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PRESSRELEASE

MAHLE range extender improves acceptance of electric drive systems

Stuttgart, September 2011 – In order to gain the acceptance of consumers, electric drive cars must offer satisfactory cruising range. The range extender developed by MAHLE Powertrain can help in this regard. The two-cylinder gasoline engine, with a displacement of 0.9 L, has a generator integrated in the crankcase that can recharge the discharged battery as needed.

The need to reduce local CO_2 emissions has led to growing interest in battery-powered electric vehicles. However, in addition to the high cost of batteries that are suitable for automotive applications, the low cruising range is currently the main disadvantage of this power train technology. Both disadvantages are compensated for by the range extender. In this drive concept, a small combustion engine is engaged as needed to charge the battery by means of a downstream generator. The battery can be much smaller and less expensive through the use of the range extender. The cruising range of the power train can be increased to an acceptable level at the same time.

MAHLE has developed the range extender completely on its own, and used the performance characteristics of a fictitious compact-class vehicle as a basis for comparison. This led to the following requirements for the design of the series production range extender concept:

- Cruising range should be at least 80 km in electric mode, without assistance from the combustion engine. This covers 70 percent of typical daily driving routes.
- Constant travel speed of 120 km/h and maximum top speed of 160 km/h should be reached.
- Starting, acceleration, and hill climbing performance comparable to or better than the reference vehicle should be reached.

MAHLE developed various concepts and evaluated their technical and commercial aspects. Various engine configurations, fuel types, and thermodynamic processes were investigated. The goals pursued included low production costs, low fuel consumption, and good NVH characteristics (Noise-Vibration-Harshness) for the engine. Driving comfort should not be impeded when the range extender is applied.

The optimal solution was found to be a two-cylinder inline four-cycle gasoline engine with rated power of 30 kW and 0.9 L displacement. The electrical generator is completely integrated in the crankcase of the engine. Combined with a 55 kW permanent magnet synchronous motor and a lithium-ion battery with 15 kWh capacity, all requirements for driving dynamics are reliably met.

Since the combustion engine has no mechanical connection to the wheels, new potential design and layout options are conceivable. The unit mainly runs under full load and has two main operating points. If battery charging is required, then the two-cylinder engine runs at 15 kW power output at the crankshaft. If the charge level of the battery is to be retained even at high speeds, then the engine runs at 30 kW power output at the crankshaft.

MAHLE has built a prototype of the range extender for proof of concept, and tested it extensively on an engine test bench. The engine achieved the target values, with a rated power of 30 kW at 4,000 rpm.

One exceptional feature of the MAHLE range extender engine is its compact dimensions. With a width of 416 mm, depth of 327 mm, and height of 481 mm, it is about the size of a carry-on bag for an airplane. With a mass of less than 70 kg (including the generator), it fits easily into the package and weight distribution concept of the automobile manufacturers. Another advantage is that the engine does not need to be installed in the conventional

manner. Any and all installation configurations are possible, from 0° (vertical) to 90° (horizontal).

Because the ignition points of the two-cylinder inline engine have been set at 0° and 180° crankshaft angle, no balance shaft is needed. The two valves on each cylinder are actuated indirectly by roller rocker arms and an overhead camshaft. This reduces the height of the engine block as well as friction in the valve train.

In order to optimally utilize the available installation space, MAHLE engineers also developed a compact intake system that is packed tightly against the engine. The intake system and the intake and exhaust geometries were designed using one-dimensional thermodynamic simulations. Together with three-dimensional FEM simulations, resonant vibration was effectively dampened, despite the short intake length.

MAHLE additionally conceived a numerical power train simulation model and employed it to evaluate various user profiles. These values were then compared to the emissions of the reference vehicle. In order to analyze the use of energy in actual driving operation, the operating and charging strategies of the battery also have to be considered. Worst-case scenarios with a dead battery were likewise investigated. All driving cycles and charging strategies generated lower CO_2 emissions values than the conventional reference drive system.

MAHLE Powertrain collaborated closely with various MAHLE business units to design the engine. For example, components such as the pistons, connecting rods, and bearings are original MAHLE products. The international network of MAHLE expertise is thus incorporated in the range extender.

The MAHLE Group is one of the 30 largest companies in the automotive supply industry worldwide. With its two business units Engine Systems and Components and Filtration and Engine Peripherals, MAHLE ranks among the top three systems suppliers worldwide for piston systems, cylinder components, as well as valve train, air management, and liquid management systems. The Industry business unit bundles the MAHLE Group's industrial activities. These include the areas of large engines, industrial filtration, as well as cooling and air-conditioning systems. The Aftermarket business unit serves the independent spare parts market with MAHLE products in OE quality. In 2010, the MAHLE Group achieved sales of approximately EUR 5.3 billion (USD 7 billion); more than 47,000 employees work at over 100 production plants and eight research and development centers.

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