Layout of Hybrid-Diesel Control

A digest of IAV's paper "Laying Out Diesel-Engine Control Systems In Passenger-Car Hybrid Drives" presented at the congress "Hybrid Vehicles and Energy Management", Feb. 14th and 15th, 2007 in Braunschweig, Germany

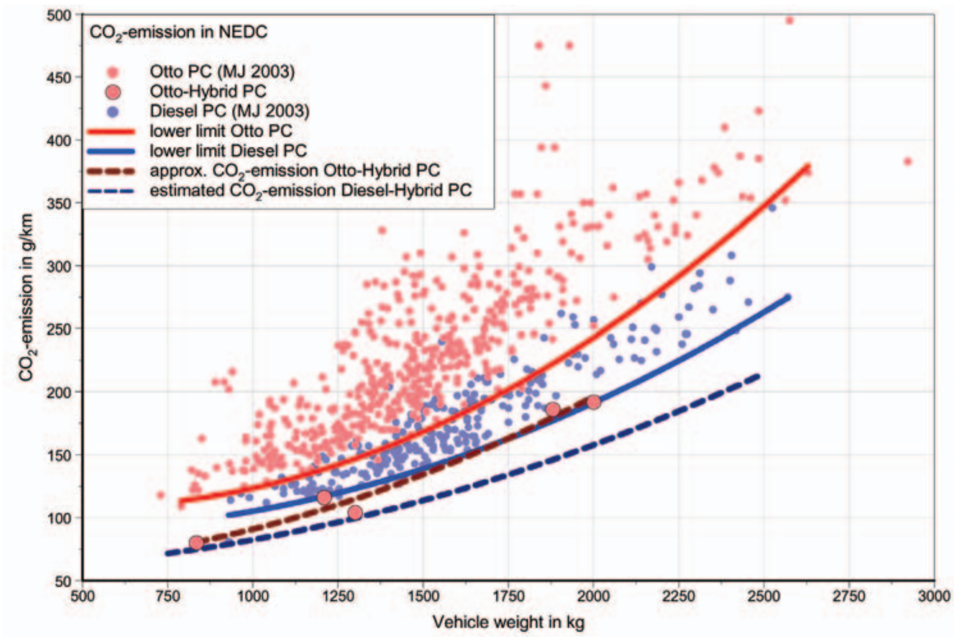


Figure 1. CO_2-emission versus vehicle weight for gasoline, hybrid-gasoline and hybrid-Diesel vehicles

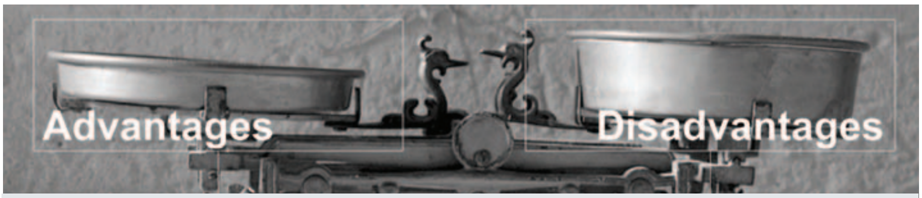
Point of departure

Particularly in Europe modern passenger cars with Diesel engines have reached high popularity. The reason for this is found in the combination of efficiency and excellent driveability. In Europe, Diesel engines currently account for about 50% of the market, expected to further grow. In addition, Diesel vehicles will also make headway in the passenger-car sector on the North American market.

Having the task of further reducing the CO_2-emission in mind it can be stated that state-of-the-art hybrid-gasoline passenger cars are able to compete in this respect with the best Diesel-powered vehicles, **figure 1.** Making some estimations about the technical and the cost efficiency a significant reduction in CO_2-emission can be reached with a Diesel-electric engine, especially for heavy vehicles like vans and SUVs.

Pros and cons of hybrid-Diesel propulsion

Figure 2 gives an overview to the feasible measures of hybridisation and the consequences that have to be taken into account. Advantageously most of the functionality in a hybrid-Diesel can also be used for the hybrid-gasoline vehicles. Moreover the hybrid propulsion technology gives way for the further development of the car's auxiliary components.



