

Mobility at the Development of Exhaust System

2011-01-1523

Published
05/17/2011Mauricio Monteagudo Galindo
Faurecia Emissions Control Technologies

Copyright © 2011 SAE International

doi:[10.4271/2011-01-1523](https://doi.org/10.4271/2011-01-1523)

ABSTRACT

This document describes the advantages of using Mobility transfer function simulations during the development of exhaust systems. The automotive industry demands increasingly stringent levels of acceptable interior noise. The exhaust system is an important contributor to the total vehicle noise and vibration and thus is a target for noise reduction. The use of good vibration isolation systems makes it possible to decrease noise in the vehicle interior compartment. In other words, the vibratory motion in automotive structures results in tactile and acoustic responses. This occurs when the energy coming from the engine (source) is transferred by the Exhaust System (path) and then is transformed into Structural Borne Noise received by the Driver (receiver) through the hanging arrangement of the Exhaust System. In this paper, a procedure to apply the Mobility transfer function to exhaust system design is first described and then an example of correlation results between experimental tests and finite element simulations are shown. These simulations are then used in an optimisation phase to define the proper design to meet the targets.

The most interesting advantage of the application of the Mobility transfer function to exhaust system design is the possibility to change the design of the hangers and/or isolators early in the development process with the support of Computer Aided Engineering (CAE) tools. When using these tools, waiting until the structural and performance validation gates step/process to make changes is avoided and thus much time is saved in the development process.

INTRODUCTION

The proliferation of exhaust system configurations has demanded the development of robust methodologies to identify the number and position of hangers as well as the correct static stiffness of the isolator. An exhaust system for passenger cars consists of hot & cold ends including decoupling and hanging elements [1]. Using advanced mathematical tools, it is possible to predict the kinetic energy that will be transferred from the system to the interior compartment during the early development phase. According to source-path-receiver principles, responses in the low frequency vibration region occur up to around 100 Hz (where structural motion is “felt”) while responses at higher frequencies occur up to around 500 Hz (where structural motion is “heard”). Using the Mobility Transfer Function (Mobility), it is possible to predict if the hanger design meets with the noise specifications.

In addition, the automotive industry is forcing the downsizing of engines according to emissions control regulations; consequently more frequent implementations of turbocharger systems are being demanded. This provides further motivation to investigate the use of Mobility to improve the efficiency of the isolation of the exhaust mounts at high frequencies. The case study examined in this paper has a four-cylinder combustion engine, in which the 2nd harmonic order is a usual source of vibration.

In addition, each development has to follow the “V” development process as shown in [Figure 1](#). The validation phase usually involves Noise, Vibration & Harshness (NVH) testing performed on representative prototypes and establishing the factor of isolation of the complete exhaust line. Typically, complete exhaust system durability testing follows. Nevertheless, reality has often demonstrated that it is

too late to change the design in the validation phase. With the proper use of the approach described in this paper, it is possible to detect potential design changes or recommendations in advance.

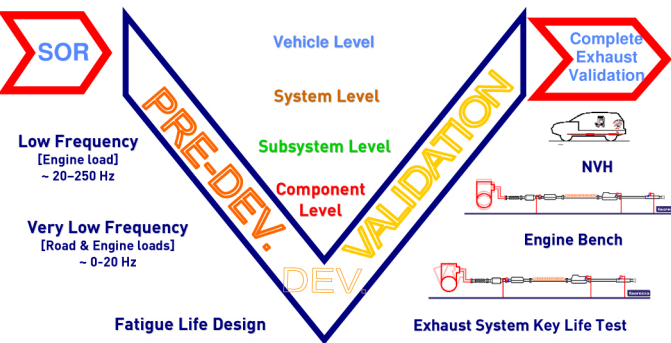


Figure 1. Standard “V” development process.

MECHANICAL TRANSFER FUNCTIONS

Dynamic systems are often characterised using transfer function measurements. A transfer function is generally defined as output/input, expressed in magnitude and phase as shown in [Figure 2](#). The term FRF (Frequency Response Function) is often used in reference to a transfer function.

Mechanical transfer functions (those associated with force and motion) are obtained experimentally or computed using math-based analysis. The motion “out” can be expressed in different ways: displacement, velocity, or acceleration. The most common forms of mechanical transfer functions and their uses are shown in [Table 1](#).

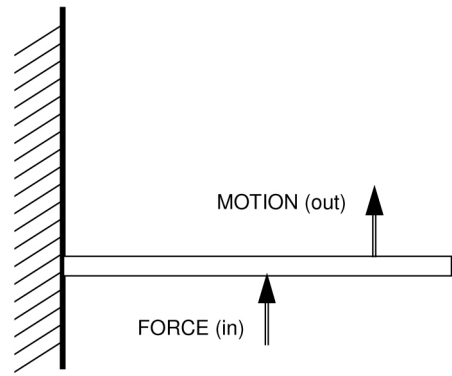


Figure 2. Transfer function sketch.

Table 1. Transfer functions.

FUNCTION	NAME	PRINCIPAL USE
Displacement / Force	Compliance	
Velocity / Force	MOBILITY	Isolation of Mech. Systems
Acceleration / Force	Inertance	Modal Analysis
Force / Displacement	Dynamic stiffness	Rubber Rates
Force / Velocity	Mechanical impedance	
Force / Acceleration	Apparent mass	

MOBILITY CONCEPT

Energy transfer between structures can be studied using mobility functions. In order to isolate mechanical vibrations, the path from the source to the responding structure must be made less efficient. When this occurs, energy will be reflected back towards the source, and sometimes dissipated in the exhaust isolator. The ability of a system to efficiently transfer or attenuate energy can be quantified using mobility measurements. The Mobility transfer function is defined as the inverse of stiffness. If stiffness is the reluctance of a structure to respond to a force, then mobility is the ease with which a structure responds to a force. High mobility means easy to move, and high stiffness means hard to move. In practice, Mobility is easier to measure.

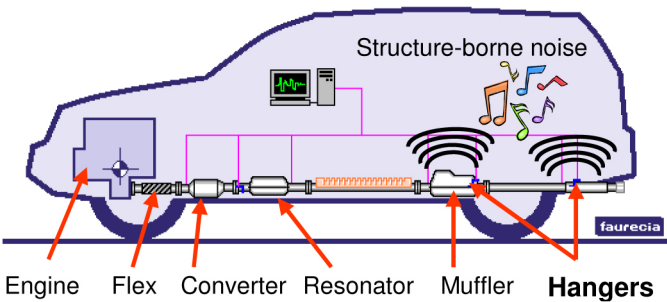


Figure 4. Exhaust components, showing source-path-receiver flow creating structure-borne noise.

The source of the energy input into the exhaust system is the engine exhaust manifold. This includes both structural vibration and exhaust gas pulsation. Exhaust pulsation and structural vibration can excite the walls and surfaces of the exhaust system components resulting in radiated shell noise. This energy can also be transmitted through the exhaust mounting system and become structure-borne noise in the vehicle; forces transmitted through structures that result in noise at the driver's ear. [Figure 4](#) shows different exhaust systems components.