February 2020

METHOD FOR CATALYST HEATING BY COMBINATION OF E-CAT AND HYBRID POWERTRAIN

Verena Blunder
Bertrandt Ingenieurbüro GmbH

METHOD FOR CATALYST HEATING BY COMBINATION OF E-CAT AND HYBRID POWERTRAIN

Technical task:
The development explained in the following makes it possible to reduce the exhaust gas pollutants emitted after starting or restarting the engine by electrically preheating the E-Cat and hybrid Powertrain.

Initial situation:
In the course of the tightening of the exhaust gas legislation beyond the status known today (EU6AP), it is to be expected that the limit values of the pollutants contained in the exhaust gas will be regulated even more than before. According to current premise papers, the component nitrogen oxide (NO + NO2) in particular will come closer to the strictest exhaust emission standard SULEV30 of US legislation.

In this context, it is necessary to reduce in particular the emission contribution of the initial start including the subsequent heating of the catalyst. In addition to application solutions and optimization of the catalyst as a component (volume, load, precious metal composition), electrically heated catalytic converter discs, in the following called E-Cats, currently appear to be an effective means of reducing emissions, especially of the components nitrogen oxides NOx, carbon monoxide CO and unburned hydrocarbons HC.

In the integration of an electrically heated catalyst element in a conventional catalytic converter, there is a primary opportunity to bring a catalytically active surface above the light-off point by means of an energy input that does not originate from the actual combustion process, without having to replace the internal combustion engine (VKM) itself. This means that when the combustion engine is started for the first time, a conversion capacity is already available that would otherwise, in the classic case, only be provided by the temperature input into the exhaust gas system.

However, there is a fundamental problem in the integration of the electrically heated catalytic converter before or in the conventional catalytic converter: Due to the stationary combustion unit (as well as the stationary vehicle), the gas mixture is also present in the exhaust system before or in the converter. The E-Cat, or the disc-shaped, electrically heated catalytic converter element, heats up quickly. Heat transfer from the E-Kat to the main catalytic converter is restricted by the mechanisms of radiation and heat conduction. The main catalytic converter therefore remains at a low temperature level - below light-off temperature - for a longer period of time and thus cannot contribute to the conversion of exhaust gas, or only to a limited extent. To improve the performance of the entire catalytic converter volume directly during engine cold start, the entire catalytic converter volume should be heated.

Solution:
If an electrically heated catalytic converter element is integrated into the exhaust tract of a hybrid vehicle, there are degrees of freedom in dealing with the problems described in the starting position, which will be explained in the following. In order to use the electrically heated catalytic converter element as efficiently as possible and at the same time ensure maximum conversion performance when the internal combustion engine is started for the first time, it makes sense to extend the heating power of the E-Cat not only to the E-Cat itself but to the entire converter. One way to do this is to improve the convective heat transfer in the catalytic converter. In a hybrid vehicle, an electric motor (ELM) is available, which is used to support or drive the vehicle, depending on the concept. The idea now is to generate a gas flow through the converter in the time before the engine is started for the first time by means of a defined starting of the VKM, which, in the sense of convection, enables the downstream converter components to be heated without direct heating of the converter itself. Figure 1 shows this principle from a thermodynamic point of view. The air flow can be adjusted via the speed of the dragged burner as well as additionally modulated via further actuators such as the throttle valve or a variable valve lift.

The intelligence of the tuning consists in modulating the air flow through the converter and along the electrically heated catalytic converter element in such a way that sufficient convective effect can be achieved, but at the same time the temperature of the electrically heated catalytic converter element does not drop too much and no or not too much hot gas leaves the converter or the exhaust system unnecessarily.