CO_2 reduction due to
- Stop/start
- Energy recuperation
- Generator efficiency
- Energy management/torque-split
- Auxiliary drive management

Emission reduction due to
- Dynamics reduction in transient operation
- Electric driving at low end load
- Implementation of PCCI combustion system

- Higher weight
- Higher space requirements
- Higher costs
- Higher system complexity
- Service of high-voltage systems

Figure 2. Benefits and engineering challenges of hybridisation

Diesel engine operating modes in a hybrid car – reduction of combustion engine dynamics

Over recent years, complex control structures – including electrically driven feedback (smart) actuators and highly responsive sensors – have been introduced into production engines. These measures have brought a significant improvement in the engine's transient behavior. For highly dynamic transient states, however, the problem of fast, high-precision air mass sensing has still not been adequately resolved. The blue line in the lower graph of **figure 3** shows an example of the effects EGR and air mass control calibration have on NO_x raw emission under transient operating conditions (NEDC acceleration ramp). In the acceleration phases the combustion engine torque can be reduced through electric boosting, followed by battery charging at constant speed. The overall energy consumption can be kept constant at a significantly lower NO_x output.

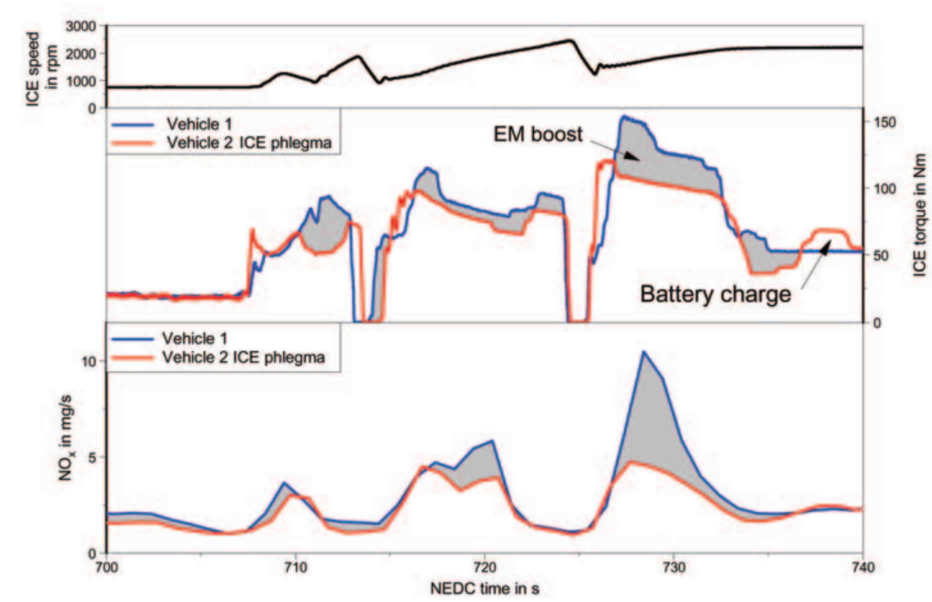


Figure 3. Effect of the reduction of combustion engine dynamics ("phlegma") in combination with electric motor boost on NO_x-emission during transients (NEDC)

Combustion optimisation and control

Optimising the combustion process towards low temperature combustion (i.e. premixed Diesel combustion, HCCI/PCCI combustion) can be said to offer a relatively wide potential in reducing NO_x and PM raw emission at a reasonable level of fuel efficiency, but only if load limit is increased and engine noise as well as combustion engine dynamics are reduced. The reduction of engine dynamics is necessary to assure the requisite increase of EGR even at transient operation. As DPFs are set to become imperative, these combustion processes might lead to less development cost and effort on NO_x aftertreatment.

