TU Darmstadt

Institute for Internal Combustion Engines and Powertrain Systems

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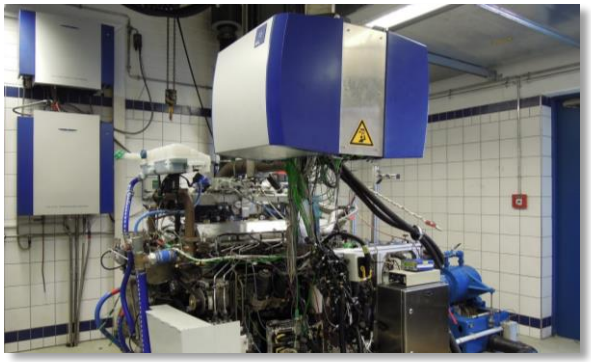

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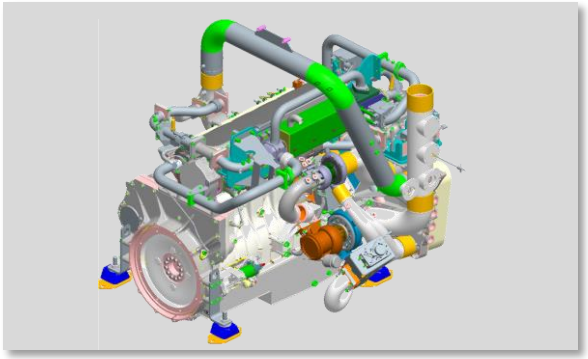

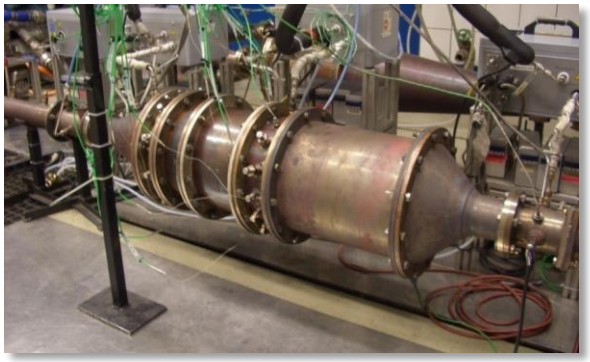

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Institute for Internal Combustion Engines and Powertrain Systems – Staff

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Prof. Dr. Christian Beidl
(Head of Institute)

Prof. Dr. Günter Hohenberg
(Emeritus)

