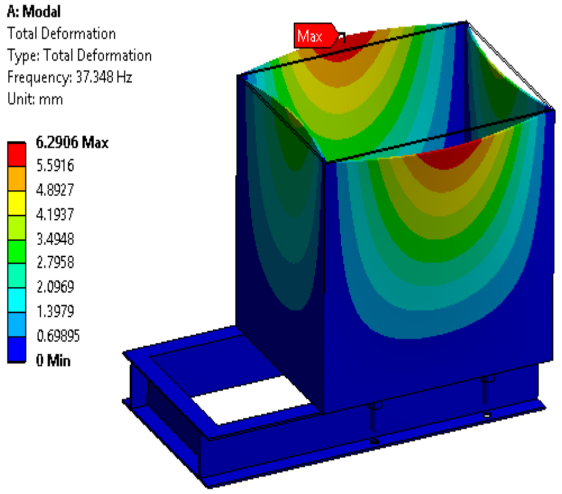
Transfer Path Analysis (TPA) designates the family of test-based methodologies to study the transmission of mechanical vibrations. Since the first adaptation of electric network analogies in the field of mechanical engineering a century ago, a multitude of TPA methods have emerged and found their way into industrial development processes.

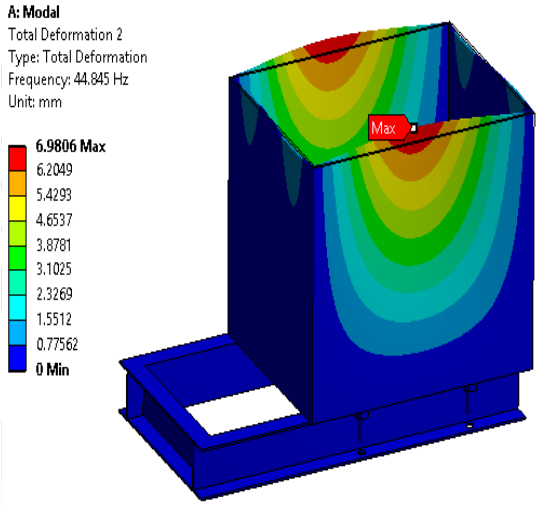
3. Results obtained :

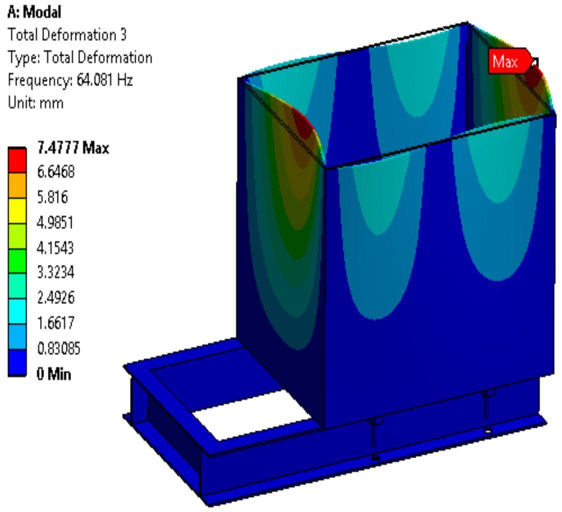
Tabular data :

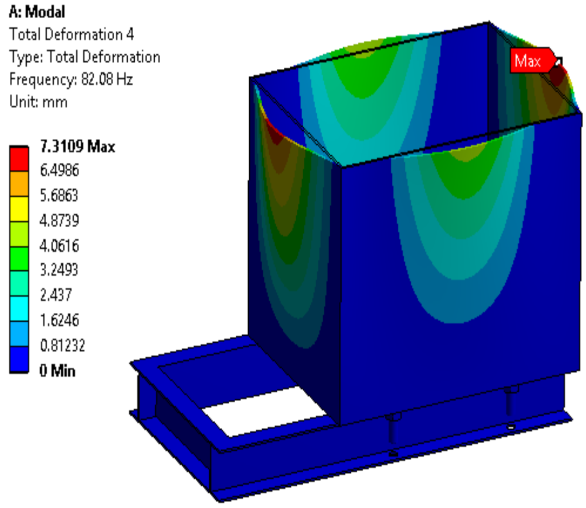
Tabular Data

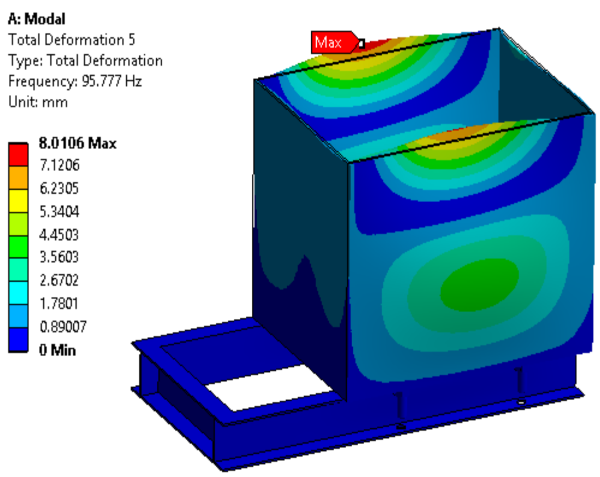
	Mode	Frequency [Hz]
1	1.	37.348
2	2.	44.845
3	3.	64.081
4	4.	82.08
5	5.	95.777
6	6.	98.164
7	7.	115.36
8	8.	122.43
9	9.	124.5
10	10.	131.86

