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High Efficiency Hydrogen Internal Combustion Engine

- Carbon Free Powertrain for Commercial Vehicles and Passenger Cars -

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In the global race to reduce CO_2 emissions, solutions for road traffic play a major role. Roughly one-fifth of Japan's entire CO_2 emissions are caused by road traffic. Governments and industry have set a focus on Battery Electric Vehicles (BEV) but a possible alternative to this are hydrogen fueled internal combustion engines. These powertrains can also be operated CO_2-free.

By using optimised combustion and exhaust aftertreatment, such engines can also be operated close to zero emissions ("zero impact"). Until now, conversions to hydrogen typically started from conventional approaches – for passenger cars from boosted direct injection gasoline engines, for commercial applications from swirl-based gas- or diesel engines.

In the future, powertrain systems with highest efficiency are needed – on the one hand to keep the energy requirement for hydrogen production on the lowest possible level, and on the other hand to increase the range of the hydrogen fueled vehicles. Because of the fact, that for passenger cars the future powertrain will be electrified, a specific layout of the hydrogen engine towards a Dedicated Hybrid Engine (DHE) is possible. For commercial vehicle powertrains, hybridization will have a significant lower market share, which means that efficiency increases can't use electrification to the same extent as in passenger cars.

This publication deals with the layout of hydrogen engines for passenger cars and commercial applications with highest efficiencies also for hybridized powertrains. By combining high compression ratio, Miller combustion system, direct hydrogen injection, lean operation and boosting, efficiencies comparable to the ones currently achieved by the best dedicated hybrid engines are feasible.

This paper also specifically introduces the further developments done on the AVL Hydrogen Engine, a 12.8l heavy duty technology demonstrator with internal and external mixture formation. In order to increase the BMEP capability and to deliver power for a conventional truck powertrain, specific optimizations were done to the engine and its ignition system. Stable combustion above 23 bar BMEP required addressing combustion irregularities by means of cooling system and gas exchange optimization. Also, the achievements in terms of pollutant control with focus on Euro VI emission will be addressed.

For passenger car applications, tumble based combustion systems as in conventional TGDI engines will serve as starting points. Injection strategy-wise Low Pressure (LP) H_2-DI appears to be the preferred route, as it not only helps mitigate the back-fire tendency of PFI, but also allows for reasonable tank utilization and thus, vehicle range. Injection components for H_2-DI are however still in their prototype state.

The much wider span of passenger car engine maps in terms of speed and load might impose a demand for combining different operation strategies throughout the map. The wide combustion range of hydrogen allows for high charge dilution rates. Pure lean operation at high excess air ratio boosts efficiency potential, but imposes high demand on the boosting systems and PFP capability when approaching higher engine output. Reducing air dilution in this area reduces boosting demand, but requires a combustion moderator (EGR, water) to mitigate irregular combustion tendency.

Fig.1 The AVL Hydrogen Engine

Depending on the combination of operation strategies, a stoichiometric (TWC) and/or lean (SCR) aftertreatment system will be required to properly control nitrogen oxide emissions with regard to the respective emission regulation an engine is targeted for.