The Three Way Catalyst in Hybrid Vehicles

The hybrid car is today one of the most favourable solutions to design more environmental friendly vehicles with decreased fuel consumption and emissions, including the CO_2. As the development progress, the hybrid cars will probably be equipped with stronger electric machines and larger batteries which enable pure electric drive for longer distances.
This constitutes a problem in the exhaust gas after treatment in the three way catalyst which has to be over a certain temperature to reduce the emissions if the internal combustion engine is started by the hybrid control system.

The reason why the three way catalyst is deactivated due to too low temperatures is because when the internal combustion engine is turned off and the vehicle is driven in pure electrical drive the three way catalyst cools off. The cooling is due to convection and radiation to the surroundings and because there is no exhaust gas that can heat the catalyst when the internal combustion engine is turned off.

The problem is most critically for a full hybrid such as the plug-in hybrid because this is designed to drive for longer distances in pure electrical drive, maybe around 50 km, unlike the mild hybrid that is not designed to drive in depletion mode, that is pure electrical drive.

The problem with thermal deactivation by the catalyst can be resolved in different ways. The solutions investigated in this project are;

- Controlling the internal combustion engine to start when the catalyst is reaching its deactivation temperature.
- Maintaining high enough temperature, to prevent deactivation, in the catalyst by electrical heating.
- Instantaneously heating the catalyst when the internal combustion engine is about to start to a temperature higher than the catalysts lightoff temperature.

For the mild hybrid driven as it is designed, that is not any longer distances in pure electrical drive, deactivation of the catalyst does not constitutes a problem but if it is driven in depletion mode, that is as far as possible in pure electrical drive before starting the internal combustion engine, deactivation of the catalyst is a problem.

The result for the mild hybrid, driven in depletion mode, indicate that the best way to prevent deactivation of the catalyst is to start the internal combustion engine when the catalyst temperature get close to the extinction temperature and then let the internal combustion engine run until the batteries are fully charged. If this control algorithm is used it can be advantageous to implement a battery in the hybrid so that the charging of the battery coincide with the heating of the catalyst.

The result for the full hybrid, that is designed to drive for longer distances in pure electrical drive, indicate that in the full hybrid it is better to let the catalyst cool and then heat it instantaneously right before the internal combustion engine starts with a powerful electrical heater. If the internal combustion engine starts suddenly due to increased power need due to heavy acceleration this control algorithm acts as a heavy reduction of the lightoff time. If this control algorithm is used it can be a great energy saver to only heat the first 25 percent of the catalyst because that's where around 75 percent of the exothermic emission reducing reactions occur, then these exothermic reactions heats the rest of the catalyst. It can be noted that if the internal combustion engine is used to heat the catalyst continuously in the full hybrid the whole concept of a full hybrid is destroyed.

This project is done with stock examples of control algorithms. The problem with thermal deactivation of the catalyst will probably need advanced control algorithms, such as the control algorithms for the drive line, when implemented in a vehicle.

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