Novel High-Tech Steam Engine system for automotive applications

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During the 60's a growing concern about air pollution from cars ends up with an interest in steam engines for cars due to the inherent advantageous qualities to offer low exhaust gas emissions. The external and low temperature combustion gives favourable combustion conditions and very low exhaust gas emissions. However, the modern steam engine system has many other inherent qualities that make it attractive for stationary as well as mobile applications. During the 70â€™s several steam engine projects for automotive applications were carried out. A JPL report concluded (among others) that steam engine systems would likely not be competitive in automotive applications. However, it is easy to understand why these conclusions came up. There was a low understanding of the particular issues that have to be addressed when realizing a modern steam

engine for the future.

Figure 1 (www.fueleconomy.gov/feg/atv.shtml)
shows that an internal combustion engine (ICE) only has an average efficiency of 12 % despite that the maximum efficiency for a gasoline engine is 35 %. The main reason to that is that a 200 kW ICE operates at very low loads (10-20 %) almost all itâ€™s live where efficiency is about 10 % instead of 35 %. A steam engine has the opposite efficiency characteristic, that is, maximum efficiency at part load (10-20 % load) and lower efficiency at full load. Complete simulation indicate 32 % efficiency at part load for a steam engine, that is 3 times lower fuel consumption for a 200-300 kW engine operating during normal conditions. Figure 1 shows also that consumption at standby/idling corresponds to 17 %. The steam engine system doesnâ€™t consume energy when standing still. Driveline losses are also lower due to the torque characteristic of a steam engine which involves a very simple gear box.

If considering all desired qualities in an automotive application it seems very well founded to make a deeper look on the novel high performance steam engine system.

The modern steam engine system has a great potential to offer the best qualities form the conventional internal combustion engine system and electric propulsion system without the negative qualities as:

- â€¢ High specific power (kW/kg, kW/litre, kW/$)
- â€¢ Low fuel consumption (high part load efficiency, no idling consumption)
- â€¢ Attractive torque direct at the wheel without any complex gear-box
- â€¢ Fuel flexibilities (Even solar energy for additional mileage)
- â€¢ Zero emission driving for a limit range

â€¢ Extremely low exhaust gas emissions (In the same order of magnitude as FC)

â€¢ Powerful regenerative engine braking (reduced also fuel consumption)

â€¢ Low maintain cost

â€¢ Low investment cost (two heat exchangers and a reciprocating piston engine)

â€¢ High performance but still energy efficient due to high part load efficiency

What does it takes to implement at modern high performance steam engine?

Steam power is associated with large and bulky system producing electricity in centralized large power plants. However steam power embodied as high revving steam engine employing high pressure will offer very high specific power (> 2 kW/kg), which makes it interesting even for aeroplane applications.

Burner will be different depending on fuel but in general all types of fuel can be used. The burner with a large air inlet area compared to internal combustion engine and the continuous combustions process makes it possible to oxidize large amount of fuel and hence the steam engine system is considerably less sensitive to the decreased air density at higher altitudes for instance, which makes it possible to high rate of climbing and altitude in aerospace applications.

Steam Generator (boiler) has to be implemented by multiplies parallel capillary tubes employing laminar flow offering a size of a shoebox instead of a large room as when adopting conventional boiler technology. Besides low weight, small occupied space, high temperature efficiency. Such a prototypes have been built and tested.

A so-called steam buffer is high temperature sensible heat storage for working fluids involving two phases of working fluids. The steam buffer offers a peak shaving function but also short terms energy storage with an energy density of approximately 100 Wh/kg and a very high power density of 10 kW/kg for solar energy stored as sensible heat. The steam buffer also makes it possible to make use of braking energy during vehicle speed retardation in the same ways as electric powertrains. Opposed to electric battery the steam buffer can absorb the high power that occurs during engine braking. Such a regenerative engine braking function could save substantial energy in automotive applications with many starts and stops as for instance city vehicles as buses. A proof of the concept of the steam buffer has passed.

The reciprocated piston engine has to operate without oil lubrications, at least not for the piston rings. Further more, it should be implemented as a high-speed oil-free multi cylinder axial piston engine. The design takes advantages of the favourable inherent torque characteristic which means a vibrations free and low irregular torque (smooth) operating characteristic within the whole shaft speed range. Such design unfolds the use of a simply and cheap gear box or even in some applications (city buses etc.) only the differential. A 300 KW steam engine will measure approximately 280 mm x 400 mm (height x diameter) and has a displacement volume of only 0,25 liters.

High pressure implies high-speed nature, which together in turn gives very high specific power for the steam engine proper. The Steam engine also offers almost the same reversed power output and offers a very powerful engine braking function that also is regenerative together with the steam buffer.

A condenser buffer offer high rate of condensing, of paramount importance for air-cooled applications with heavy fluctuating power demand. Even if the air-cooled condenser is efficient it is difficult to condense the high rate of steam that can occur during acceleration in automotive applications without the Condenser Buffer.

The air-cooled condenser is a crucial component for realising high performance air-cooled steam power system. Such an air-cooled heat exchangers is very important when realising an automotive steam power system because almost all waste heat has to be rejected to the ambient air (as also for the fuel cell) contrary to internal combustion engine where a large part of the waste heat is also rejected in the exhaust gas pipe and thus donâ€™t call for such a high thermal performance as in the steam power case. The air-cooled condenser has to offer high compactness but still offer low-pressure drops. It must offers large heat transfer areas behind a small inlet area but still involving low pressure drop and thus reduced fan power or RAM-pressure. Such air-cooled condenser has been built and tested where the corresponding fan power is only in the order of 1 % of the exchanged heat in the heat exchanger.

The steam engine system can also harness solar energy, adding further mileages without burning any fossil fuel. The solar energy evaporates the water which, is used either for propelling the vehicle directly or stored as sensible heat in the Steam Buffer for use the next coming hours. The modern steam engine system will realise a propulsion system that can use liquid fuel (the most favourable energy storage form) but can also make use of the intermittent, unpredictable, environmental-friendly solar energy when it is possible.