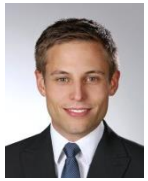
Dr. Bernd Lenzen

Christoph Halscheidt

Mikula Thiem

Alexander Kuznik

Harun Zlojo



Tim Steinhaus

Alexander Mokros

Daniel Schade

Markus Münz

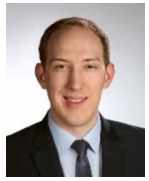
Raja Sangili Vadamalu

Deborah Schmidt

Sebastian Fischer

Johannes Hipp

Sascha Bauer



Henning Nies

David Töpfer

Nicolas Hummel

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VKM – Research Areas

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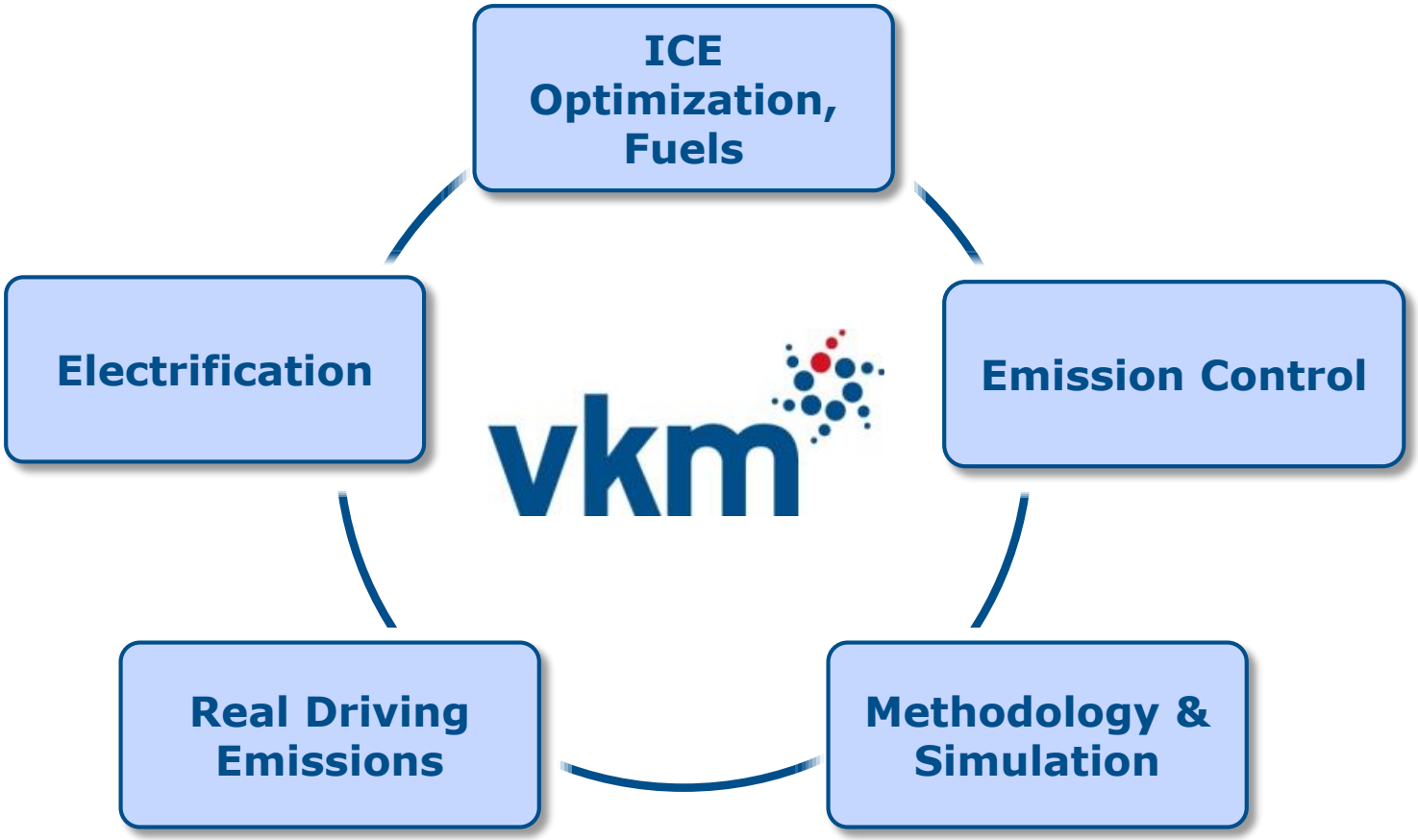

Research Area
ICE Optimization and Fuels

Special fuel supply on each testbed

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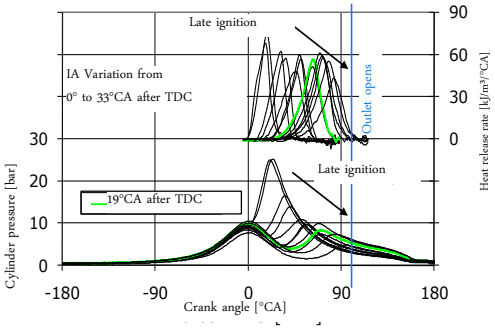
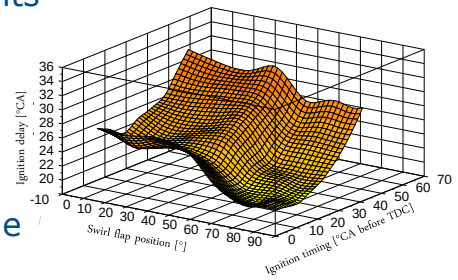
Thermodynamic Analysis

- Indicating
- Calculation
- Visualization
- Optimization of internal engine processes



Application

- Design of experiments
- Dynamic application
- Map based application
- Catalyst thermal management
- Freely programmable engine electronics



Gas Exchange

- Flow bench
- Simulation
- Optimization

Alternative Fuels

- CNG
- LPG
- GTL
- BTL
- H_2-Additives
- OME
- 1-Cylinder research engine

Special fuel supply on each testbed
World's first OME research vehicle

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Research Area
Emission Control

