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Experimental and numerical research of the selective catalytic reduction system for diesel engine cars

PhD thesis of

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Abstract

The aim of the dissertation was to conduct experimental and numerical research for a selective catalytic reduction (SCR) system of a passenger cars with a diesel engine. The research consists of comparing the results for two different SCR systems, existing and new developed. The developed SCR system is aimed at introducing it to the secondary market (Aftermarket), which is also associated with the development of its own mixer design.

Due to increasingly stringent emission standards in particular nitrogen oxides (NO_X), the SCR systems have recently been invented and installed in diesel cars around the world. These systems must be validated during emission tests on the reduction of NO_X to the appropriate limit, in order to authorise a car do drive. To achieve this goal a coupled approach needs to be applied incorporating both extensive experimental research and advanced numerical methods based on computational fluid dynamics (CFD).

Therefore, in the research work various design variants of the SCR system and mixers at different operational parameters were studied. Several solutions were investigated under conditions that reflected the real operating conditions of the diesel engine operation. Among other things, pressure drops on monoliths, gas distribution and conversion of nitrogen oxides were tested and analyzed on prototypes in Tenneco laboratories. Furthermore, for the purpose of numerical model development, laser scanning was used to extract 3D models of the real geometries of the system elements by using a reverse engineering approach.

A commercial code ANSYS Fluent was used to perform the multiphase computational fluid dynamics studies. A careful analysis has been done for the subsequent processes occurring in the system, i.e. the evaporation and mixing of the reactants prior to the catalyst, proper distribution of flow through the catalyst and selection of appropriate thermal conditions for the process. Attention was given to the implementation of the SCR reaction kinetics. The CFD model was then validated against the experimental data showing good agreement between the measured and simulated parameters.

The final design of the replacement SCR part was compared with an original system delivered by the original equipment manufacturer. It was found that application of the new mixer in the replacement SCR system led to slightly lower NO_X emission, which was confirmed in the certification unit through emission tests in a car on the chassis dynamometer.