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Zero-Emission, Maximum Performance - The Latest Generation of Hydrogen Combustion Engines

The development pathway that ultimately led to an innovative hydrogen combustion concept, bringing hydrogen engine powered vehicles back to the road

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The vehicle industry is challenged to develop technologies that can be easily and quickly integrated into existing engine platforms and make existing diesel or gasoline engines clean and at the same time more efficient. KEYOU shows how a highly efficient hydrogen engine can be developed with the help of lean combustion, intelligent engine strategy, and hydrogen-specific components, thus achieving the balancing act between economic efficiency, zero-emission, and maximum performance.

Establishing a new global standard for commercial powertrains by replacing gas and diesel with hydrogen is an enormous challenge. KEYOU's concept has been to rethink the internal combustion engine from the characteristics of hydrogen. Rather than start engine development from scratch, we have been able to take existing diesel and gas engines and repower them with hydrogen to achieve zero-emission with uncompromising performance: high power density, best efficiency, an attractive load response, and economics that match today's diesel. Since its foundation in 2015, KEYOU's team has steadily moved, year after year, toward that goal.

The innovated concept developed by KEYOU comprises four basic elements: (i) lean-burn combustion to avoid emissions and augment efficiency, (ii) optimized air-charging in order to maximize the utilization of the lower exhaust gas enthalpy and at the same time maximize air intake to produce more power (iii) an effective injection strategy to ensure maximum filling with homogeneous mixture formation, and (iv) high exhaust gas recirculation rates control with the goal of considerably decrease the maximum combustion temperature and in this way allow richer mixtures for increase power density without producing NOx emissions.

With the application of the right combustion concept, a conventional Diesel engine was converted into a hydrogen engine that meets today's customers' expectations with only minor adaptation effort. It was possible for KEYOU to achieve already promising performance figures in 2017, during the first stable run of the engine. The development of tailored components (fuel and air supply, ignition system, mechanical parts) together with the inclusion of several controls and software features qualified the engine for performance (stationary and dynamic) and reliability improvements. The use and optimization of exhaust gas recirculation played a pivotal role in this process. In 2020, the KEYOU hydrogen engine attained the stationary performance described in Table 1.

Table 1 - Stationary performance of KEYOU hydrogen engine.

Power density	27kW/L @ 2200 rpm
Maximum Torque	1,000Nm @ 1000-2000 rpm
Peak Break Efficiency	44.5%
NOx Raw Emissions	<0.09g/kWh in 80% of map

Resorting to the holistic and harmonized control of air supply, fuel supply, ignition timing and exhaust gas recirculation rate, it was possible to calibrate the engine dynamically. While running a world harmonized transient cycle (Fig. 1), the hydrogen engine performed as fast as a diesel engine in load response and, at the same time, with average NOx raw emissions of about 0,2 g/kWh, which is less than half of EURO 6 and J-PNLT imposed limits. Moreover, CO2 emissions stayed below 1g/kWh, meaning achieving the "zero-emission" vehicle label.

In 2022, KEYOU will begin testing a 18t truck and a 12m bus powered by the latest generation of hydrogen engines on public roads as demonstration vehicles, both based on major European manufacturer chassis (Fig. 2).

Hydrogen and hydrogen engines promise a solution to energy sourcing and climate-change challenges globally. KEYOU opens the market in Germany and Japan because both countries share an ambitious vision of the hydrogen economy. From there the technology will expand to other markets and multiple applications.

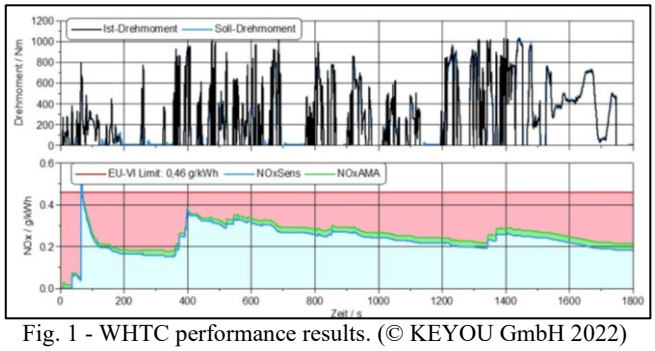

Fig. 1 - WHTC performance results. (© KEYOU GmbH 2022)

Fig. 2 - KEYOU bus & truck prototypes. (© KEYOU GmbH 2022)