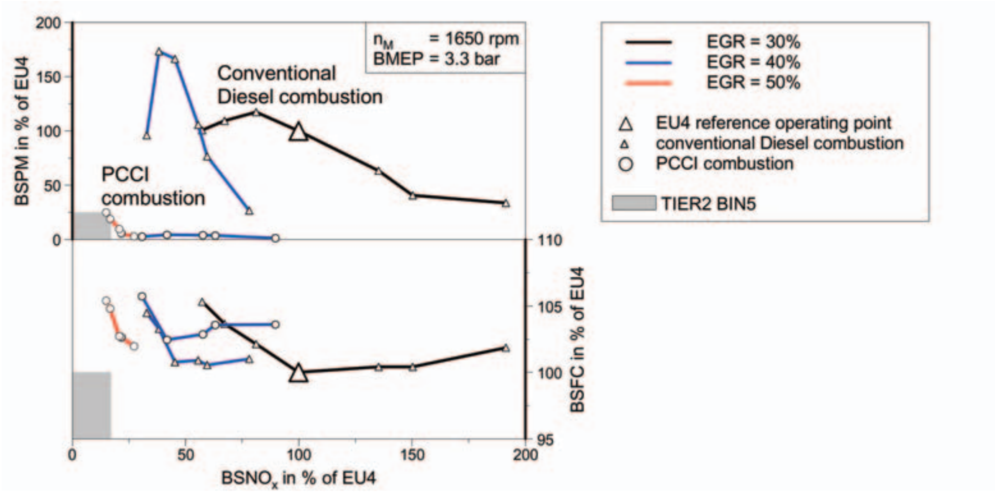


Figure 4. Comparison of conventional low temperature Diesel combustion mode and PCCI combustion mode at part load

For a robust engine operation in the HCCI or PCCI mode a new engine control concept is needed. In clear contrast to today's conventional drives, introducing a high-EGR combustion concept necessarily leads to a combustion engine management system governed by the current combustion air/fuel ratio λ. In a λ-controlled system, the charge mass and composition in the cylinder is determined on a cycle-synchronous and cycle-specific basis in order then to meter fuel exactly. This will be done by a leading modelbased air-path control. Fuel injection timing and quantity are based on the calculated charge-air conditions in the cylinder. A closed-loop control algorithm for adequate combustion phasing (and noise control) is the key for a smooth and efficient engine operation. **Figure 5** gives a schematic view on the control architecture.

