# Case Study: **Tenneco Inc.**

# Exhaust Active Noise Cancellation

## Overview

An automobile's exhaust system is becoming more and more critical to its success in the marketplace. Most important, the sound produced by the vehicle serves to a considerable degree as the signature of the brand. For example, an auto enthusiast can recognize the approach of a Bentley or Ferrari with his or her eyes closed. Purchasers of lower-priced vehicles may not be quite so finicky but they still expect to hear a certain sound when they start up the engine. Meanwhile, automotive original equipment manufacturers (OEM) are being forced by government regulations to reduce the levels of noise emitted from the tailpipe. Automakers are also hoping to reduce the back pressure of exhaust systems in order to achieve improvements in fuel economy.

It's becoming increasingly difficult to meet these often conflicting goals using conventional passive exhaust system technology which relies upon the use of perforated tubes and chambers to filter out acoustic waves. Automotive original equipment manufacturers (OEMs) are looking at active exhaust systems as a way to address these issues. Active exhaust systems use a loudspeaker driven by a microprocessor to cancel out unwanted sound generated by the engine as well as to produce more desirable sounds. A key advantage of active exhaust systems is that they can be controlled by software to adjust the output of the loudspeaker to deliver just the right sound under a wide range of different operating conditions.

**"Simulation will make it possible to evaluate the performance of many alternative design concepts in a minimal amount of time without the expense of building physical prototypes. (It) will also make it possible to bring new products to market faster."**

Nicolas Driot, Senior Core Science Engineer, Tenneco, Inc.

## Challenge

Tenneco is currently in the process of developing an active exhaust system that is capable of both noise cancellation and sound generation for its OEM customers. One of the many challenges faced by Tenneco engineers in this project is the design of the housing used to mount the loudspeaker. The housing affects the performance of the loudspeaker, particularly by increasing the range of frequencies where the speaker operates most efficiently. Tenneco engineers are designing the housing to minimize this effect so that the speaker will operate very efficiently at low frequencies in order to cancel out the low frequency sounds emitted by the engine without consuming excessive electrical power.

In the past, engineers designing active speaker systems have primarily relied upon physical testing to design components such as the speaker housing. But this approach requires the construction of a prototype of each exhaust system configuration that is tested. This is expensive, time-consuming and also the information that can be captured by physical testing is limited by difficulties involved in instrumenting the exhaust system. Tenneco engineers needed a method to accurately simulate the performance of their active exhaust system using a software prototype of the exhaust system including the loudspeaker and housing.

## Solution/Validation

Tenneco engineers selected Actran acoustic simulation software because of its capability to provide full electroacoustic modeling of the loudspeaker in order to track how the electrical power is converted into acoustic power and thus evaluate the sound pressure level generated by the speaker in relation to the amount of power consumed from the battery. With Actran, Tenneco engineers were able to completely model the speaker as a vibrating component including all structural components while maintaining the coupling between the speaker membrane and the air in front of and behind the membrane, and including the electromagnetic modeling in a user friendly way.

Tenneco engineers used Actran to create a finite element model of the loudspeaker alone and then integrated it in a complete exhaust system. In both cases the loudspeaker was excited and simulation results correlated very well with physical testing. Later, they implemented the noise cancellation loop by adding an inlet boundary condition that represents the sound injected into the exhaust system by the engine. Initially, they used a simple constant frequency sine wave at the inlet and constant temperature air throughout the exhaust system. They provided an electrical signal to the speaker to cancel the engine noise and looked at how much sound reduction was achieved. Finally, Tenneco engineers added more complex boundary conditions including a realistic acoustic input and temperature gradients to provide a close match to actual operating conditions.

## Results

"Actran has enabled Tenneco to develop a process for electroacoustic simulation

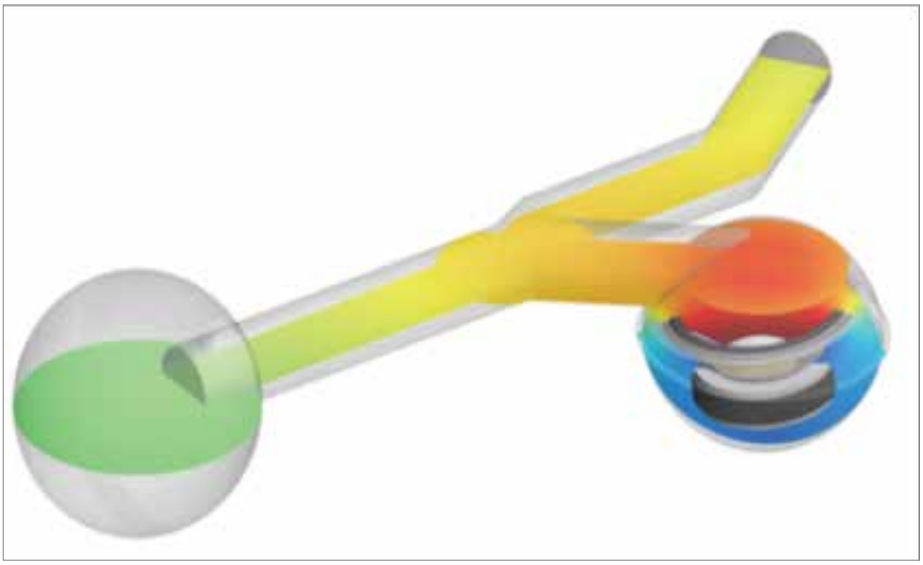
### Key Highlights:

**Product:** Actran

**Industry:** Automotive

**Benefits:**

- Actran results match very closely with physical test measurements both when modeling the loudspeaker alone and then when simulating the loudspeaker integrated it in a complete exhaust system.
- Simulation allows evaluating the performance of many alternative design concepts for active noise cancellation in a minimal amount of time without the expense of building physical prototypes.



Exhaust acoustic pressure cancellation

Exhaust line with Active Noise Cancellation system: Top view and Side view

of an active exhaust system including the loudspeaker and housing that correlates very well with physical experiments," said Nicolas Driot, Senior Core Science Engineer for Tenneco. "We are now using simulation to develop our next generation active exhaust system. Simulation will make it possible to evaluate the performance of many alternative design concepts in a minimal amount of time without the expense of building physical prototypes. This should make it possible to improve the performance of the exhaust system beyond what can be achieved with the traditional process where only a few different design alternatives can normally be evaluated. Simulation will also make it possible to bring new products to market faster."

## About Tenneco

Tenneco Inc. is one of the world's leading designers, manufacturers and distributors of clean air and ride performance products and systems for the automotive, commercial truck and off-highway markets and the aftermarket. Tenneco integrates emissions components and supplies its customers with exhaust systems that support gasoline, gasoline direct injection, flex-fuel and diesel applications. The company has revenue of $8.2 billion, nearly 30,000 employees and more than 90 manufacturing facilities worldwide.

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