DME as an alternative fuel for Compression-Ignition Engines

A race against time

A collaborative research project coordinated by FVV investigated whether synthetic fuels based on methyl ether are suitable as a replacement for diesel. Within the scope of the "Neue Fahrzeug- und Systemtechnologien / New Vehicle and System Technologies" specialist programme of the German Federal Ministry for Economic Affairs and Energy (BMWi), the research project on renewable oxygenated fuels received €3.5 million of funding. The result was that, if the right molecule is selected, there is a considerable decrease in CO_2 emissions and pollutants. We discussed this with Dr Werner Willems, a specialist at the Ford Research and Innovation Center Aachen.

Text: Johannes Winterhagen | Pictures: Charles Yunck

You are an engine developer – why are you involved in fuel research?

Willems: When we started the preliminary work for the XME project, I was still developing combustion processes for diesel engines. The main objective here was to make compression-ignition engines even cleaner and more efficient. Having achieved a lot in terms of combustion and exhaust gas aftertreatment, we were faced with a couple of questions: How can pollutants be reduced even more significantly? And what role does the fuel play in this?

So the possibility of producing fuels synthetically and therefore virtually CO_2-neutrally was not actually the focus at the outset?

Willems: From the very beginning, we knew that up to 10% less CO_2 is produced when DME – the simplest methyl ether – is burned than when fossil fuels are used. Therefore, our requirement was to reduce emissions of both pollutants and CO_2.

You investigated two different methyl ethers in the FVV project: DME and the oxymethylene ether OME-1. Based on everything you have learned, which fuel would you choose?

Willems: I would choose DME, for a variety of reasons. Firstly, OME fuels produce more CO_2 during combustion as the chain length of the molecule increases. Although this would be unimportant for synthetic production with a closed CO_2 cycle, for the foreseeable future the automotive industry will have to deal with CO_2 legislation that solely relates to vehicle emissions. Secondly, DME is already being produced in great quantities, such as for the cosmetics industry and as a component of refrigerants. The advantage of this is that there are already international standards for this material. This is important because, in the development of climate-friendly powertrain and drive systems, we are in a race against time.

Dr. Werner Willems driving the test vehicle - a modified Ford Mondeo

Neither DME nor OME can simply be poured into the tank of a normal diesel vehicle, however. What are the greatest challenges facing engine developers?

Willems: First of all, of course, the higher aggressiveness towards plastics, and towards elastomers in particular, needs to be taken into account. Similarly to when ethanol is used, all fuel-carrying components must therefore be suitable. This is no problem if the correct materials are chosen. The lubrication properties are more of a challenge. DME and the OME-1 we investigated are relatively short-chained molecules with poor lubrication properties. This has an effect on the injection system, for example. We used an oil-lubricated system from Denso in the project – and it worked well with DME.

DME as an alternative fuel for Compression-Ignition Engines
A race against time

Above all, however, you need a higher throughput due to the lower calorific value of the fuels…
Willems: That's right. If you want to achieve the same performance as a diesel engine, you need to adapt the injector nozzles, among other things. The rail pressure must also be reduced – 1,000 bar is the maximum for a DME system. But as this represents the same performance as a 2,000-bar diesel system, it is not a problem.

You have conducted tests on injection test benches, single-cylinder engines, complete engines and in the vehicle – did you achieve the result you were hoping for?
Willems: We were able to confirm the emission benefits we were hoping for, even at full load. One reason for this is carburation: when DME is used, a clear separation between injection and combustion can be observed, so that no localised rich zones are formed. The higher oxygen content in the fuel also plays a role, of course, as it results in more complete combustion.

Unlike in many other FVV projects, you also performed vehicle tests with DME. What motivated you to do this?
Willems: We wanted to see how an engine run with DME can be used in a car. As far as I am aware, this has only previously been done with a truck engine.

In terms of driving experience, the test vehicle - a Ford Mondeo with a 1.5-litre diesel engine - does not sound any different from a normal diesel vehicle.

DME is a liquid gas with a vapour pressure curve comparable to LPG. Therefore LPG-like tanks and components can be used for fuel supply.

And? How does the modified Ford Mondeo drive?
Willems: VIn terms of the overall driving experience, our test vehicle is no different from a normal diesel vehicle and even sounds the same. The only difference you notice as a driver concerns the tank system, which is based on a retrofitted LPG system.

What is the range of a vehicle with this tank?
Willems: The additional tank has a volume of around 60 litres, which would be enough for 500 to 600 kilometres.

During the course of the experimental investigations, you also conducted tests with diesel on the DME-calibrated engine. Why?
Willems: DME is currently not available at any public petrol station. Even if it did go into mass production, it would not be available across the board from the beginning. Our motivation was therefore to simulate possible emergency operation with diesel fuel. Normally, you would expect the engine to produce large amounts of soot due to the larger diameter of the holes in the injector nozzles. By making an adaptation, however, we were able to significantly reduce particulate emissions – so it would be adequate for emergency operation at least.

