A New Cat Hits the Streets of Europe

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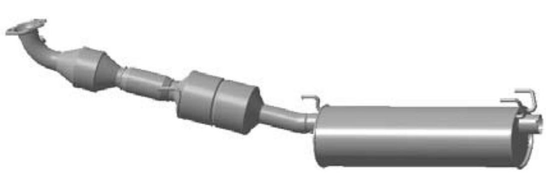


The Euro 4 baseline exhaust system

THE EUROPEAN UNION has introduced emissions regulations for various vehicles during the past several years. In 2006, the Euro 4 regulations were targeted at new light duty vehicles with the goal of reducing NOx emissions and harmful particulates. To meet the new emissions targets, aftertreatment devices have been added to the exhaust system of the IVECO Daily line of trucks and vans, one of the most popular lines of light duty vehicles in Europe. Engineers from IVECO and the Exhaust System Division of Cornaglia worked together to design the new exhaust system, using FLUENT to optimize the flow distribution in the catalytic converter (cat) while keeping the system backpressure under control.

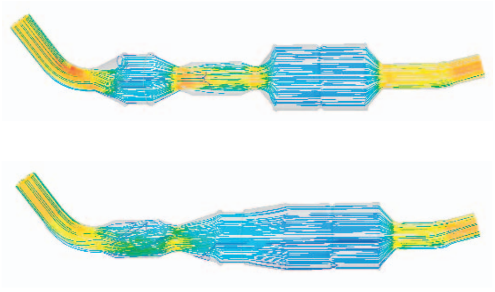
A baseline exhaust system was studied first, focusing upstream of the muffler where higher temperatures exist and the main contribution to the system backpressure occurs. The geometry was then modified and new calculations were performed to optimize the following parameters:

- the flow uniformity index, γ, evaluated on inlet sections of the pre-cat and main-cat monoliths and defined as the average of the deviations between the mean and local flow velocities
- the system backpressure, or difference between the static pressure on the inlet section of the system and the ambient pressure

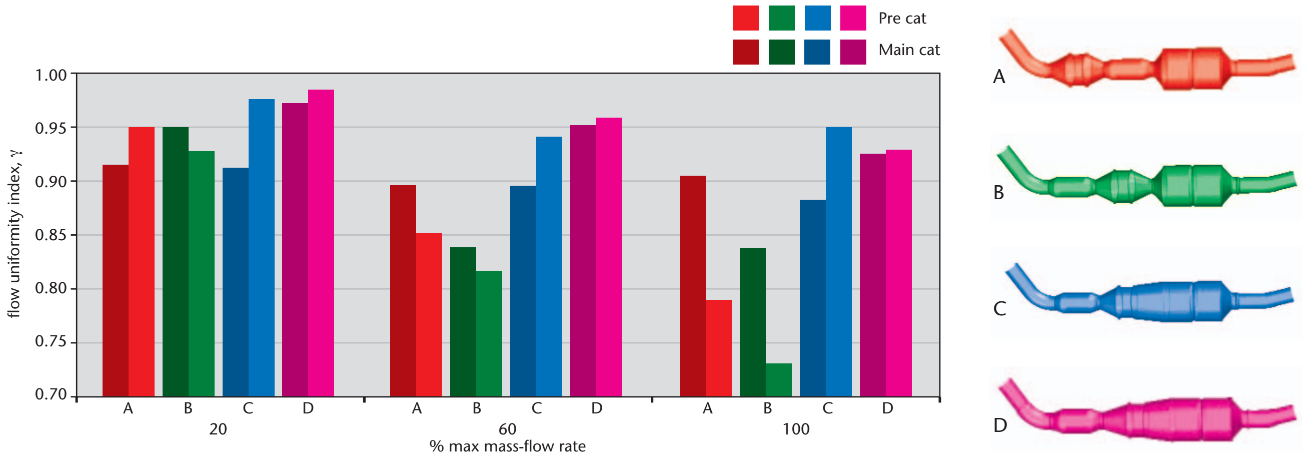
A 600,000 cell mesh was generated using GAMBIT. The pipes and monoliths were modeled with hexahedral elements, while the conical sections were modeled with tetrahedra. Steady-state calculations were performed using the k-ε turbulence model with non-equilibrium wall functions. The ideal gas law was used for the exhaust gases, and heat transfer at the walls was included. The monoliths were treated as porous regions, and the upstream muffler static pressure, measured on an engine bench, was used for the exit condition. Mass flow rates of 20%, 60%, and 100% of the maximum flow rate of the IVECO F1C JTD engine were used as inlet conditions.

Four geometric configurations were analyzed to study the effect of different designs on the flow uniformity index and backpressure reduction. Configuration D was found to perform the best overall, causing the most uniform flow for all but one flow condition and a 12% reduction in backpressure compared to Configuration A. The predicted improvement was confirmed by experimental tests, and Configuration D was subsequently adopted for serial production. The Cornaglia exhaust system, optimized by this study, is currently mounted on the Iveco Daily light duty vehicles throughout Europe. The use of CFD for the optimization process reduced the development time and the cost of prototype manufacturing. ■

Surface mesh used for the baseline system



Pathlines colored by velocity magnitude illustrate the flow through designs A (top) and D (bottom)



Pre-cat (darker colors) and main-cat (brighter colors) flow uniformity index performance for the four geometries studied: the baseline configuration (A, red); an exchanged position of the flexible joint and pre-cat (B, green); the introduction of a single cone connecting the pre-cat to the main-cat (C, blue); and an increased pre-cat inlet cone length with same total system length as C (D, magenta)