Abstract Submitted to
FISITA 2008 - World Automotive Congress
Munich, September 14-19, 2008

Signal- and process model-based fault detection and diagnosis of a common rail injection system[1]

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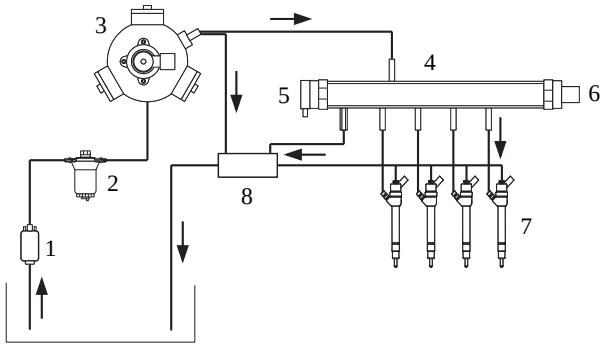
Due to the rising reduction requirement on emissions highly-developed common rail fuel injection systems are widely-used in modern internal-combustion engines. In order to fulfill the different emission standards, reduce maintenance costs and increase the reliability these systems need to be supervised.

Therefore a fault-detection module for such a common rail system has been developed and is presented in this paper. The observed common rail system is shown in Fig. 1. It accumulates the fuel



(1) electrical pre-feeding pump, (2) fuel filter, (3) high pressure pump with fuel metering valve, (4) common rail, (5) pressure control valve, (6) high pressure sensor, (7) injectors, (8) damper

Figure 1: Overview of the common rail system

under high pressure on the so called common rail in order to supply the injectors time independent and with a large scale of pressure levels. Within the considered fault detection module five features are generated by appropriate model-based signal processing. In particular signal model-based methods as well as parity equations are applied. Additionally a new approach based on a special input excitation is used. The model-based fault detection algorithms have been implemented with a dSPACE rapid control prototyping system and verified on an Opel four-cylinder Diesel engine at the testbed. Measurements show that the considered faults can be detected and isolated by the provided features. Beside a detailed description of the common rail system and the below-mentioned residuals several plots of measured data will be shown in the full paper.

Residual rail pressure mean value The moving mean of the rail pressure in the fault free case depends on the positions of the metering and pressure control valve, the engine speed and the

[1]This work was supported by the Forschungsvereinigung Verbrennungskraftmaschienen e.V.

injection quantity. This dependency can be approximated by neural networks. With the resulting model and the rail pressure sensor value a residual is found which is sensitive to different faults and straightforward to implement.

Residual high pressure pump volume flow The volume flow through the high pressure pump in steady state depends on the rail pressure, the position of the metering valve and the engine speed. In overrun state the mean amplitude of the rail pressure oscillations over one pump cycle is a measure for this volume flow. By comparing online computed amplitudes to stored ones an easy to implement residual is found which is only sensitive to faults in the low pressure system and to rail pressure sensor faults.

Residual smooth running of high pressure pump Theoretically the three pump elements of the high pressure pump have identically fuel delivery quantities in steady state. Therefore the moving mean of the sum of volume rates to and from the rail over the duration of one pumping stroke is zero but on faulty conditions nonzero. By computing the considered mean value using the rail pressure sensor signal corrected of interfering injector influences a residual is found which is only sensitive to faults of the high pressure pump and can be implemented easily.

Residual smooth injection As well as the pump elements should have identically fuel delivery quantities in steady state the volume flow through the injectors should be equal in the fault free case. Using the same algorithm as for the smooth running analysis of the high pressure pump but correcting the rail pressure sensor signal of the high pressure pump's influences one finds a residual which is only sensitive to injector faults.

Residual metering valve's control ranges In order to verify the rail pressure sensor value a so called fault describing function which maps a process model output to a faulty process output is computed. This function has different characteristics in regard to sensor and process faults and thus it is capable to isolate sensor faults.

In summary it can be stressed that using the developed fault detection module it is possible to detect and isolate all considered faults. Furthermore the presented residuals are straightforward to implement with low computational effort.