DME as an alternative fuel for Compression-Ignition Engines
A race against time

According to the final report, even a vehicle run on DME would still need a particulate filter.
Willems: Yes. Although the particle mass when DME is used is almost zero, it is not zero – even though the number of particles is better than when using diesel. This is mainly a result of oil entering the combustion chamber. However, the intervals for the regeneration of the particulate filter are far longer.

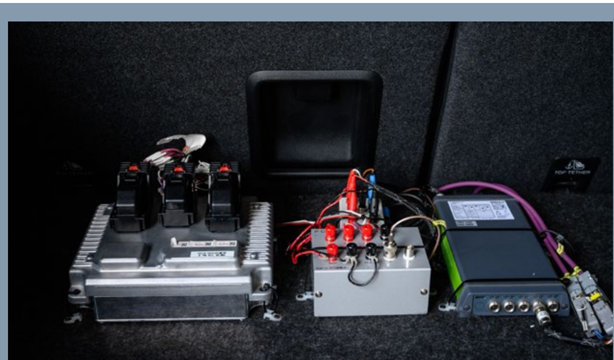
But DME is not suitable as a gaseous fuel for admixing with normal diesel, is it?
Willems: Until a few months ago, I would have agreed with you. But recent developments show that it may be possible to mix DME and diesel after all – resulting in a kind of sparkling liquid. We are currently preparing a new research project on this subject. A blend like this could be made widely available more quickly, and users could also benefit from the superior lubrication properties of diesel. We may even be able to use the conventional diesel injection system, saving much of the effort and expense associated with retrofitting.

Until now, the DME used for industrial purposes has been produced on the basis of fossils. What could a CO_2-neutral production chain look like?
Willems: One European project investigated the process for manufacturing DME from black liquor, a waste product from the paper industry. This saves up to 96% of the CO_2 emissions across the entire lifecycle. However, it is unlikely to be sufficient for larger quantities; synthetic processes based on power-to-X are needed for this. This is an advantage for DME, however, as it is produced from methanol. In turn, methanol can be produced from solar or wind energy in many parts of the world, transported to Central Europe by ship and processed here – using plant engineering that already exists today. We would then have large quantities of a synthetic fuel available immediately.

If the European standardisation of DME as a fuel and everything else go to plan, how soon could compatible vehicles enter mass production?
Willems: Alongside the standardisation of the fuel, the type approval procedure for the vehicles plays a major role. There is certainly a long process ahead of us. And, of course, sufficient capacity needs to be put in place for the sustainable production of methanol. But if everything goes well, the first series or retrofitted vehicles running on DME fuel could be on the road in the second half of the 2020s.

How did you find the collaboration on the XME project at FVV?
Willems: To a certain extent we were lucky, as we had the right project at the right time. However, the main reason we were able to deliver such good results is because the project was supported from all sides and everyone who worked on it was highly motivated.

The 1.5 l diesel engine had to be adapted for the DME injection components.



The DME injection system is operated by a control unit in the trunk. Engine and injection control communicate with each other via a specific CAN interface.

DME as an alternative fuel for Compression-Ignition Engines
A race against time

About | Dr.-Ing. Werner Willems (Ford Research and Innovation Center)

Dr.-Ing. Werner Willems studied and earned his doctorate at RWTH Aachen University, before starting his professional career at FEV Motorentechnik. He joined Ford in 1999, where he was responsible for fields including combustion process development for European diesel engines. Since last year, the specialist at the Ford Research and Innovation Center in Aachen has been solely working on sustainable fuels.

What is the potential of oxygenated methyl ether-based synthetic fuels for replacing fossil-based diesel in an auto-igniting combustion process? In the "XME Diesel" research project supported by FVV, which is funded as part of the "Neue Fahrzeug- und Systemtechnologien" [New Vehicle and System Technologies] specialist programme of the German Federal Ministry for Economic Affairs and Energy (BMWi), research institutes at RWTH Aachen University and the Technical University of Munich investigated the suitability of DME (dimethyl ether) and OME-1 (mono-oxymethylene ether) in collaboration with Denso, Ford and IAV. The main goal of the project was to adapt the combustion process to the physical and chemical properties of the new fuels in such a way that raw pollutant emissions are reduced significantly while the efficiency of the engine improves.

FVV | A race against time

Research Association for Combustion Engines (FVV) eV
Lyoner Strasse 18
60528 Frankfurt / M., Germany
T +49 69 6603 1876
F +49 69 6603 2876
smieja@fvv-net.de

→ www.primemovers.de/en | Experience