November 2022| Volume 01 | Issue 03 | Pages 01-02

Future Publishing LLC

Journal homepage: https://fupubco.com/futech

Future Technology

https://doi.org/10.55670/fpll.futech.1.3.1

Open Access Journal

ISSN 2832-0379

News & Views

Developments and scope for the use of hydrogen in future combustion engines

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With electrification still found wanting when it comes to heavier vehicles and modes of transportation, marine, rail and large commercial on- and off-highway applications are seen as the main applications where internal combustion engines (ICE) fed with non-fossil hydrocarbons and hydrogen (H_2) can play an important role. Hydrogen IC engines can provide a durable, reliable, and cost-efficient solution based on well-known existing technology, contributing to a fast transition towards carbon-free mobility. The following view provides a summary of the main roles (and a few challenges) associated with H_2ICE employment.

The current demands from propulsion technology developers are such that they require the highest possible CO_2 reduction, within very short time scales. In practice, climate measures have seen a shift towards rapid electrification in passengers and part of the commercial vehicle fleet. However, electrification is still lacking when it comes to heavier vehicles and modes of transportation. Marine, rail and large commercial on- and off-highway applications are seen as the main applications where internal combustion engines (ICE) fed with non-fossil hydrocarbons and hydrogen (H_2) can play an important role [1]. The universal applicability of hydrogen for modern energy needs has boosted significant development of renewable hydrogen production and investment in many countries. In transportation, hydrogen has the capacity to address some of the key emission reduction challenges when combined with ICE technologies, since there are few other near-zero emission energy carriers (i.e., electricity and advanced biofuels) [2]. The H_2-fuelled ICE (H_2ICE) is the only alternative with no tank-to-wheel CO_2 emissions at the tailpipe (along with IC engines fed with ammonia, however, these are more suitable for ship applications). H_2ICEs generate power through the combustion of hydrogen and use fuel pumping and injection systems that are modified versions of those to be found in gasoline engines. Except for the combustion of small amounts of engine oil (same as with gasoline engines), hydrogen engines emit no CO_2 when in use. H_2ICEs emit water or water vapor as a by-product, but today's hydrogen fuel production is not a carbon-free emission process. However, even with inefficient and the least green processes available hydrogen can cut CO_2 emissions by more than 30%, compared with gasoline. A hydrogen internal combustion engine vehicle (HICEV) is different from hydrogen fuel cell electrified vehicles (FCEVs), which use a fuel cell in which hydrogen reacts with oxygen in the air, in a chemical process to produce electricity in order to power an electric motor (the part that provides rotational motion to the vehicle's wheels). The key difference between HICEVs and FCEVs lies in the way hydrogen is utilized. In H_2ICE-power vehicles (HICEVs) hydrogen is combusted, while in FCEVs an electrochemical reaction takes place that uses liquid hydrogen to generate power for its electric motor. In contrast to the use of hydrogen in fuel cells, H_2ICEs can be fuelled with non-purified hydrogen, resulting in a significantly lower production cost of hydrogen fuel. H_2ICEs can take advantage of existing advanced combustion and engine control technologies (e.g., direct injection, Miller cycle, lean/diluted combustion, pre-chamber ignition, etc). Thus, the thermodynamic efficiency of direct injection H_2ICEs can be similar to the overall efficiency of the fuel cell powertrain. In addition, H_2ICEs are attractive because they can take advantage of current advanced ICE features such as reliability and durability, existing supply chains, existing manufacturing and recycling infrastructure, and affordability. Furthermore, H_2ICE technology can be less expensive than the current state of technology for Electric Vehicle (EV) powertrains, due to its low dependence on expensive materials such as rare earth metals. In addition, H_2ICEs can contribute to job security and sustainability of industrial and employability growth as they utilise the same production facilities and follow the same manufacturing processes as conventional ICEs [3]. On the debit side, main issues with the fielding of hydrogen include the availability and production of H_2 and its safe storage at the user end. These factors involve economic considerations that require balancing against the costs to society, associated with the potential reduction of carbon emissions from existing hydrocarbon fuels. In terms of H_2ICE operation, NO_x can be generated due to traces of particulates resulting from the combustion of elements of lubricating oil. These can be alleviated entirely by the suitable choice of lubricating oil, lean mixture, and a suitable choice of after-treatment system [4]. In addition, hydrogen can be produced from diverse resources such as steam methane reforming, coal gasification, and electrolysis. Depending on the method, the efficiency of hydrogen production can be very high and the production costs relatively low but with high levels of CO_2 emission. Only solar and wind-driven production can allow zero-emissions hydrogen production at an increased cost, however. In the words of Dr. Fatih Birol of the International Energy Agency "Hydrogen is today enjoying unprecedented momentum. The world should not miss this unique chance to make hydrogen an important part of our clean and secure energy future." Overall, hydrogen IC engines will provide a durable, reliable, and cost-efficient solution based on well-known existing technology, contributing to a fast transition towards carbon-free mobility. The competitively low total cost of ownership, particularly in the heavy-duty sector, and the minimal dependence on low availability and high cost, make this solution appealing and convenient in several transportation application fields.

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