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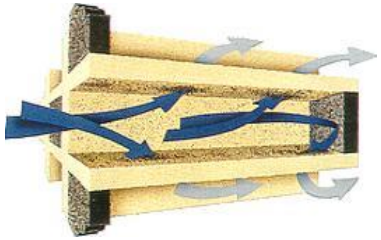
Analysis of DPF and GPF

- Heavy & light duty
- Maximum soot load
- Balance point
- Regeneration strategies
- Backpressure
- Filtration efficiency

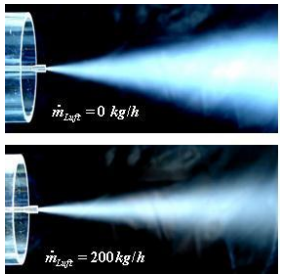


Catalyst Investigations

- Heavy & light duty
- Light-off determination
- Aging factors
- Sulphur contamination (DOC)
- Characteristics in dyn. test cycles
- Thermal management for catalysts
- Operating conditions and specific requirements in hybrid electric vehicles

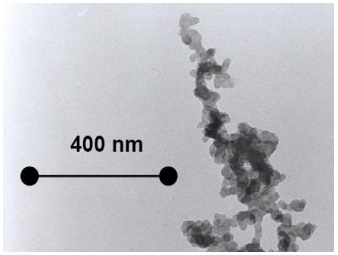
SCR-Analysis

- Heavy & light duty
- Light-off behaviour
- Dosing strategies
- NH_3-storage charact.
- NO_X-conversion
- Active / passive SCR
- Nozzle geometry / evaporation
- Catalytic reduction of particulate matter



Particulate Measurement

- Gravimetric analysis of TPM
- HPLC-Liquid-Chromatography
- Thermodissorption analysis
- Particle size distribution



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Research Area
Methodology and Simulation

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CAx-Systems

- CFD
- Combustion analysis
- Gas exchange calculation
- NVH-Simulation
- Drivetrain simulation
- CAD
- 3D vehicle / driving environment simulation

GT-Power

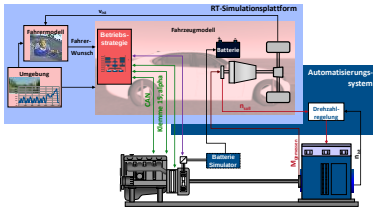
BOOST FIRE CRUISE EXCITE CATIA

Highly Dynamic Testbed

- High resolution simulation
- Driveability analysis
- Analysis of drivetrain dynamics
- Start simulation for component specification
- Drivetrain evaluation

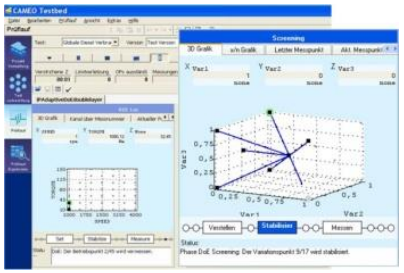
X in the Loop Test bed

- System design and construction
- Evaluation methodology
- Maneuver based testing
- Electric motor controller with universal inverter and battery simulator
- Implementation of the methodology in the development process
- Real Driving Emissions at the test bed



Test Design

- Design of Experiments
- Optimization of hybrid strategies using DoE
- Workshop for professionals and students



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Research Area Electrification

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Testbed

- X-in-the-Loop
- Vehicle realtime simulation
- Comparison vehicle – testbed with real world driving
- Concept evaluation
- Operating strategy
- Multicriteria optimization
- Battery simulation
- Measurement of electric motors

Testing Hybrids

- 3 own plus external hybrid test vehicles
- Concept evaluation & comparison vehicle – testbed on real world test tracks
- Mobile exhaust measurement
- Mobile combustion analysis



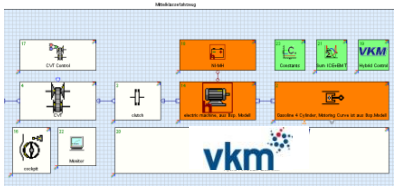


Concept development and application

- Range-Extender-Concept
- Comfort optimization
  - vibration damping with electrical motor
- NVH-Analysis and evaluation
- Operating strategy development and optimization
- Direct-start/ Hybrid-start


Simulation

- Realtime simulation
- Concept evaluation
- Fuel consumption simulation
- Driveability evaluation
- Offline optimization
- Real world driving
- RealSiMM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Research Area
Real Driving Emissions

