Vehicle Engine Aftertreatment System Simulation (Veass) Model: Application to a Controls Design Strategy for Active Regeneration of a Catalyzed Particulate Filter

Nishant Singh, John H. Johnson, Gordon G. Parker, Song-Lin Yang

Abstract

Heavy-duty diesel engine particulate matter (PM) emissions must be reduced from 0.1 to 0.01 grams per brake horsepower-hour by 2007 due to EPA regulations. A catalyzed particulate filter (CPF) is used to capture PM in the exhaust stream, but as PM accumulates in the CPF, exhaust flow is restricted resulting in reduced horsepower and increased fuel consumption. PM must therefore be burned off, referred to as CPF regeneration. Unfortunately, nominal exhaust temperatures are not always high enough to cause stable self-regeneration when needed. One promising method for active CPF regeneration is to inject fuel into the exhaust stream upstream of an oxidation catalytic converter (OCC). The chemical energy released during the oxidation of the fuel in the OCC raises the exhaust temperature and allows regeneration. This approach facilitates active control of the regeneration process so that the CPF can be operated in a sufficiently clean state to maintain engine performance and fuel economy. Development of active regeneration control strategies is challenging since a balance must be struck between fuel consumption for the regeneration process, keeping backpressure low by burning off PM, and maintaining regeneration stability.

This paper describes the development of a lumped parameter heavy- duty vehicle engine aftertreatment system simulation (VEASS) suitable for designing and evaluating the performance of CPF active regeneration control strategies. A candidate control strategy is also proposed and evaluated using this model calibrated to load cycle data for an International 9700 heavy-duty truck with a Cummins ISM 2002 diesel engine. The PM collected in the CPF is estimated from the pressure drop across the CPF. It was found that fuel injection for active regeneration should not be allowed to respond to high frequency components in the CPF pressure drop and the CPF exhaust inlet temperature. A filter-based approach is described for avoiding the negative effects of responding to the high frequency measurements. For the sample case study considered, the fuel penalty associated with CPF usage was reduced with higher PM loadings of the CPF, higher target temperatures at the inlet to the CPF and higher time constant of the low pass filter to the OCC inlet temperature.

Also, different-sized exhaust systems can be evaluated for active regeneration strategies using the VEASS model and a different-sized CPF is simulated for illustration.