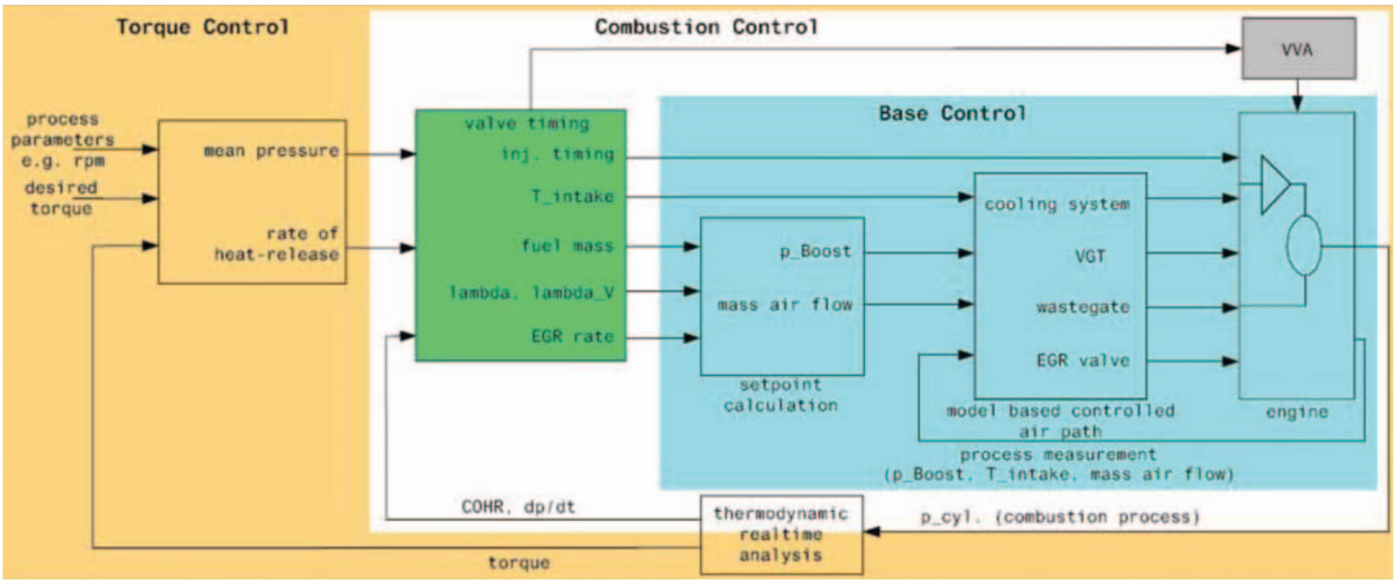


Figure 5. Cascaded λ-controlled engine management

Furthermore the drive management in a hybrid vehicle is more complex than in conventional combustion-engine drives. This is best illustrated by the fact that in addition to the combustion-engine and transmission control unit, many hybrid vehicles also use a hybrid-vehicle control unit. **Figure 6** shows a typical configuration of this control-unit network.

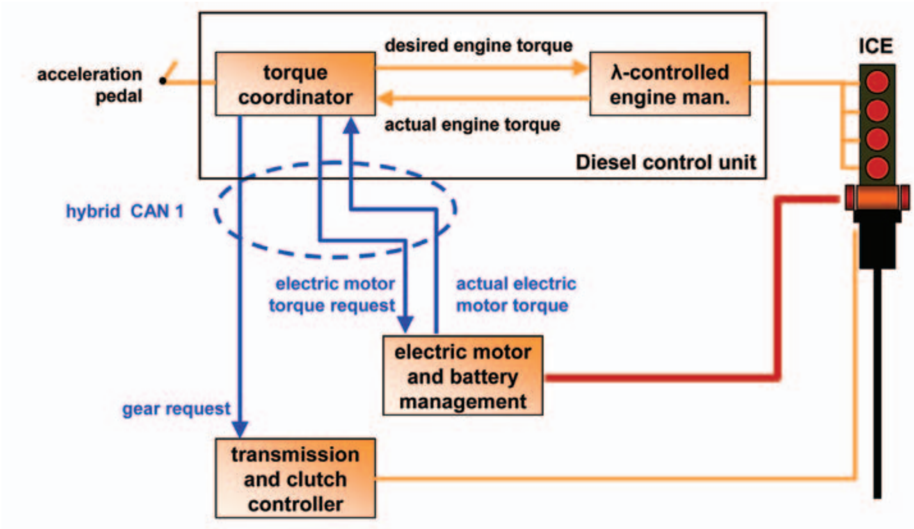


Figure 6. Typical network and interface concept behind hybrid-vehicle control systems

The drive management must aim at optimising the operating strategy, achieving an adequate level of exhaust emission at excellent fuel consumption as well as providing pleasing driveability and comfort.

Aspects of powertrain management include:

- Concept for interlinking engine, electric motor and transmission control units involved
- Mode-optimised translation of the driver's request into vehicle acceleration
- Brand-independent control-unit and algorithm topology
- Torque structure for all control units based on wheel torque
- Coordinating drive torque of combustion engine and electric motor
- Extended monitoring and “limp-home” functions for enhanced drive-by-wire reliability failure safety
- Recuperation concepts for optimum driveability

Summary and outlook

Hybridising Diesel vehicles in the passenger-car segment is a meaningful way of extending drive concepts hitherto familiar. In addition to reducing CO_2-emission, it also provides advantages in cutting pollutant emission.
This demands coordinating calibration of the drive electronics to suit the requirements of the hybrid-drive system. In this context, integrating λ-controlled Diesel-engine management offers particular potential for reducing exhaust emission.
By its very nature, an engine management system of this type shows certain delays in response to spontaneous torque requests. This makes it particularly suitable for hybrid vehicles because an electric-motor drive can be used to compensate for temporary torque restrictions.

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