SUCCESS STORY

LEC HybTec
Hybrid Technologies for Enhanced Reliability of Ultra High-performance Engines.

Programme: COMET – Competence Centers for Excellent Technologies

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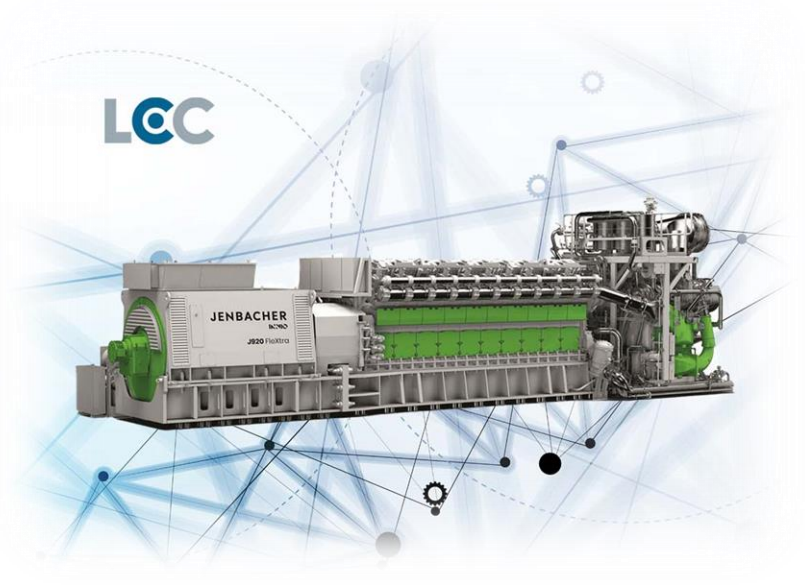

VIRTUAL SENSORS AS A COST-EFFECTIVE ALTERNATIVE FOR OPTIMAL ENGINE CONTROL

MEASURED VALUES OF ACCELERATION SENSORS IN COMBINATION WITH NEURAL NETWORKS PROVIDE A COST-EFFECTIVE AND RELIABLE ALTERNATIVE TO EXPENSIVE AND HIGH-MAINTENANCE CYLINDER PRESSURE SENSORS.

Especially with climate-neutral fuels such as hydrogen and ammonia, optimal control of the engine combustion process makes it possible to achieve the lowest emissions and the highest efficiency. In a closed-loop control strategy, thermodynamic parameters that are derived from cylinder pressure are critical. Cylinder pressure is normally recorded by pressure sensors that are installed directly in the combustion chamber. The high loads that occur there result in a shorter lifespan and high maintenance requirements. One promising alternative is the use of virtual sensors based on measurement information from outside the combustion chamber. In the LEC HybTec COMET module project "Ultra-fast Knock Prediction", two concepts for reconstructing cylinder pressure based on acceleration sensors — in this specific case knock sensors — have been developed using machine learning and successfully tested on different large gas engine data sets.

Development of a virtual pressure sensor

To reconstruct cylinder pressure based on the acceleration signal of a knock sensor, two different methods have been derived that combine regressions using machine learning and other data-driven methods. The models that serve as the basis for engine control concepts fundamentally differ in how they prepare signals and provide results. Both

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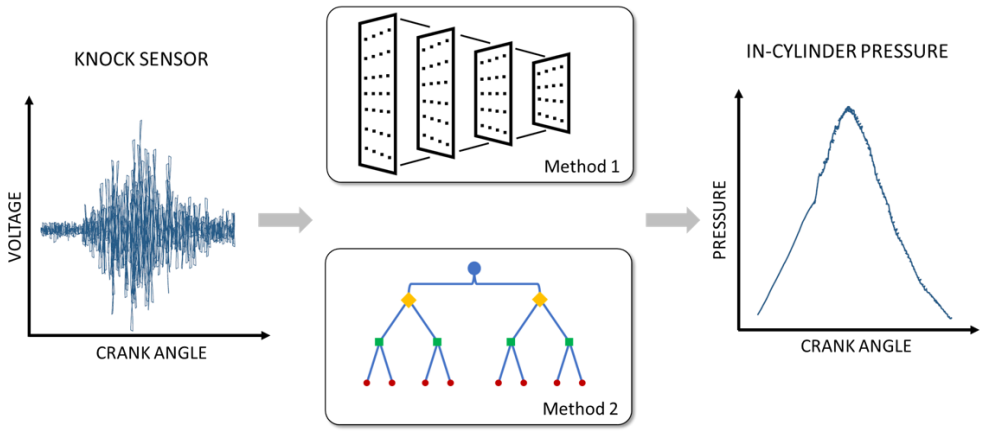
methods have already been published in peer-reviewed journals.

Method 1 – Branched 1D convolutional neural network: This approach combines two signal branches in a convolutional neural network. The first branch uses the raw knock sensor signal and the second branch uses the high-pass filtered one. The training behavior of the network was optimized by introducing an adjusted error function. This method makes it possible to reconstruct the entire cylinder pressure curve in the high-pressure part of the engine cycle.

Method 2 – Statistical parameters and decision trees: The aim of the second approach is direct prediction of scalar thermodynamic quantities such as peak firing pressure and conversion rate. Statistical properties of the knock sensor signal are used as input values for a regression model. This case employs a model based on a combination of decision trees (XGBoost). The direct prediction of scalar quantities makes it possible to forgo a later analysis of cylinder pressure.

Virtual sensors to increase the cost-effectiveness and sustainability of large engines

The methods developed to predict the cylinder pressure curve and important engine control parameters have the potential to greatly reduce the cost of engine operation since the use of costly, high-maintenance cylinder pressure sensors for engine control may be avoided.



Methods for determining the cylinder pressure signal from the knock sensor signal, Copyright © LEC GmbH

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