FOX EXHAUST SYSTEMS Sportauspuffanlagen
ILK Dresden

Electricity from the Exhaust-Gas Heat of Motorcars

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Everybody talks about energy efficiency and traffic is responsible for a large fraction of greenhouse gases. The use of efficient engines can generate several advantages at the same time. Less fuel consumption means more money in the pocket, less global warming and better air in our cities. But how this can be achieved? Even modern engines convert only about one third of the chemical energy of the fuel into movement. The rest is wasted to the environment.

Since several years car manufacturers are working on solutions to convert the heat, mainly coming from the up to 1000°C hot exhaust gases, into electric or mechanical power. Hereby different processes are used.

BMW is working on a thermoelectric generator operating by use of the inverse Peltier effect. Such Peltier elements are commonly used in cooling boxes. An applied voltage results in a temperature difference. One side of the element gets warm, the other one gets cold. In the case of the thermoelectric generator one side is connected to the hot exhaust gas, the other side is actively cooled. So, electric power is generated. However, until now only about one percent of the heat is converted into electricity. The scientists research for new alloys which are useful for the Peltier technology and so to increase the coefficient of performance (COP).[1]

The company Amovis[2] works on a different principle, which is similar to the steam engine. A working agent is evaporated with the exhaust heat. The pressure rises until a turbine can be operated. After this the cooling water is used to liquefy the vapor and a pump brings it back to the evaporator. This system is flexible to assemble. Void volumes in the car can be filled with the components. However, so far the prototype occupies the whole trunk. Disadvantages are given by the additional pump and the position sensitivity. Details about costs and COP are not available.

The use of shape memory alloys (SMA) is relatively new. Researchers at General Motors are trying to connect the effect shape changes due to temperature changes to a generator. The advantage of such SMA is their high force and power density. But for a practically useful machine further material research is needed. Therefore costs, dimensions and reachable COP are not specified at this time. Until now, wire bunches of a nickel titanium alloy are used. This alloy undergoes a pseudoelastic change of 8 % between 20 and 100°C.[3]

The aim of the following project is to realize a lightweight, compact, COP-efficient and cost effective system. For that the company FOX Autotechnik[4] in cooperation with the Research Institute of Air Handling and Refrigeration in Dresden (ILK)[5] have developed a thermal power engine, which converts exhaust heat into power by use of a Stirling engine principle. Especially in the case of higher exhaust temperatures, which occur for instance in naturally-aspirated engines with larger volumes, high coefficients of performance are reached.

In contrast to common Stirling engines the FOX / ILK development has no moving displacer piston in the hot part of the engine, the part which is connected to the exhaust line. So the problem of piston guidance, sealing and lubrication in a temperature range up to 1000°C can be avoided. In principle this idea behind is not new. It comes from the low-temperature technology. Gifford and Longsworth discovered a special kind of low-temperature cooler without a mechanical displacer. They forgot to mount it into a common cryocooler, however it got cold. The piston guidance, sealing and lubrication at temperatures of –200°C are as complicated as in the case of 1000°C. So the development of FOX / ILK is a consequent way to transfer the experiences coming from low-temperature technology in the development of thermal power engines. Not only hot parts can be avoided. Also the number of moving parts can be reduced to a single moving piston. For low noise and less vibration during the operation of the system in a car two pistons at environmental temperature are used.

[1] www.atzonline.com/index.php;do=show/site=a4e/alloc=3/id=9593
[2] www.amovis.de/en/kompetenzen.htm
[3] www.gm.com/experience/technology/news/2009/coolheat_102709.jsp
[4] www.fox-sportauspuff.de
[5] www.ilkdresden.de

The construction principle of the FOX / ILK thermal power engine is shown in Figure 1. The engine consists of an expander with the electric generator and the thermal head. That is sub-divided in a heat exchanger for the cooling water, the regenerator, the exhaust heat exchanger and a buffer volume.

