WESTPORT FUEL SYSTEMS

A recent test of a Westport Fuel Systems hydrogen fuel injection system in Älmhult.

Progress with hydrogen as fuel for engines: "Extremely significant improvement"

Both Volvo and Scania are investing in combustion engines powered by hydrogen. Fuel system manufacturer Westport claims significant progress in their own tests. "For already super-efficient diesel engines, this is an extremely significant improvement," says Ulf Lundqvist, Director Business Development

Developing combustion engines is a painstaking process. The product has been refined for so long that major leaps are no longer taken. An annual reduction in fuel consumption of half to one percent is considered successful.

In addition to electrification with batteries and fuel cells, hydrogen-powered engines are a technology path that both Volvo and Scania are pursuing to reduce emissions from their trucks. Now, fuel system manufacturer Westport Fuel Systems claims that the company has made significant advancements in the technology.

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Ulf Lundqvist.

– I have spent my life with engines, but I have not seen a development step like this, says Ulf Lundqvist, Director Business Development for Heavy Vehicles at Westport Fuel Systems, to Ny Teknik.

In their own tests, they have managed to achieve a 51.5 percent thermal efficiency with a 13-liter Scania CBE1 engine running on hydrogen. The same engine achieves 50 percent efficiency with diesel fuel, which means that hydrogen provides a 3 percent improvement.

– Generally, we achieve a 3–5 percent efficiency improvement relative to the diesel baseline engine. For already super-efficient diesel engines, this is an extremely significant improvement, says Ulf Lundqvist.

One reason for this is that 24 percent more energy is released when hydrogen is burned compared to diesel, assuming the same amount of air is used. Additionally, since the fuel is injected at the top dead center of the piston (when the piston is at its highest point in the cylinder), the compressed hydrogen also helps push the piston downward in the cylinder. So, the engine harnesses some of the work that was done when the fuel was compressed by the fuel supplier.

Westport describes this solution as an effective and economical way to reduce the carbon footprint for businesses involved in heavy road transportation. The hope is that truck manufacturers, who have already invested large sums in combustion engines, will want to continue investing in the technology with the help of Westport's hydrogen injection system.

Westport calls the injection system H_2 HPDI (High Pressure Direct Injection). It provides 20 percent more power and 15 percent more torque compared to using diesel. The reason for the improved performance is that power and torque in a compression engine are limited by the maximum cylinder pressure and exhaust temperature.

Hydrogen releases more energy during combustion, allowing for lower charging pressure, which lowers cylinder pressure. Furthermore, compressed hydrogen is cold and has 2.5 times greater cooling effect than diesel. This results in exhaust temperatures being 50–100 degrees Celsius lower than with diesel, including the vaporization effect. The compressed hydrogen's properties are simply leveraged to optimize the combustion process.

The technology can be used in a conventional compression engine (typically powered by diesel) with some adjustments. A special injection nozzle is required, which is the same as those used for natural gas engines. The nozzle has two concentric needles. One flows hydrogen fuel, and the other flows a pilot liquid fuel consisting of diesel or HVO (Hydrogenated Vegetable Oil). The energy in the pilot liquid fuel accounts for only a small percentage of the total energy supply but is necessary to ignite the hydrogen and lubricate the system.

– You can reuse the diesel engine as it is and only change the fuel system. That's what truck manufacturers like, says Ulf Lundqvist.

He adds that hydrogen in a gasoline engine (typically powered by gasoline) is a much more complicated matter. The premixed air-fuel mixture required for gasoline engines can lead to leakage into the crankcase, posing a risk of explosions. Additionally, a lot of water is formed in the crankcase.

– With a gasoline engine, forced ventilation is required to make it work, says Ulf Lundqvist.

Nevertheless, some additional equipment is required for the hydrogen technology to function in a compression engine. Hydrogen is stored in tanks at an initial pressure of 700 bars. The injection system operates at just over 300 bars. As hydrogen is consumed, the pressure in the tanks will decrease and reach 300 bars.

At the transition point, a compressor is required. However, the compressor is actually engaged before the pressure drops to 300 bars, for optimization reasons, explains Ulf Lundqvist. The power needed to drive the compressor is shown as the blue curve in the diagram below.

As the diagram also shows, the system with 80 kg of

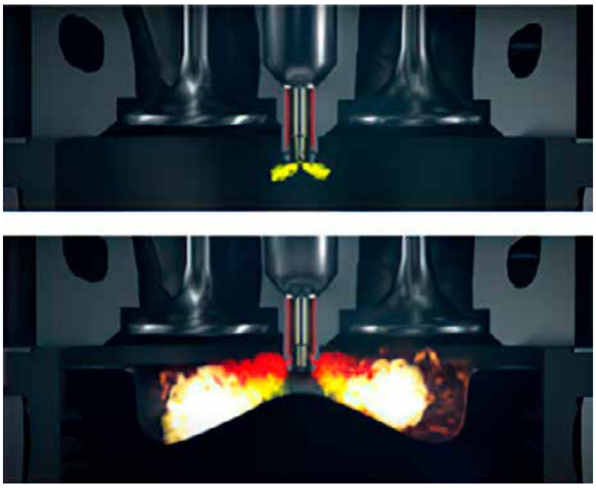

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Image depicting the ignition process in the cylinder.

hydrogen has a range of about 950 km during simulated driving on moderately hilly roads with a 20-ton load. This corresponds to the work that can be performed with 270 litres of diesel.

