# Experiments and modeling for system-wide control of biodiesel engines and after treatment systems

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## Main achievements of the project:

Previous literature in the area of automotive emissions control focus mainly on the performance of aftertreatement devices. While these devices are vital in ensuring that the stringent government regulations on emissions are met, combustion modifications, or engine-level strategies, are equally crucial. The core of this project lies in mathematical modeling of these two techniques for NOx control, together. At this point of time, the efficaciousness of Exhaust Gas Recirculation has been evaluated against Catalytic Reduction, for NO control. Several interesting insights have been obtained.

The various components of this project have together much to offer to the field of automotive NOx treatment. First, the kinetics based modeling of engine performance is necessary in order to fully understand and optimize NO formation in automobiles – we believe that the methodology of this work is superior to others in published literature, for this purpose. The aftertreatment options that are optimal under various scenarios can only be envisaged based on the output of such models. In our studies, the predominance of the Zeldovich pathway in NO formation is highlighted, which is in line with literature studies. When the engine operating conditions are kept at nominal values, the CI engine results of this work are therefore equally applicable to biodiesel fuels as well, as demonstrated.

Second, the aftertreatment options for NO including reduction by CO and HC are examined. The experimental data-base of results generated here indicated that while CO is efficacious as a reductant, propene is not effective except in a narrow range of operating conditions, for Pt-based pellet catalysts. This demonstrates the need to further closely examine HC-SCR which is often cited in literature as an important technique for CNG based engines. Our results indicate that this strategy will require much optimization, particularly on the economics, as the Platinum Group metal catalysts are expensive.

Finally, the System-Wide model results with the simple HCCI + EGR + SCR modules indicate the likelihood that EGR may be a far less effective strategy than SCR in the reduction of tail-pipe NOx emissions, for these conditions. Of course, the quantitative aspects of these results will vary when we consider more realistic models of fuels and engines, but the overall results are likely to remain the same. Overall, our results thus far indicate that efforts spent on optimizing catalytic aftertreatment options for automobiles is the best bet, particularly with regards to developing cheaper catalysts that work at lower temperatures and with quicker light-off times.

The main achievements of this project, are stated below in brief, bullet points. Overall, This work underscores the importance of kinetics-based modeling for automotive engines. Only such models can indicate clearly the differences in NO emissions due to differences in formation pathways inside the engine:

- A laboratory-scale high temperature catalytic reactor for kinetics determination for NO reduction in automotive aftertreatment devices was set up as shown in the photograph, incorporating a sophisticated chemiluminescent analyser
- Lab-scale experiments on aftertreament devices under carefully controlled operating conditions indicate that $C_3H_6$ is not as effective a reductant for NO as CO, for Pt-catalyst based devices. Thus the strategy for HC-SCR has to be carefully re-considered.
- System-wide models for kinetics-based engine models + aftertreatment devices demonstrated here indicate that exhaust gas recirculation and catalytic reduction both have different impacts on tail-pipe NO, and that operating variables including the temperature and reductant used are critical in determining optimal strategies for NO reduction.

Several publications and conferences presentations over the course of the project have led to significant discussion in the research community on this unique approach to automotive emissions control.

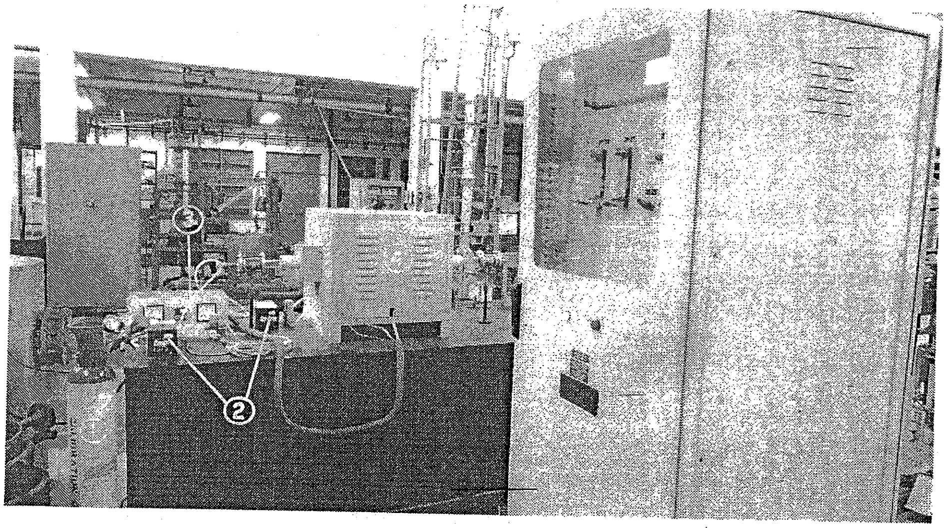

**Fig. 1: Lab -scale experimental set-up for NO reduction (Dept. of chemical engineering, IIT Madras)** ***(1. Feed gas cylinder 2. Mass flow controllers 3. Temperature control panel 4. Furnace 5. CLD and gas analyzer system)***

***Shortfalls/constraints faced:***

In this project, extensive kinetics based modeling was performed for SI, CI and HCCI engines. Various fuels – petrol, diesel and biodiesel were examined from the view-point of NO emissions control, and a good overall picture obtained from the simulation studies. One of the shortfalls was that the CNG engines could not be examined, due to paucity of time.