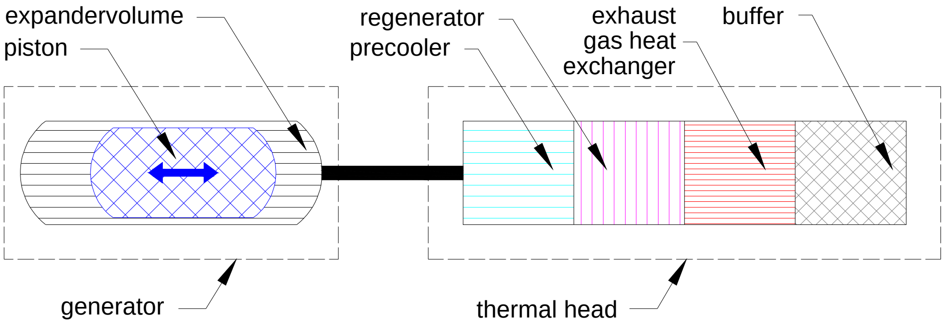

Figure 1: Principle of construction of the FOX / ILK engine

For the operation the engine uses the two-stroke thermal drag principle. During the compression the piston moves towards the thermal head minimizing the expander volume. The gas flows through the pre-cooler, the regenerator and the heater into the buffer. The compression heat is rejected by the pre-cooler. Inside the regenerator the gas is heated to a temperature close to the heater temperature. Under further compression the gas flows through the heater into the reservoir. Because the gas temperature is close to the heater temperature only a small amount of heat is transferred to the gas and the compression pressure is kept small.

Expansion occurs as the piston moves back. Because the gas temperature decreases during the transition of the gas from the buffer to the heater, a larger amount of heat flows into the gas and the pressure is kept high through a certain fraction of the expansion process. Some excess heat coming from the heater is used to warm up the regenerator for the next cycle. In the pre-cooler the gas is cooled down to the temperature starting point of the next cycle. The thermal power engine generates in this way electricity from thermal power with a COP of at least 12 % (e.g. the prototype generates electric power of 4 kW from a thermal power of 32 kW).

The patented system has the advantages of a maintenance free and position independent operation with a high COP especially at high exhaust gas temperatures. Figure 2 shows schematically the integration of the system into the exhaust tract. This project is supported by the SAB[6].

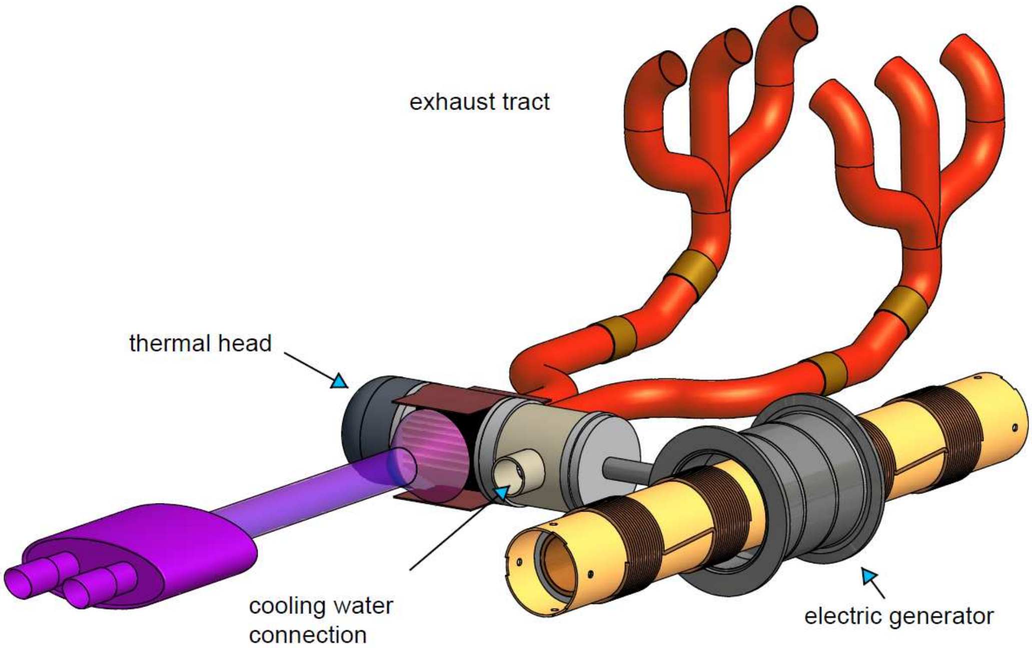

Figure 2: Integration of the FOX / ILK thermal engine within the exhaust tract

The above described system, however, is not suitable for Otto- and Diesel engines equipped with exhaust gas turbochargers where the exhaust temperature is only between 200 and 500°C. Therefore, the FOX / ILK team works on a new development of another Stirling-like engine with a different working fluid. With this new design a significant part of the heat from the lower gas temperature can be converted into utilizable electricity.

[6] www.sab.sachsen.de