Annex 54: GDI Engines and Alcohol Fuels

Project Duration	April 2016–April 2019
Participants **Task Sharing** **Cost Sharing**	 Canada, Chile, Germany, Israel, United States No Cost Sharing
Total Budget	~ €330,000 ($394,808 US)
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Purpose, Objectives, and Key Question

Under certain conditions, gasoline direct injection (GDI) may increase particle emissions in comparison with port fuel injection (PFI) engine technologies, up to levels that are over the emissions from diesel vehicles equipped with diesel particulate filters (DPFs). Both gasoline particulate filters (GPFs) and alcohol fuel blends, mainly E85 (85% ethanol in gasoline fuel), have shown the potential to reduce particulate matter (PM) emissions from GDI vehicles.

The objective of this Annex is to determine the impacts of alcohol fuels on emissions from GDI engines. In addition to gaseous emissions, the focus will be on the tailpipe emissions of PM and black carbon (BC), along with the secondary organic aerosol (SOA) formation potential. The fuels investigated include ethanol blends (E10 and E85) and methanol blends (M56, M15, and M30). The impacts of GPFs on particles from GDI engines with varying fuels will also be investigated.

Activities

The main activities of this Annex are chassis dynamometer tests of vehicles with GDI engines and comparable counterpart engines. These vehicles will be chassis dynamometer tested over varying drive cycles and ambient temperatures. The vehicles will also be tested with fuels of varying alcohol content (e.g., ethanol and methanol) to assess the impact of alcohol fuels on emissions from GDI engines. Some vehicles will be equipped with GPFs in order to determine their efficiency in reducing emissions from GDI engines.

The focus of this project is to obtain detailed information about particulate and particle emissions from GDI technologies; along with gaseous emissions, fuel economy and efficiency will be quantified.
The impact of alcohol fuels and GPFs on PM, particle number (PN), and BC emission rates will be measured. Also, the SOA formation potential of different vehicle fuel and technology combinations will be assessed.

Canada's Task-Sharing Contribution
Experiments will be carried out at the Emissions Research and Measurement Section of Environment and Climate Change Canada. A light-duty GDI vehicle will be tested on a chassis dynamometer with low-level ethanol blends. The drive cycle used will be the Federal Test Procedure (FTP) with cold start at 25°C, −7°C, and −18°C. The US06 cycle will also be conducted at 25°C. Additional tests will be conducted with the GDI vehicle equipped with a GPF.

Along with fuel economy and criteria air contaminants, detailed characterization of PM and particle emissions will be undertaken. This characterization will include gravimetric PM, organic and elemental carbon, PN per mile, and particle size distribution.

Chile's Task-Sharing Contribution
Chile's contribution will be led by the Centro Mario Molina (CMMCh). Experiments will be carried out at the Center for Vehicle Control and Certification (3CV) laboratory and photochemical chamber at the Ministry for Transport and Telecommunication (MTT). Chassis dynamometer tests will be conducted with light-duty vehicles using the New European Driving Cycle (NEDC) and FTP test cycle, with varying blends of ethanol fuel (E0, E10, and E85). In addition to measurements of nitrogen oxides (NO_x) and nonmethane hydrocarbons (NMHCs), particle chemical composition and PN size distribution will be quantified for ultraviolet irradiation-aged emissions. Determinations of SOA formation potential for each vehicle fuel combination will be made. A light-duty diesel vehicle will also be tested for comparative purposes.

Germany's Task-Sharing Contribution
The addition of the German studies conducted at institutes of engineering thermodynamics (LTT, FAU Erlangen-Nürnberg) will allow for fundamental investigations of soot formation in an optically accessible GDI engine using laser-based diagnostics. Further characterizations of PM are conducted in the exhaust gas duct of a metal GDI engine potentially equipped with a GPF. Different ethanol-gasoline mixtures (e.g., E10, E20)

and other model fuel-mixtures (including ISO-octane and toluene) as well as butanol mixtures (B10, B20) are studied in a wide range of operating points.

Israel's Task-Sharing Contribution

Emissions tests will be conducted with GDI vehicles fueled with methanol gasoline and ethanol gasoline fuel mixtures (M56, E85, M15, E10, and M30). Emission testing will be performed according to NEDC and US06 cycles. Emissions characterization will include NO_x, HC, carbon monoxide, PM, PN, and formaldehyde. The test vehicles will include both GDI and PFI engines.

United States' Task-Sharing Contribution

This contribution will be provided by Argonne National Laboratory's Center for Transportation Research, Advanced Powertrain Research Facility. Tasks will include chassis dynamometer tests of two vehicles of the same model types: one vehicle with a GDI engine powertrain with a GPF and one vehicle with a GDI engine powertrain without a GPF. The test protocol will include an FTP with cold start and the NEDC with hot start at 22°C ambient temperature. Detailed characterization of PM will include transient soot mass, particle size distributions, primary total solid PN, and emissions of heavy hydrocarbons known to have high SOA potential.

Main Conclusions

Experimental work has just started. This Annex will result in the following:

- Comparative emissions rates of PM and particles from GDI test vehicles operated under varying conditions with different blends of alcohol fuels;
- Reports of criteria air contaminant emissions, along with fuel consumption; and
- For a select set of vehicle tests, provision of comparative information on the SOA forming potential.

The overall outcome will focus on the impacts of alcohol fuels and exhaust emission controls on PM, particles, BC, and the SOA forming potential from GDI and comparable technology vehicles.

Publications

Annex 54 work will result in a Final Report, "GDI Engines and Alcohol Fuel."