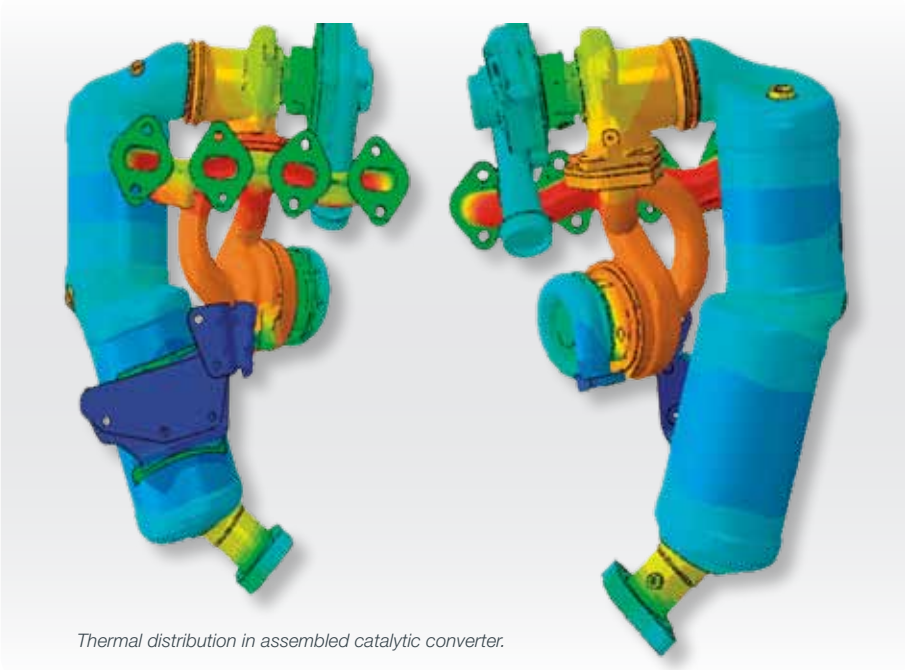
Universidad Autonoma de Nuevo Leon Successfully Simulates Vibrations in a Catalytic Converter for Diesel Engines

Automotive manufacturers are faced with many challenges to meet industry standards and satisfy customer demands. One common requirement is to produce greener automobiles by reducing toxic emissions. Since the first emissions standards were passed in the 1970s, manufacturers have strived to develop technologies to detoxify the exhaust, which are an essential part of emissions control. To study the complex thermal and mechanical phenomena of these components, engineers are leveraging realistic simulation to improve designs and select the best materials for optimum performance.

A good example is the catalytic converter, a device installed in the exhaust system to reduce the toxicity of exhaust gases generated by the combustion process. Car manufacturers assess the noise control of the exhaust pipe, the amount of the emissions after treatment, the reliability of achieving heat transfer, the surrounding components that can be damaged by temperature, and exhaust fumes that create discomfort to passengers or pedestrians.

There are many important mechanical and thermal aspects to assure the catalytic converter meets its required operating performance. It is critical to understand the different modes of heat transfer involved in and around the exhaust system to be able to improve the design of components. A high-quality design and a proper material selection are the key to preventing damage early in the life of the catalytic converter components.

Thermo-mechanical stresses in the system are caused by thermal cycles or thermal shocks. The resulting high temperature gradients can cause thermal fatigue in the components. These same thermal gradients can radically alter the dynamic response of the components themselves (through contact, thermal strains, and thermal softening). Finally, at high temperatures the exhaust system components could experience degradation by corrosion as they regularly reach up to 1000° C. Some of the mechanical aspects that influence the catalytic converter performance are related to the structural vibration from the engine and road profile. The stresses caused by the vibration inputs into the catalytic converter must be correctly distributed to avoid the nucleation of cracks that could lead to an early fracture.



Thermal distribution in assembled catalytic converter.

Table 1. Cold and Hot Modal Results (Hz)

Modal	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 7	Mode 8
Cold modal	156.95	233.83	254.68	267.45	323.84	341.36	398.35	448.46
Hot modal	131.55	174.10	186.34	210.02	234.87	271.25	318.73	353.24

To properly simulate the operating conditions of the catalytic converter, a full 3D model was created in Abaqus. Geometries were imported, assembled, meshed, and material properties were assigned to them. A thermal analysis using the output from a CFD code was created, then cold and hot modal analysis were run using Abaqus. For the thermal analysis, a heat transfer step was created at steady state. Convection and radiation boundary conditions were imposed, as well as temperatures of the gas and components. In order to obtain the frequencies of the assembly, a frequency step was set up. For the frequency, the Lanczos Eigensolver was used to calculate the first 10 modes (see Table 1). It is readily seen that the component response dramatically varies when different thermal conditions are considered—these differences in turn can impact both the system-level performance and the resultant fatigue life.

The obtained results could be utilized for further optimization of the design to meet the automotive manufacturer's requirements, and various operational and thermal scenarios. This may affect the materials used, the geometries of the different components or the location of the supports. Also, it is possible to accurately predict the catalytic converter performance and to gain deeper understanding and even simulate the fatigue life and noise of the system.

This article is based on a paper presented at the 2011 3DS SIMULIA Customer Conference by Nestor Martinez, Miguel Amado, and Martha P. Guerrero, Universidad Autonoma de Nuevo Leon.

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