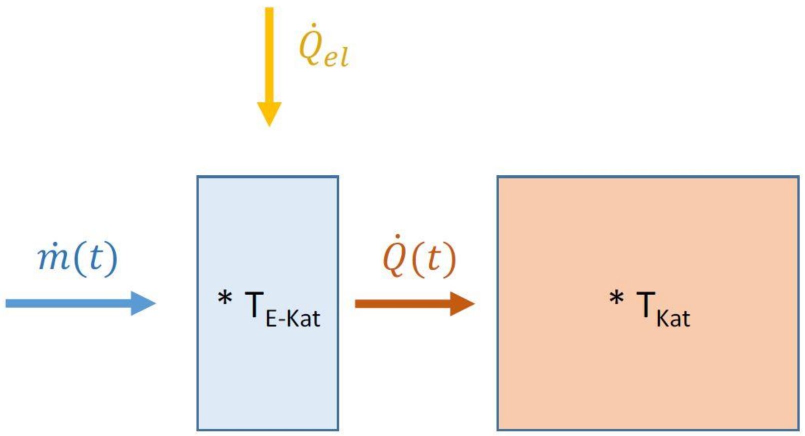

Figure 1: Supplied heat and (air) mass flows with regard to E-Cat and main cat

In a further dimension, this process can be integrated in all conceivable driving situations, especially in plug-in hybrids. Before the initial start, the electric machine can tow the combustion engine from a standstill. During the journey, this can be done for the purpose of keeping the catalytic converter warm or warming it up after a cold descent by means of appropriate torque control on the electric machine and targeted actuation of a central separating clutch (K0) installed depending on the concept. Figure 2 illustrates this principle by means of a schematic representation of the temperature rise in the catalytic converter due to a defined air mass flow through the converter heated by the E-Cat. A higher mass flow at the beginning serves to heat up the catalytic converter more quickly. A converter-capable catalytic converter (T > Light-Off) is thus already available for subsequent engine starting. In the further course of a journey, the same function with a variable mass flow can be used to keep the catalytic converter warm. For differentiation purposes, in Figure 2, fired (red) and unfired phases (blue) are highlighted in separate colours.

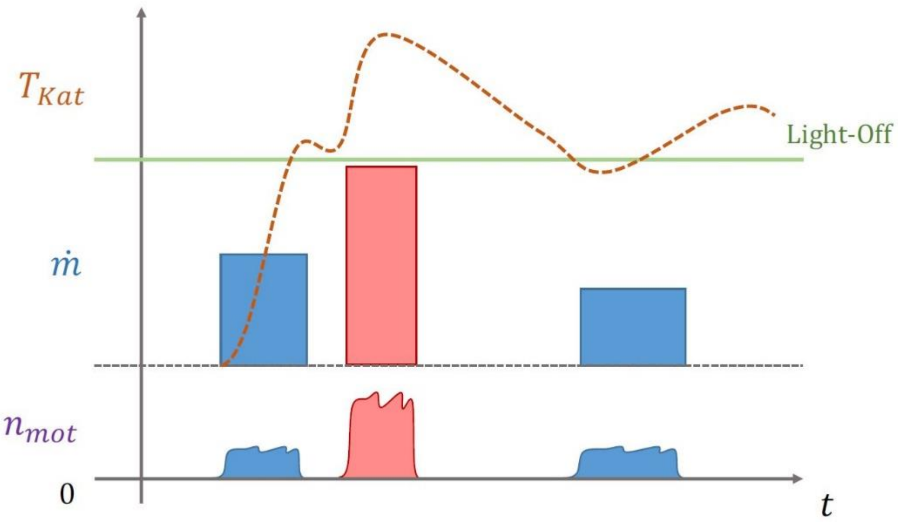

Figure 2: Cat temperature as a function of the air mass conveyed by VKM (towing) operation

In all cases, the aim is to preheat the entire catalyst volume or the entire surface available for the conversion of the pollutants to such an extent that the temperature to be overcome is lower after initial engine start and the conversion performance in the first few seconds is thus significantly higher than the technical initial solution.

Advantages:
- Electrical preheating of the entire catalyst
- Higher conversion efficiency of the exhaust gases after starting the engine or after repeated starting and cooling of the catalytic converter in electric driving situations
- Reduction of the emission of exhaust gas pollutants after engine start or repeat start