Investigation of field suitable microwave cavity measurement approaches

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Editorial

The optimum operation of a combustion process requires that one know the inner state of the exhaust catalyst nowadays indispensable for exhaust-gas aftertreatment. To date, one does not measure this state (e. g., the oxygen storage ratio in a three-way catalyst, or TWC) directly, but rather infers it from measurements upstream and downstream of the catalyst (in the case of the TWC, this is what lambda probes are used for). A direct method based on the interaction between microwaves and the catalyst has been described quite thoroughly in the literature by now, but these results are based on equipment such as vector network analyzers (VNA) which cannot be used as field devices for cost and size reasons.

The present work investigates hardware and software approaches which have the potential to be used in field devices deployable in vehicles and similar environments on a routine basis for in-situ non-destructive catalyst-state diagnostics. It is demonstrated that scalar reflectometry lends itself to the task of monitoring a housed catalyst if an appropriate signal processing strategy is implemented.

In the course of the work, two demonstrators have been designed, implemented and characterized, and the methodology of extracting resonance frequencies from (even shallow) return-loss spectra has been investigated. It is shown that the precision of the return loss measured by the demonstrators is acceptable by comparison to commercial VNAs and that the accuracy is about 0.03 dB. Based on this, resonance frequencies in the range from 1 to 6 GHz can be determined at an effective rate of 10 to 40 Hz, which is an order of magnitude faster than previously possible with VNA-based systems.

The measurement system is validated through dynamic tests with a TWC subjected to gas flows of varying oxygen content. The resulting agreement between the TWC loading state and the measured resonance frequency is convincing. This, together with further results on the short- and long-time stability of the demonstrators and with cost estimates, corroborates the applicability of the approach to the task of monitoring an electrochemical system in situ by a field device.

Bayreuth, May 2017
Prof. Dr.-Ing. Gerhard Fischerauer, Prof. Dr.-Ing. Ralf Moos

To my dear and loving wife Sunny,

Who convinced me to pursue a Ph.D. degree.

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