– If you complete the entire cycle, it means a two percent loss due to the compressor, despite that, the hydrogen system has a higher efficiency than diesel. Most drivers also do not drive the full range but refuel after two-thirds to have a buffer against an empty tank, which will further minimize compressor losses, says Ulf Lundqvist.

Hydrogen engines will be compared to alternative technologies such as batteries and fuel cells. Compared to batteries, the efficiency is considerably lower, and the fuel is more expensive, but the range is much better. One advantage is that hydrogen can be produced when electricity is cheap, which is expected to become increasingly important as the share of wind and solar power increases.

Compared to fuel cells, the range is similar, and the fuel cost is roughly the same. However, according to Westport, cooling fuel cells (with relatively low operating temperatures) is more challenging to solve than for a combustion engine, where most of the heat disappears with the exhaust gases. This can make fuel cells more difficult to use in hot climates, for example.

The downside of hydrogen engines is that they still emit hazardous nitrogen oxides, NOx. The pilot flame also results in a smaller amount of particles and carbon dioxide being produced.

According to Westport, a hydrogen engine with the company's technology emits approximately 6–12 grams of NOx per kilowatt-hour before aftertreatment. Through cooled exhaust gas recirculation (EGR), emissions can be reduced to 3 g/kWh. After exhaust gas treatment, the levels are slightly less than a tenth of a gram of NOx per kWh, and the small amount of particles is filtered out, according to Westport.

Together with Scania, the company believes that the engine will meet the upcoming Euro7 requirements for Europe and EPA27 requirements for the USA. It will also meet the future criteria for zero-emission vehicles, like battery and fuel cell trucks according to the Commission's latest proposal, according to Ulf Lundqvist.

One general drawback of hydrogen is that it can lead to so-called hydrogen embrittlement of metals. Westport's system is validated for natural gas but not yet for hydrogen.

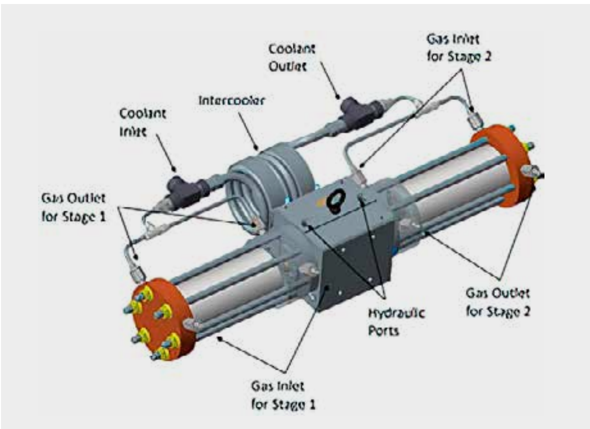
– So far, we have not seen any problems. An interesting aspect is that you keep the hydrogen in the fuel system, and it burns as soon as you inject it into the cylinder. So, the engine components never come into contact with the hydrogen. The pilot flame also contributes a small amount of hydrocarbons that lubricate and form a film, preventing embrittlement, says Ulf Lundqvist.

Öivind Andersson, a professor at Lund University, believes that Westport's performance figures seem reasonable. He is not aware of any other company developing injection systems based on pilot injection ignition for hydrogen, like Westport.

JOHAN PERSSON

Öivind Andersson.

– Previous hydrogen engines have been knock-limited because they used an otto cycle. With HPDI technology, the fuel is injected near the top dead center and burns somewhat like in a diesel engine, eliminating the risk of knocking and the engine damage that can result from it. So, you can use the same compression ratio as in a diesel engine, which provides similar efficiency, Öivind Andersson writes in an email to Ny Teknik.



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Westport's compressor.

Marcus Lundgren, a researcher at LTH, has seen articles describing similar injection nozzles, but in the context of maritime applications.

– The advantage of HPDI is that the pilot fuel introduces multiple ignition points for hydrogen, whereas the spark plug only contributes one. By removing the spark plug, you also eliminate a source of spontaneous ignition, that is knocking, as the spark plug heats up over time. This, in turn, allows for higher compression, says Marcus Lundgren.

The disadvantage is that the pilot fuel introduces a small amount of carbon that is noticeable in the exhaust, which is not the case when a gasoline engine with spark plugs is used, he adds.

Öivind Andersson emphasizes that fuel cells have advantages over hydrogen engines, especially regarding nitrogen oxide emissions, but it is not a guarantee that fuel cells will ultimately win.

– If it turns out that hydrogen engines practically have better efficiency than fuel cell vehicles, they will gain a larger market share simply due to lower operating costs and more robust technology, says Öivind Andersson.

An unmarked Volvo truck equipped with H2 HPDI from Westport Fuel Systems was recently showcased in Älmhult, Sweden, where Ikea has a large warehouse.

When asked when Westport plans to start series production of the hydrogen technology, Ulf Lundqvist says they are ready to start tomorrow – but it depends on the truck manufacturers. Volvo has had the technology in production since 2018, but for liquefied natural gas vehicles.

– It's no secret that we are working with Scania and Volvo. Other manufacturers are showing interest, but it's not something I can talk about. You might think it's just a matter of getting started, but as with all engine projects, it usually takes three to five years before production can be ramped up. We hope to be able to create demo fleets with selected customers. The system can also be retrofitted in theory, but that's not our primary focus, Ulf Lundqvist says.

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