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Zero Emission Engine

An Economic and Environmental Benefit

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1 Introduction

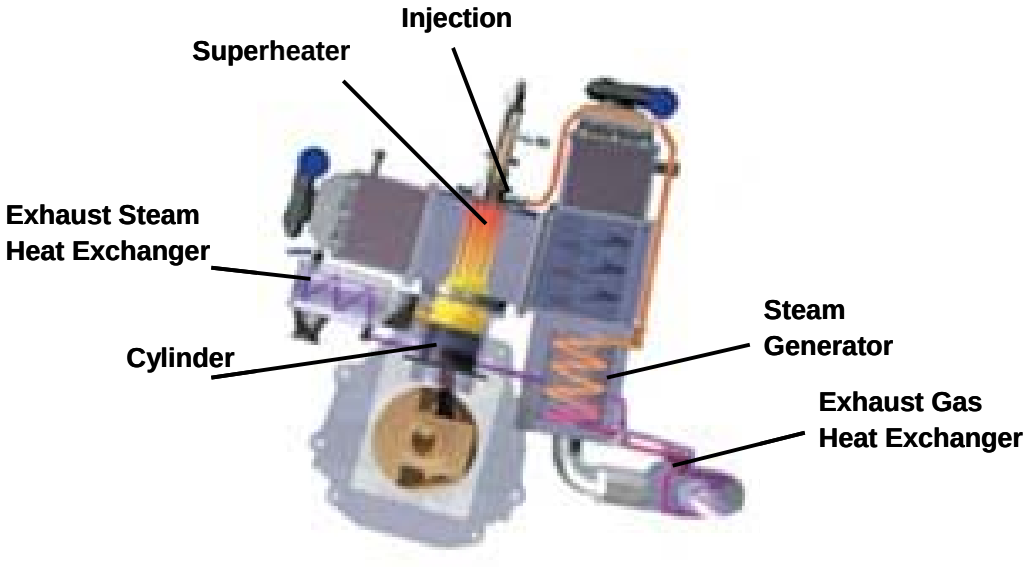
In 1994 the German engineering company IAV GmbH - Ingenieurgesellschaft Auto und Verkehr started the development of a modern automotive power train based on the concept of a conventional steam engine. Innovative developments in burning technologies provided the initial idea to create an engine which meets the growing requirements in environmental performance with low emissions and a decrease in fuel consumption. In the late 1990s at the Institute of Fluid Dynamics of Erlangen-Nuremberg a novel concept burner technology was established which fulfilled a variety of individual requirements at the same time. The so called porous burner technology operates at a very efficient level compared to conventional burner technologies and has a very low emission output. With this novel burner technology and the well-known concept of a steam engine the IAV GmbH created an innovative engine which could be an economic and environmentally friendly power supply for the transportation sector– the Zero Emission Engine (ZEE).

2 Design of the Zero Emission Engine

The ZEE is similar to the well-known steam engine and uses the same components such as an external heat source and conventional peripherals like pumps, steam generators, heat exchangers and condensers.

In general, it is a cyclically operating device that converts heat into work. Feed water is the working fluid. A feed pump increases the pressure level of the feed water up to 50 bar. On each cylinder, the feed water first passes through an exhaust steam heat exchanger. Then it enters the exhaust gas heat exchanger where a second preheating of the feed water is achieved and the waste heat of the engine that must be dissipated is captured efficiently. Feed water has to evaporate first by absorbing the heat to reach its operating temperature of about 500C° in the steam generator. It will be injected into the cylinder passing the superheater that controls the temperature for the varying power demand of the engine. Depending on power demand the steam could reach a temperature of about 900°C and an actual power output up to 50kW. In the reciprocating piston the thermal energy will be converted into mechanical energy by moving the piston. Condensation of the steam starts by depressurization and heat rejection after passing the cylinder. Later on, the water returns to the tank and remains until reentering the cycle.

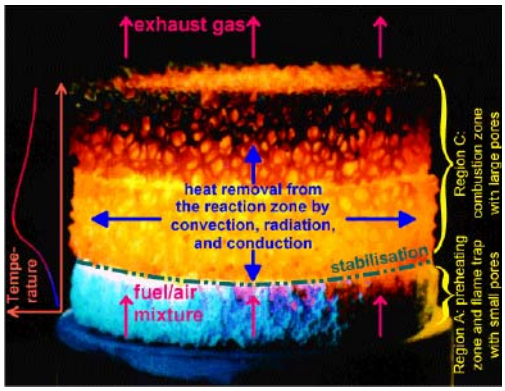
The innovation on this engine is the novel porous burner technology and the modern concepts of material science, control engineering, and thermodynamics. The prototype ZEE03 shown in picture 1 as a cutaway view is a 3- cylinder steam engine that has a modular configuration and reflects the latest research prototype. [1] Six identical burners ensure the handling of basic and peak loads.



Picture 1: Cutaway View of the ZEE03

As already mentioned, the main innovation of this technology is the porous burner technology. The burner is a porous inert medium (e.g. ceramic material) where combustion takes place in its three dimensionally arranged cavities and with invisible flames. Compared to conventional premixed burners the porous burner provides excellent advantages concerning compactness, power turndown, multi-fuel capacity and emission output. The porous burner system is about 10 times smaller in volume than conventional burners with comparable thermal loads and with its high power density it could vary in shape so that the appliance could be adapted very easily to the installation which is often limited in space in automotive applications. It has a wide variable dynamic power range of 1:20 while causing very low emissions (C_{CO} < 7mg/kWh and C_{NOX} < 25 mg/kWh)[2] and stable combustion. Because of the ability to burn different gaseous and liquid fuels such as gasoline, natural gas, hydrogen or rapeseed oil the burner provides free fuel selection for automotive applications as an additional advantage.

