Key Messages from AMF Research

Annex 54 **February 2020**

GDI Engines and Alcohol Fuels

Operating Agent: Emissions Research and Measurement Section, Environment and Climate Change Canada
Partners: Canada, Germany, Israel, Switzerland, United States
Supporting Information: Chile

Major Conclusion

Ethanol is the most widely used biofuel around the globe. In addition to reducing greenhouse gas emissions, ethanol, generally has beneficial effects on both gaseous and particulate matter (PM) tailpipe emissions. Fuel-efficient gasoline direct injection (GDI) engines tend to have high PM emissions and genotoxicity compared to diesel engines, however, both the use of ethanol as a blending component and gasoline particulate filters can alleviate this issue. Annex 54 contributed to the understanding of particulate formation as well as mitigation.

Background

GDI vehicles have seen rapid market penetration in light duty vehicle fleets due to their increased efficiency and reduced CO_2 emissions but tend to produce higher PM emissions compared to vehicles with the more common port fuel injection engines. Governments have imposed stricter standards to control PM emissions measured by mass or number of particles emitted per distance travelled. The beneficial effects of alcohol fuels and the use of gasoline particulate filters (GPF) are considered as pathways to meet such existing and future regulations. Better understanding of the potential toxicity of these emissions and their potential to contribute to further particulate matter formation in the atmosphere are also issues of importance.

Research Protocol

Most studies are based on chassis dynamometer tests of vehicles with GDI engines, focusing especially on particulate matter emissions, under different driving cycles and the use of different fuel blends. The contribution from Germany looks at the fundamental processes of combustion and pollutant formation in a unique single cylinder engine. The contributions from Chile and Switzerland address secondary organic aerosol formation potential of GDI emissions as well as reporting on tailpipe emission results. The contribution from Switzerland also addresses the genotoxicity of GDI vehicle emissions.

Key Findings

Fundamentals of combustion and pollutant formation in a GDI Engine

The high-speed visualization fuel-air mixing and sooting combustion in an optically accessible single cylinder engine offers an effective technique for understanding the mechanisms leading to PM formation in GDI engines. These observations show that soot is formed in fuel rich regions with incomplete evaporation of fuel droplets remaining from the injection event.

Effect of Alcohol Fuel Blends on Emissions from GDI Vehicles

Alcohol fueld blends had generally beneficial effects on both gaseous and PM tailpipe emissions. However there were also cases were higher PM formation/emission was observed.

Effect of Start-Stop Operation on Emissions from GDI Vehicles

The effect of the start-stop operation mode available in some GDI vehicles on gaseous and PM emissions was studied with one vehicle. The effects were relatively minor over complete driving cycles and suggested that additional stops and starts after the catalyst had heated up would not make significant additional contributions to emissions.

Effect of Gasoline Particulate Filters on Emissions from GDI Vehicles

The gasoline particulate filters studied with GDI engines were generally effective in reducing PM emissions quantified by mass or number of particles emitted per distance travelled. Some of these results showed particle number (PN) emissions that could meet the regulatory limit of 6 x 10E11 particles/km.

Secondary Organic Aerosol Formation Potential of Emissions from GDI Vehicles

A smog chamber study suggested that the rate of secondary pollutant formation in the atmosphere would be slower from GDI vehicle exhaust using alcohol blended fuels , thus representing a positive impact on air quality. In another study it was observed that while GPFs may be effective in removing elemental black carbon particles, the volatile components of primary organic aerosol are not significantly reduced, thus secondary organic aerosol (SOA) formation was not affected by the tested GPFs. It was suggested that future work on “4-way” catalysts should be conducted to achieve simultaneous reductions of SOA precursors, SOA production, and semi-volatile primary PM.

Genotoxicity of Emissions from GDI Vehicles

Using the toxicity equivalents approach for eight polycyclic aromatic hydrocarbon (PAH) compounds, the genotoxic potential of the emissions from GDI vehicles were observed to be higher than a diesel vehicle equipped with a particle filter. It was noted that fully integrated catalytic GPFs, operated at higher temperatures, allowing the combustion of accumulated soot and adsorbates, will be needed to lower the genotoxic potential of GDI vehicle exhaust to levels already achieved for diesel vehicles with particulate filters.