

Nanoparticle Transport and Reaction Phenomena in Diesel Particulate Filters

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Advanced fuel injection technology in conjunction with an inherent high thermal efficiency have lead to increased market share of diesel powered vehicles especially in Europe, and the trend is expected to continue if the diesel engine is able to meet ever more stringent emission limits in the future. This is dependent on the deployment of cost efficient, advanced emission control systems for particulate and NOx emissions. However the adverse health effects of combustion generated nanoparticles, such as diesel soot, generate a highly visible public debate, where the role of aerosol scientists and technologists becomes very important both in terms of measurement and assessment technologies as well as technological solution developers/providers.

Particulate emission control entails measures to reduce both the solid (soot) particle emissions and liquid particle (droplet) emissions formed due to condensation of the exhaust as it cools down. The latter can be readily reduced by regulating their precursors (reducing the fuel sulfur level and installing advanced diesel oxidation catalysts to oxidize the complete spectrum of hydrocarbon (HC) emissions). The solid soot emissions however remain intimately connected with the nature of the diesel combustion process and their reduction can be achieved either by in-cylinder measures improving the combustion process itself, or by deploying aftertreatment systems such as Diesel Particulate Filters (DPFs).

The paper starts with recent results on the characterization of soot nanoparticles emitted from modern diesel engines. This is followed by a discussion of the effects of engine operating conditions on the microstructure and permeability of soot particle deposits in DPFs. A combined experimental and computational methodology for studying DPF performance is then described, addressing the following aspects: filter flow resistance behavior, size specific filtration efficiency, kinetics of filter loading and regeneration (by oxidation of the collected soot via thermal, catalytic and NO₂-assisted techniques) behavior and ash particle induced aging.

The use of advanced simulation tools (based on discrete as well as continuum approaches) coupling phenomena occurring over widely disparate spatial and temporal scales is then discussed and their application is demonstrated for the development of advanced multifunctional porous materials as well as for the system design, monitoring and control of modern emission control systems.

Examples of computer reconstructed DPF porous media are given in Figure 1 and encompass all currently available filtration media: extruded ceramic filters (including reaction formed media as cordierite and grain-sintered media as SiC), fibrous filters, foams and sintered metal powder/wiremesh.

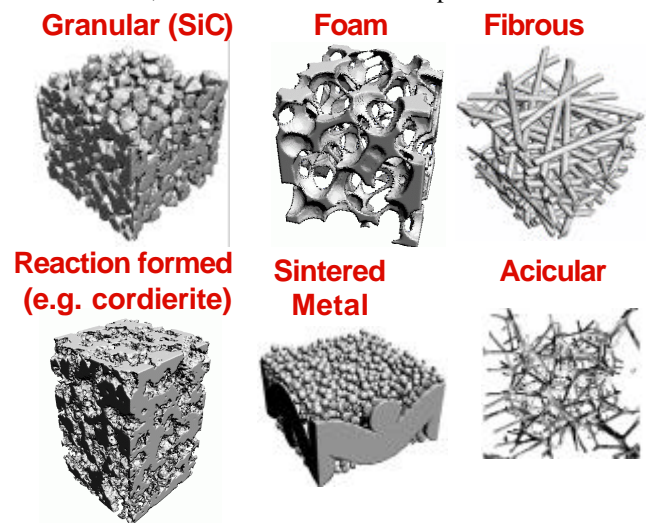


Figure 1: Computer reconstruction of various porous filters.

Using the reconstructed porous material and the computed flow field the computation of soot deposition in the filter can be carried out. An example of soot deposition in a granular (SiC) filter is seen in Figure 2.

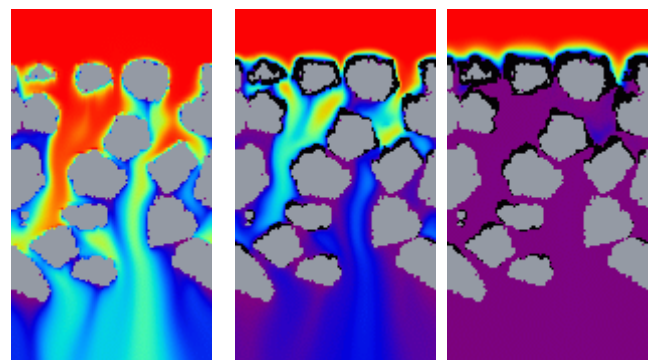


Figure 2: Soot concentration and deposits in a cross-section of a porous filter wall.

Such results are expected to improve our understanding of the microstructural factors that affect Diesel Particulate Filter performance.