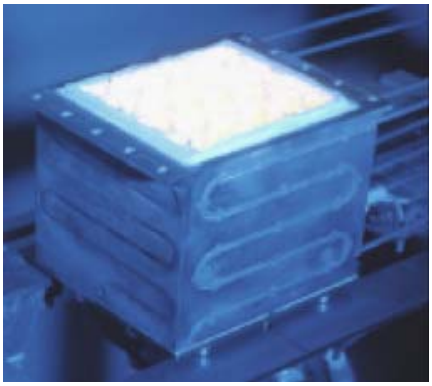
[1] http://www.iav.de/_downloads/de/techn_veroeffentlichungen/Dampfmotor.pdf
[2] http://powerlab.mech.okayama-u.ac.jp/~esd/comodia2001/2-28.pdf



Picture 2: Porous Burner

As shown in picture 2, fuel/air mixture enters the inert medium from the bottom through the so called preheating zone and flame trap with small pores. In the reaction zone the combustion takes place in large pores and spread out its heat by convection, radiation and conduction to all sides.

The ZEE03 uses the cubic porous burner shown in picture 3. As already mentioned, the ZEE03 includes six burners which can release a total thermal power ranging from 9 kW up to 220kW and a nominal power output per burner of 30kW. The emission behavior of the ZEE03 burner showing NO_X emissions below 8ppm is very low, even without using a catalyst.



Picture 3: Cubic Porous Burner in the ZEE03

The power of the ZEE with its fuel consumption of about 6 l/100km is comparable to an existing Otto Diesel Injection (DI) engine by emitting NO_X emissions of less than 3mg/km compared to Otto DI with about 250 mg/km at similar conditions.

However, the research on this engine has not been finished yet. Especially in material science and in the overall car-arrangement further developments have to be implemented.

Further, the engine would need additional 10 to 20 seconds to warm-up depending on environment conditions. Feed water treatment and anti-freeze protection have to be further investigated as well.

3 Economic and Environmental Benefit

The ZEE technology brings together economic and environmental benefits at the same time. Although the concept of a conventional steam engine is a well-known and sophisticated technology the ZEE demonstrates that conventional technologies can be a basis for innovative technology developments in today's everyday life. In times where natural energy sources are depleting and scientists are claiming about environmental damages caused by anthropogenic activity which uses natural resources 'recklessly', existing technologies have to be reviewed and optimized.

The ZEE could be a key development closing the gap between economic innovations on the one hand and environmentally friendly solutions on the other hand in the automotive transportation sector. This novel steam engine is able to achieve familiar convenience in the individual means of transportation and driving performance. With its power output of about 35KW and compactness the ZEE03 is comparable to the engine in a traditional passenger car. In addition to that, it can be run with different fuels and is not dependant on high fuel quality standards. The ZEE has been established to realize the idea of an engine which could run with different fuels and without using catalysts while reducing emissions lower than already developed technologies such as the California SULEV (**S**uper **U**ltra **L**ow **E**mission **V**ehicle). The SULEV standard is currently at 0,02 grams/mile[3] (approx. 0,124g/km) for NO_X emissions. The ZEE03 meets this target with an overall emission output of about 4,7 mg/mile NO_X and demonstrates its environmental performance in combination with additional advantages in the automotive industry.

Nevertheless, this technology has not been fully developed as a power train application. Control engineering and material research are the two most difficult parts to look at when creating an individual vehicle. High temperatures, pressures and a complex thermodynamic system which have to be adjusted to changing driving conditions need further progress in research as well as general safety conditions.

However, this technology is already in use as a slightly different modification. As the so called Auxiliary Power Units (APUs) the porous burner technology and the concept of the

[3] http://www.cleancarcampaign.org/emissions.shtml

conventional steam engine are used as energy sources in co-generation power plants or even in leisure power engines such as boat motors or current generators for homes. An alternative to current power units in remote areas which are often inefficient and harmful for the environment this technology could help to meet emission regulations as well.

4 Prospects and Conclusion

The automobile with its individual gift of flexibility and comfort is on the one hand a highly appreciated invention in the transportation sector but on the other hand this technology is a great consumer of natural resources and espouses environmental damages with its emissions. Regarding current developments in environmental sciences and politics this loved commodity will not be untroubled by public attention and technology review. In 1994 the IAV started an experiment to show how to meet future requirements in environmental performance in the transportation sector. Cars have to be individual, functional, comfortable, environmentally friendly and affordable for consumers. Therefore, the ZEE demonstrates the first step towards the development and redesign of the conventional vehicle.

The ZEE combines innovative concepts such as the novel porous burner technology and high performance materials together with conventional technologies and developed a modern steam engine which once could be used as a power train in future cars. That technology might be an alternative in the currently emerging market of drive trains such as the fuel cell technology. Unlike fuel cells which are completely new developed appliances the ZEE utilizes conventional equipment in existing applications which gives developers and consumers a familiar basis for optimization and practice.

Using the ZEE technology as energy generators in co-generation plants or for private current generation is an alternative and more market competitive application for this engine. In these cases, details of the ZEE such as requirements for control engineering and adaptation of design do not have such great impact as with conventional automobiles.

In conclusion, the development of this modern steam engine demonstrates that optimization of conventional technologies can be done with great effect on environmental performances while not restraining competitiveness. In addition, the IAV has shown that steam engines are indeed feasible as vehicle power trains and can meet future requirements in the transportation sector.

5 References

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[3] Clean Car Campaign USA:
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