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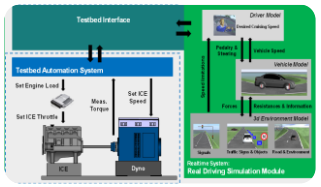
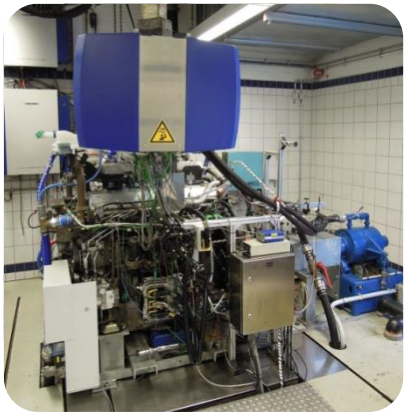
RDE at passenger car engine dyno with RDE module

- Realtime simulation of vehicle, driver, track and traffic
- Identification of critical emission relevant dirving scenarios
- Evaluation using EMROAD & CLEAR
- Operating strategy development
- Multicriteria optimization



RDE at heavy duty engine dyno with RDE module

- SCR system calibration with dosing strategy development
- DeNOx-Performance Optimization: stationary and transient
- RDE compliant engine design and combustion system development



RDE at chassis dyno

- Real time simulation of track and traffic
- Measurement with PEMS and stationary measurement systems
- Maneuver based RDE tests
- Robot driver or real driver

Road tests

- Measurement with PEMS System
- Influence of real driver characteristics
- Statistical evaluation of track severity

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Infrastructure & Equipment

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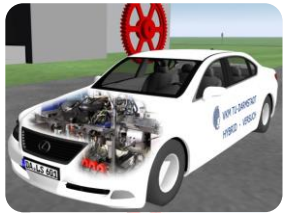
12 Testbeds
with Emission Testing &
Combustion Analysis

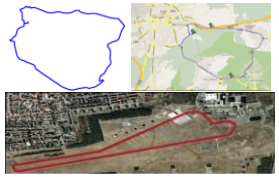
Highend-Multiflex
Testbed (VVETB)

4x4 Advanced
Chassis Dyno (TUZ)

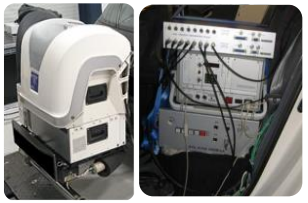


Hybrid Testbed
Engine-in-the-Loop

Test Vehicles



Test Tracks &
Real World Cycles



Vehicle Test
Instrumentation & Gas/
Particle PEMS

RT-Vehicle
Simulation

Flow Bench

Chemistry Lab

FTIR

Battery
emulator

Particle
Measurement

Simulation
Environment

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Mobile emission measurement
Real Driving Emissions

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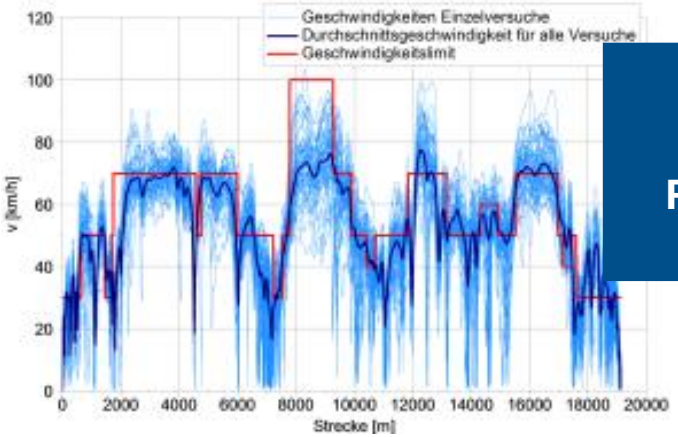
Real Driving Emissions – Development Methodology

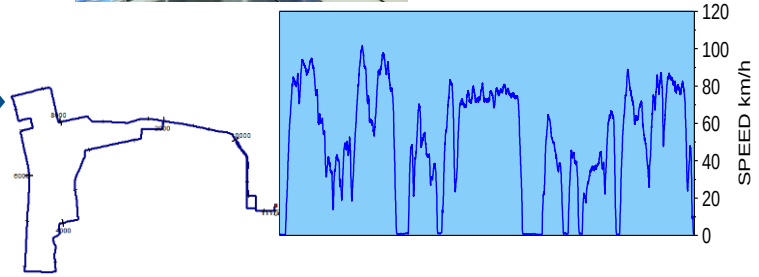


Transfer
Road-to-Rig

- Consideration of driver influence
- RDE Measurements (PEMS)