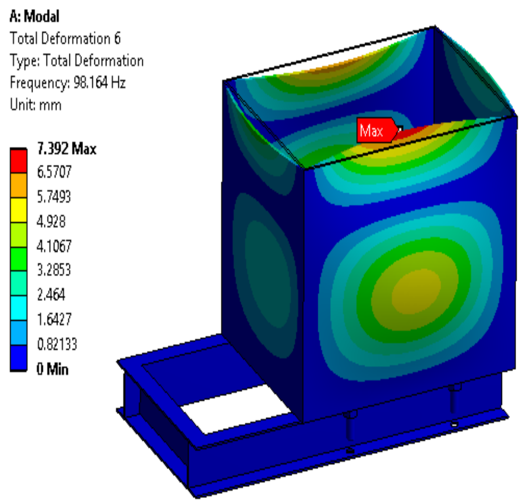


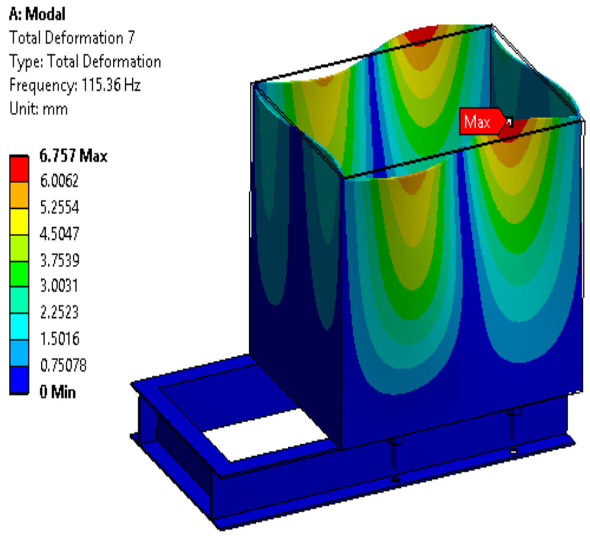


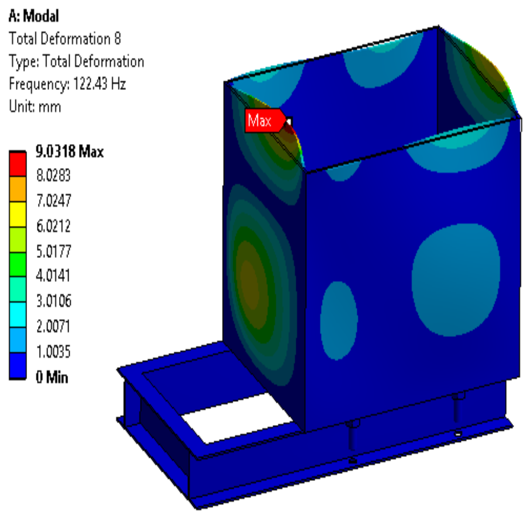


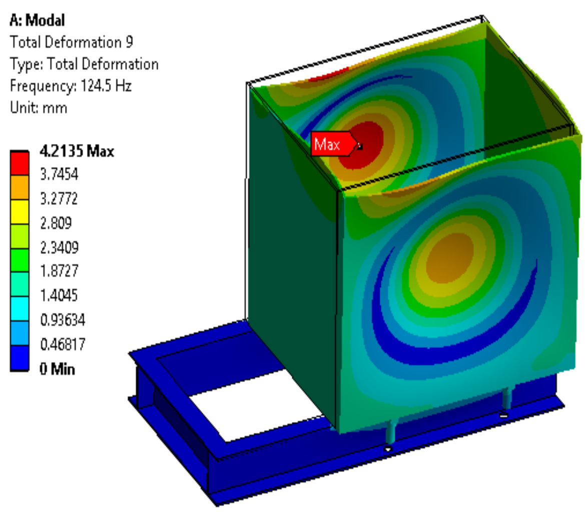


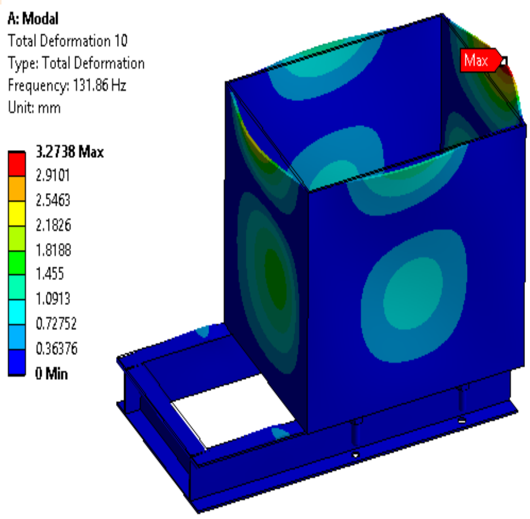












4. Conclusion:

- From above Natural frequencies and mode shapes it is clear that rear body will have resonance from 37 to 130 Hz excitation frequency
- Also mode shapes suggests probable patters for stiffeners parts for increasing stiffness of rear body panel

REFERENCES:

[1] Experimental and numerical study of Advanced Transfer Path Analysis applied to a box prototype
ÀngelsAragonès
[2] Influences of system uncertainties on the numerical transfer path analysis of engine systems
Acri
[3] Transfer path analysis: Current practice, trade-offs and consideration of damping
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