IEA-Advanced Motor Fuels
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Annex 51

Technology Collaboration Programme
by iea

Annex 51: Methane Emission Control

Project Duration	May 2013 - December 2018
Participants **Task Sharing** **Cost Sharing**	Denmark, Finland, Japan (LEVO), Korea, Sweden, Switzerland
Total Budget	To be determined
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Purpose, Objectives, and Key Question

The use of methane (natural gas, biogas) for transport will increase. Although diesel dual fuel (DDF) technology could bring the efficiency of gas engines close to the efficiency of diesel engines, Annex 39 (2010-2014) clearly demonstrated that methane slip remains a serious problem for current DDF engines. Alternatively, advanced spark ignition (SI) technologies (e.g., variable valve trains, cylinder deactivation, and high-level exhaust gas recirculation) could be applied to increase engine efficiency. However, methane catalysts would still be needed because of the unsatisfactory performance and durability of current methane catalysts.

Annex 51 is based on the experience of Annex 39, with the goal of improving engine-out methane emissions, methane catalyst efficiency, and methane emissions from other parts of the vehicle. The annex will also continue to follow up on any information about methane heavy-duty vehicle (HDV) fleets, thus adding to the data already available.

Combustion engines for vehicles can be replaced by or converted to liquefied natural gas (LNG) operation. This conversion has benefits in terms of emissions of CO_2, nitrogen oxides (NO_x), and particulates. Reductions in CO_2 occur partly because the ratio between carbon and hydrogen is less for natural gas than for liquid hydrocarbons (e.g., diesel, gasoline), and partly because the LNG engines can be more efficient than the traditional ones, depending on the combustion principle chosen. With regard to GHG effects, it is a disadvantage that LNG engines emit significantly larger quantities of unburned methane than do traditional engines. Because methane is a GHG 20 times more powerful than CO_2, the overall result could easily be an increase in GHG emissions from vehicles if their engines were converted to run on LNG.

Researchers have considerable experience in studying unburned hydrocarbons in automobile engines. This experience has motivated them to develop engines that emit very low levels of hydrocarbons. Methane, however, is a particularly stable hydrocarbon and is not converted as efficiently as are the other hydrocarbons in combustion engines. At the higher temperatures that occur during the main combustion, the methane is burned as completely as the other hydrocarbons. In colder areas near walls and in crevices, however, some unburned hydrocarbons escape the main combustion. These hydrocarbons are normally post-oxidized in the hot combustion gas, but methane molecules are too stable to be converted at these lower temperatures. This stability also causes problems with regard to converting methane in after-treatment systems like three-way catalytic converters. The onboard storage system for methane (either compressed or liquefied) can also be a source of vehicle methane emissions.

Activities

This annex is comprised of six work packages (WPs).

WP 1: Application of Natural Gas in Combustion Engines

An overview of the application of natural gas in combustion engines for transportation purposes will be given. The project will focus on road and marine transportation, since these are the transport sectors in which the idea of implementing methane in the form of natural gas or biogas dominates.

WP 2: Fundamental Investigations of Methane Combustion

The project will be carried out partly as a theoretical study of the fundamental physical and chemical processes that occur in a natural gas engine. Mathematical models of the processes will be formulated to describe the phenomena that occur during the conversion of the fuel in the engine. The models will describe the influence of the combustion principle (SI or dual-fuel), the combustion chamber geometry, and the application of mixed fuels. For example, mixtures of natural gas and a smaller amount of hydrogen make it possible to reduce unburned methane emissions because the hydrogen promotes the combustion of methane. Methanol/dimethyl ether is another fuel option to promote methane conversion. The models will be verified in experiments in which the relevant engine parameters will be varied.

The unburned methane from engines can be reduced by after-treatment in a catalytic converter in the exhaust pipe. However, it is still difficult to convert the methane at the temperatures that are available. Studies of the most suitable catalyst materials and systems will be carried out, as will studies of the conversion of methane at different concentrations, temperatures, and pressures.

WP 3: Methane Emissions from Parts of the Vehicle Other Than the Engine and Exhaust System
Compared with liquid fuels like diesel, gaseous fuels are more likely to escape from the vehicle. During refueling, the connection and disconnection of the dispensing nozzle could result in small amounts of methane escaping to the ambient air. When both liquefied and compressed methane fuel are being stored, they could be vented to the atmosphere to avoid overpressurization. High-pressure fuel lines and joints could also be a source of leakage that needs to be investigated. The purpose of this project is to study the possibility of methane emissions from parts of the vehicle other than the engine or exhaust system.

WP 4: Natural Gas Application in Light-Duty Vehicles (LDVs)
An overview of the knowledge about unburned methane from today's LDV engines will be given. The study will reveal the available data that can be used for verifying the models developed in WP 2. Furthermore, the study will focus on both the present technologies that are available and any policies or future plans for using methane-containing fuels in these vehicles.

WP 5: Natural Gas Application in Heavy-Duty Vehicles
An overview of the knowledge about unburned methane from today's HDV engines will be given. The study will reveal the available data that can be used for verifying the models developed in WP 2. Furthermore, the study will focus on both the present technologies that are available and any policies or future plans for using methane-containing fuels in these vehicles.

WP 6: Natural Gas Application in Marine Engines
An overview of the knowledge about unburned methane from today's marine engines will be given. The study will reveal the available data that can be used for verifying the models developed in WP 2. Furthermore, the study will focus on both the present technologies that are available and any policies or future plans for using methane-containing fuels in the marine sector.

Main Conclusions

Project results will not only enhance our current understanding of why vehicles emit high levels of unburned methane, but also facilitate determining the best means of reducing these emissions.