Evaluation of customer specific Real world driving scenarios

vkm - *RealSiMM*
Real World Simulation and Measurement Methodolgy
Real World Simulations- und Messmethodik



- Identification of significant scenario parameters
- Approach to parameterize for real driving scenarios
- Implementation of connected functionality

„Real world test“ for Engine-, Chassis- and X-in-the-Loop Testbeds

Cooperation with the Center for Innovation and Environment, TÜV Hessen

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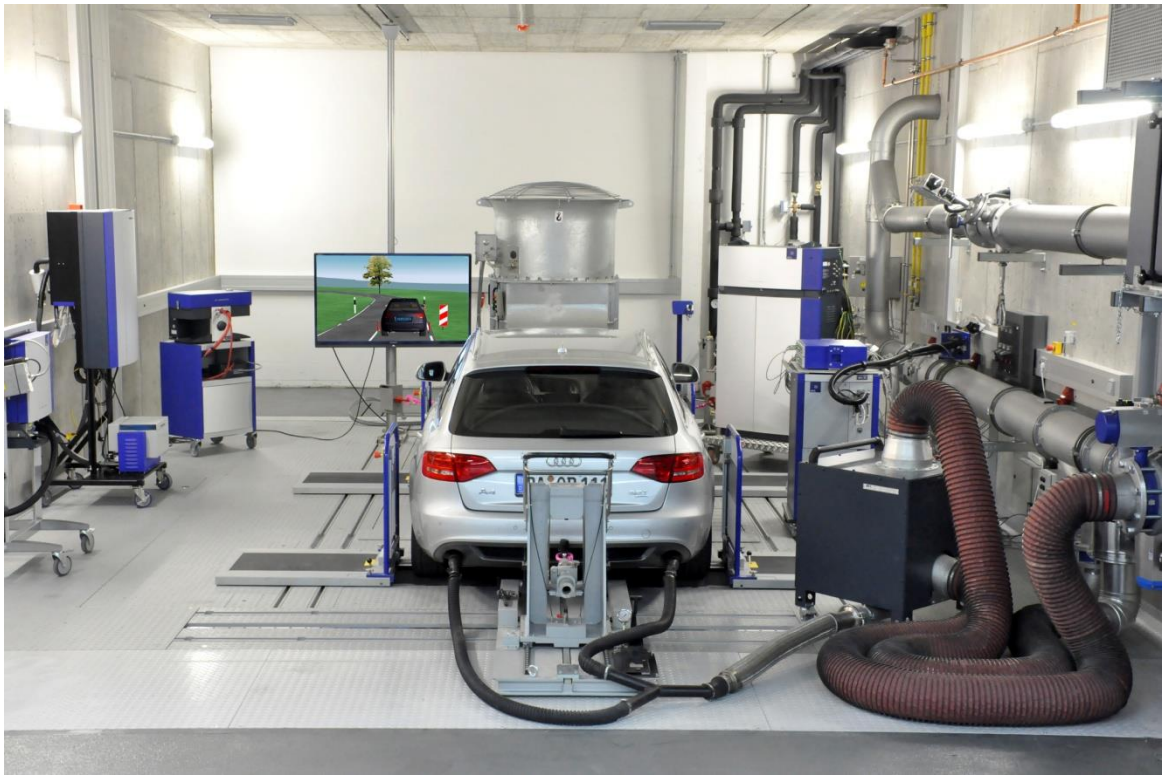
AVL 4x4 Advanced Chassis Dyno with RealTime Simulation



TUZ, TÜV Hessen, Pfungstadt

- **Consistent toolchain with engine and powertrain testbeds**
- **Idealy suited for manoeverbased testing and future RDE requirements**
- **Joint Methodology development with**

AVL

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E-Mobility and Hybrid Center

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- **Conceptualised for equipping vehicles with Conventional and Electrified Powertrains with Portable Emission Measurement Systems and other measurement devices**
- **Ideally suited for maneuver based testing and methodolody development for future RDE requirements**

