Title: Metrology for fuel injection of biodiesel blends

Abstract

The use of biodiesel as a road transport fuel is one of the tools for the EU member states to meet the requirement in the Renewable Energy Directive 2009/28/EC for a 10 % share of renewables in transport fuel by 2020. However, it is currently unknown how the long term use of biodiesel blends would affect modern diesel engines, which can be affected by solid deposits that form inside the small (80 µm) spray holes used in diesel fuel injectors. Engine manufacturers and designers require reliable metrological methods, with ensured traceability, for the characterisation of biodiesel and the deposits that result from its combustion. Understanding the influence of injector deposits on spray behaviour will accelerate the development and use of advanced biofuels and the design of new more efficient diesel engines.

Keywords

Biodiesel, fuel, physical properties, fuel injection, ignition temperature, nozzle characterisation, tactile topographical measurement, atomisation, breakup, injector deposits, microprobe

Background to the Metrological Challenges

The use of biodiesel blends in fuel injected diesel engines is important because it is a sustainable alternative to using fossil fuels with attractive environmental benefits such as reduced greenhouse gas emissions. However, modern diesel injectors, with reduced nozzle hole diameters, are less resistant to injector deposit formation and injector nozzle coking. Therefore, the long term effects of using biodiesel should be investigated and this requires higher quality measurements. This research is expected to benefit engine manufacturers and designers by providing reliable metrological methods, with ensured traceability, for the characterisation of biodiesel and the deposits that result from its combustion. In the longer term this is expected to lead to i) models to predict deposit formation, ii) new injector designs and iii) additives to prevent the formation of deposits. Stakeholders would benefit by using the developed metrology equipment for final product quality validation and this would help to lower production costs. Standards bodies could also benefit from this work through a coordinated development of CEN specifications on both standard reference fuels and new engine technologies. Similarly, CEN / TC 305 'WG1: Test methods for determining the flammability characteristics of substances' is expected to benefit from a reference measurement method to determine the ignition temperature of blends of biofuels at elevated pressures with traceable uncertainty and repeatability.

The formation of nozzle deposits is influenced by the physical and chemical properties of the fuel. At the moment these deposits have to be studied using a special non-engine injector deposit formation test rig. However, the development of high precision 3D tactile microprobes would allow the traceable measurement of the Young's modulus as well as the thickness of deposit layers in injection nozzle holes which would enable a systematic investigation of the formation of deposit layers in real motors instead of in test rigs. These non-destructive measurements would for the first time allow running on successive load cycles and measurements in between. It may soon also become possible to detect the thickness of deposit layers and to implement tribology functions. Scratching measurements would give valuable information concerning the adhesion of deposit layers and their thickness. Electron microscopy and electron energy loss spectroscopy could also be used to reveal images of the deposits and to determine the species in the deposits. Additionally, electrospray ionisation mass spectrometry could be used to identify fragments of organic molecules.

The liquid properties of blends of biodiesel such as their viscosity, surface tension and density, which are measured using reference methods, affect the initial breakup of the liquid jet, spray development and liquid-gas mixing. Importantly, the influence of injector deposits, and the manufacturing tolerances of the nozzle diameter, should be investigated. It is already known that the initial breakup of a high-speed liquid jet when discharged into stagnant dense air is related to velocity fluctuations inside the nozzle, and turbulence and the collapse of cavitation bubbles are strongly influenced by these nozzle deposits and geometries. The use of optical measurements has so far been limited by light scattering effects, but structured illumination techniques and dual structured laser illumination planar imaging (SLIPI) have shown some promise, especially the latter, for validating numerical models. For these reasons, such numerical simulations are challenging, but methods have been proposed to couple liquid jets to spray simulations. The inclusion of in-nozzle flows in 3D time-dependent simulations would also be of great benefit. Pulsating injection may be one solution for improving liquid gas-mixing through inter-pulse collisions and large turbulent structures.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement and characterisation of fuel injection of biodiesel blends.

The specific objectives are

1. To characterise selected reference fuels representing carefully chosen blends of biodiesel for use as future fuel options. The fuels' composition and their chemical and physical parameters should be determined with the smallest possible measurement uncertainties e.g. the caloric value with an uncertainty of about 0.6 % or the viscosity with an uncertainty of about 1 %. Measurement capabilities should be developed to determine traceable data at elevated temperatures and pressures. This objective should be undertaken in close cooperation with CEN and ISO to support the development of new standards.
2. To develop and validate traceable measurement capabilities in the field of precision measurements. This should include the development of a vibrating microprobe for use in the measurement of injector characteristics with nanometre uncertainty and repeatability. These new capabilities should be used to characterise the layer thickness of injector deposits that occur when the selected reference fuels are injected.
3. To develop measurement capabilities for determining the composition and temporal evolution of injector deposits with a nozzle tip temperature of up to 350 °C and with an injection pressure of up to 2000 bar.
4. To characterise the influence of injector deposits, and the manufacturing tolerances of the nozzle diameter, on the atomisation and breakup of biodiesel. The most significant characteristic spray parameters should be determined.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories), standards developing organisations (CEN, ISO) and end users (automotive industry).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art, and explain how their proposed research goes beyond this.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.0 M€, and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 35 % of the total EU Contribution to the project.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the "end user" community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the automotive sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.