Warmed up and raring to go

When an engine cold-starts, it produces far more   
pollutants than during the actual journey. This is   
because a cold catalytic converter is much less   
efficient at cleaning the exhaust gas. So what’s the answer? Preheat the cat with microwaves.

TEXT: Rainer Klose / PICTURES: BAFU, PSI

90 percent of all pollutants are produced in the first minute after a modern gasoline engine is cold-started. Or to put it another way: the first 500 meters on the road pollute the air just as much as the next 5,000 kilometers if the vehicle were to be driven nonstop.

Catalytic converters for cars that warm up as fast as possible or – even better – already clean the exhaust gas efficiently during the first engine revolution are thus vital if we want to improve air quality. Potis Dimopoulos Eggenschwiler, an exhaust gas treatment specialist at Empa’s Automotive Powertrain TechnologiesLaboratory, has spent the last two years searching for a solution to the cold-start problem, which especially pollutes the air in cities (see box). The project is funded by the Swiss National Science Foundation (SNSF) and the Federal Office for the Environment (FOEN).

For a catalytic converter to be heated to 250 degrees Celsius by the car’s power supply using as little energy as possible before the engine starts, it needs to be small and as heat-conductive as possible. Dimopoulos Eggenschwiler proposes an open-pored structure with a special coating, which can be heated up by a small microwave transmitter within ten seconds – much like the microwave oven at home. Back in 2012, the Empa team already developed a particularly efficient catalytic converter: a ceramic cast of a polyurethane foam that swirls the exhaust gases more effectively and generates less counter-pressure than a catalytic converter with its conventional honeycomb structure.

Ceramics from the 3D printer

The Foamcat then sparked the next idea: a geometric grid structure made of thin ceramic struts that makes do with a coating containing a low amount of precious metal yet still cleans the exhaust gas swirling inside   
it efficiently. “First of all, we looked for an   
ideal structure on the computer,” says   
Dimopoulos Eggenschwiler. “A structure that heats up rapidly, accelerates chemical reactions and hampers the gas flow as little as possible. Then we set about recreating the structure in ceramics.” Specialists at the Scuola universitaria professionale della Svizzera italiana (SUPSI) in Lugano constructed the lattice designed on the computer using stereolithography, a kind of 3D print from liquids and UV light. Experts at Empa then coated the ceramics with silicon carbide, zirconium oxide and aluminum oxide – and the active catalytic converter substances consisting of platinum, rhodium and palladium.

**Expectations met**

What is probably the world’s first 3D-printed catalytic exhaust converter lived up to expectations in field tests: in the exhaust from Empa’s model gas reactor the polyhedron-shaped cat actually cleaned the pollutants even more effectively than the 2012 Foamcat. In the wake of their successful initial lab tests using small model cats, the researchers are now talking to industrial partners to integrate one of these catalytic converters in full size in a test vehicle.

The next step for Dimopoulos Eggenschwiler will be to incorporate the microwave heating. “It’s important that we don’t heat up the entire ceramic structure,” he says. “We want the microwaves that are   
generated by using precious battery power to only affect the ultrathin catalytic coating.”

According to the exhaust gas specialist, one to two kilowatts can easily be diverted from a vehicle’s battery for ten to 20 seconds. “That should be enough.” As soon as the engine is running, the exhaust gas and the chemical reactions in the catalytic converter supply sufficient heat to keep it hot, at which point the microwave can be switched off. //

Bildtexte

Left

Potis Dimopoulos Eggenschwiler (right) heads the project initiated   
by the Federal Office for the Environment (FOEN) to develop a novel exhaust gas catalytic converter for gasoline cars. Alberto Ortona (left) from the University of Applied Sciences and Arts of Southern Switzerland (SUPSI) 3D-printed the ceramic structure.

**Large Photo below**

The geometric ceramic structure of the test catalytic converter designed on the computer. Specialists at Empa coated it with the catalytically active layer and tested the cleaning effect in an artificial stream of exhaust gas.

Böxli:

Particles for breakfast

Particulate matter in city centers isn’t just caused by diesel vehicles without filters; petrol cars also play a role – especially when they start up from cold in the carpark or an underground garage.

A team of researchers headed by André Prévôt from PSI succeeded in demonstrating how these fine particles develop in a so-called smog chamber. Within the scope of the GasOMeP project (see page 14), the researchers collected exhaust gases from test vehicles in a 12-cubic-meter blow-up chamber with transparent Teflon film walls. Inside, the car exhaust gases are mixed with dampened air and irradiated with UV lamps for several hours to simulate a sunny day. The “fresh” exhaust gas, which initially contains gaseous substances such as benzene, toluene, nitric oxides and ammonia, now transforms into something completely different: salt particles such as ammonium nitrate. The unburnt hydrocarbons oxidize in the air and are converted into a liquid or solid state, which produces a toxic fog that accumulates on the newly formed salt particles and the soot particles from the engine. Some days, as much as 90 percent of the fine dust pollution can be generated in this way.

Studies conducted at the University of Bern in 2015 revealed that secondary fine particulate matter from a Euro 5 petrol engine harms the pulmonary tissue directly and can affect the ability of the lungs to fight off infections.