Emissions Control Through Carbon Canisters

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The geometry of the carbon canister, showing the inflow port (blue), 3 chambers packed with carbon pellets (gray) and vent port (yellow)

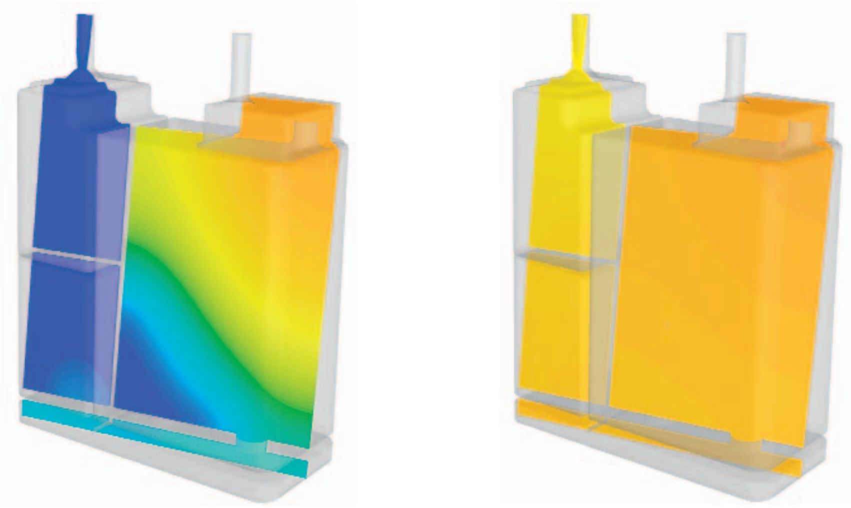
CARBON CANISTERS ARE DEVICES commonly used to control the emissions of volatile hydrocarbons. Hydrocarbons (HC) are hazardous to human health and the environment. For automobiles, HC emissions are produced during the filling of the fuel tank, and during vehicle operation. When the engine is off, evaporation from the vehicle fuel system still occurs, even at ambient temperatures typical of the diurnal cycle. Allowable HC emission limits are set by government regulations; for example, the LEV II (Low Emitting Vehicle-II) standard allows a certain amount of hydrocarbon emissions for a specific range of gross vehicle weight.

Carbon canisters are part of the evaporative emission control system, which includes the fuel tank, vent and purge valves, and fuel lines. The role of the carbon canister is to store the fuel vapor generated in the system instead of having it escape into the atmosphere. The HCs are then burned off by purging the canister into the intake manifold when the engine is running. An optimum design includes a high working capacity, minimal pressure drop in the evaporative emissions system, space and size restrictions, and the ability to meet the mandated emission standards. Furthermore, the carbon utilization in the canister should be uniform; when less carbon material is needed, savings are realized. In today's competitive market, carbon canister manufacturers must be able to predict canister performance without having to build and test various prototypes.

One carbon canister design from Expert Corp. has been simulated using FLUENT. The purpose of the CFD simulation was twofold: first, to compute the canister capacity and pressure drop at 60 l/min of air flow, and second, to predict canister breakthrough for a gaseous mixture of butane and nitrogen entering the canister at 15 g/hr. The mixture reacts with packed carbon pellets (adsorbing and desorbing), until breakthrough is achieved, i.e. when a set cumulative amount of butane passes through the canister outlet. Arrhenius reaction rates for the adsorption and desorption reactions were prescribed. The carbon pellets were modeled as a porous region. A mesh of 184,000 hexahedral elements was used for the laminar simulation.

The CFD results were used to assess the design. Using pathlines, a region with little or no flow was identified in the first chamber. Ideally, the canister design should provide uniform utilization of the carbon media in all of the chambers, and this result suggests that it does not. Mass fraction contours were used to illustrate the distribution of butane at several times during the canister loading process. The growth of butane inside the canister is the result of the ongoing surface reactions with the carbon pellets, so this provides another measure of how well the unit is operating as a whole. A plot of the butane mass fraction at the outlet as a function of loading time can also be used to indicate the time when breakthrough is achieved. The carbon canister capacity is computed by integrating under this curve. ■

Pathlines show a dead zone in the upper left corner in the first carbon-filled chamber; the presence of dead zones points to underutilization of carbon



Contours of butane mass fraction on a slice through the canister during loading (left) and once the canister has reached capacity (right)