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The Effect of Swirl on the Flow Distribution in Automotive Exhaust Catalysts

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Abstract : The application of turbocharging in automotive engines leads to swirling flow entering the catalyst. The behaviour of this type of flow within the catalyst has yet to be adequately documented. This work discusses the effect of swirling flow on the flow distribution in automotive exhaust catalysts. Compressed air supplied to a moving-block swirl generator allowed for swirling flow with variable intensities to be generated. Swirl intensities were measured at the swirl generator outlet using single-sensor hot-wire probes. The swirling flow was fed into diffusers with total angles of 10°, 30° and 180°. Downstream of the diffusers, a wash-coated diesel oxidation catalyst (DOC) of length 143.8 mm, diameter 76.2 mm and nominal cell density of 400 cpsi was fitted. Velocity profiles were measured at the outlet sleeve about 30 mm downstream of the monolith outlet using single-sensor hot-wire probes. Wall static pressure was recorded using a multi-tube manometer connected to pressure taps positioned along the diffuser walls. The results show that as swirl is increased, more of the flow is directed towards the diffuser walls. The velocity decreases around the centre-line and maximum velocities are observed close to the outer radius of the monolith for all flow rates. At the maximum swirl intensity, reversed flow was recorded near the centre of the monolith. Wall static pressure measurements in the 180° diffuser indicated no pressure recovery as the flow enters the diffuser. This is indicative of flow separation at the inlet to the diffuser. To gain insight into the flow structure, CFD simulations have been performed for the 180° diffuser for a flow rate of 63 g/s. The geometry of the model consists of the complete assembly from the upstream swirl generator to the outlet sleeve. Modelling of the flow in the monolith was achieved using the porous medium approach, where the monolith with parallel flow channels is modelled as a porous medium that resists the flow. A reasonably good agreement was achieved between the experimental and CFD results downstream of the monolith. The CFD simulations allowed visualisation of the separation zones and central toroidal recirculation zones that occur within the expansion region at certain swirl intensities which are highlighted.

Keywords : catalyst, computational fluid dynamics, diffuser, hot-wire anemometry, swirling flow
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