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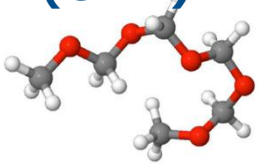
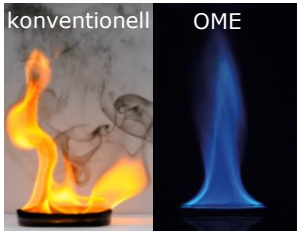
CO_2-neutral Synthetic Fuels

Example of CO_2-neutrale Synthetic Fuels : Oxymethylenether (OME)



CH_3-O(-CH_2-O)$_n$-CH_3

- Combustion process as in Diesel Engines
- Possibility of blending with conventional fuels
- Higher Oxygen Content in the molecule without C-C-Bonding
  - Soot free combustion
- Successfull Implementation and Validation in vkm-Test Vehicle



Renovation of Testbed Infrastructure 2010/2011

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Events 2018

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- Vehicle & Powertrain Seminar, TU Darmstadt
  Invited Keynote Speakers from Industry

- HdT Tagung – Plug-In-Hybride und Range Extender
  20.11. - 21.11.2018, Darmstadt

- Workshop Design of Experiments for students and professionals,
  25. - 27. September 2018, TU Darmstadt

ATZ live

- VPC - Simulation und Test 2017, 20. MTZ-Fachtagung,
  25. - 26. September 2018, Hanau bei Frankfurt am Main

- AVL Tech Day „Indizierung“,
  28. September 2017 , TU Darmstadt

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Publications 2017

TECHNISCHE UNIVERSITÄT DARMSTADT

- Maschmeyer, H.; Beidl, C: Konzeptspezifische RDE-Entwicklung auf Motorenprüfständen; Test Facility Forum 2017, Frankenthal, 26. September 2017
- W. Hauptmann, T. Utschig, B. Barth, C. Tomanik, U. Goebel, I. Grisstede, W. Mueller Umicore AG & Co. KG, Hanau, Germany, J. Hipp, C. Beidl Technische Universitaet Darmstadt, Institute for Internal Combustion Engines and Powertrain Systems: Challenge RDE: Sustainable Diesel Exhaust Systems for Euro 6d, 26th Aachen Colloquium Automobile and Engine Technology 2017
- Fischer, S., Beidl, C.: Potentials of the Plug-in-hybrid powertrain concept „Two Drive Transmission with Range Extender" (DE-REX) to reduce pollutant emissions, E-MOTIVE 9. Expertenforum Elektrische Fahrzeugantriebe, Hannover, September 2017
- Mokros, A.; Münz, M., Beidl, C.: Potential for ultra-low emissions with OME and TWC on a CI engine. 5th TMFB International Conference 2017. Aachen, Juni 2017
- Fischer, S.; Beidl, C.; Viehmann, A., Rinderknecht, S.: Plug-in-Hybride für den Volumenmarkt, In: MTZ – Motortechnische Zeitschrift Nr. 78 (2017), Nr. 5
- Hipp, J.; Beidl, C.; Noack, H.-D.; Göbel, U.; Grisstede, I.: The Diesel in the focus of urban air quality – Exhaust concepts to fulfill RDE, 17th International Symposium, Stuttgart, 2017
- Dautfest, A.; Thiem, M.; Beidl, C.: Entwicklung eines Batteriesystems für elektrifizierte LKW-Anhänger. Kongress Elektromobilität, Juni 2017.
- Maschmeyer, H.; Beidl, C.: Methodischer Ansatz für die RDE-Entwicklung am Motorenprüfstand, AVL TechDay Emission, Bietigheim-Bissingen, Mai 2017
- Eckert, M.; Thiem, M.; Beidl, C.: Development of an Electric Powertrain System for Truck Trailers, VDI-Tagung Nutzfahrzeuge 2017, Mai 2017
- Schmidt, D.; Beidl, C.; Steffan, R.; Hofmann, P.: Hybridisierung und 48 V – Eine bestechend effiziente Kombination, Artikel in ATZ-Extra „48 V – Konzepte für die Zukunft" Springer Vieweg April 2017
- Stritzke, F.; van der Kley, S.; Feiling, A.; Dreizler A.; Wagner, S.: Ammonia concentration distribution measurements in the exhaust of a heavy duty diesel engine based on limited data absorption tomography, Optics Express, Vol. 25, Issue 7, pp. 8180-8191, 2017.
- Münz, M.; Töpfer, D.; Mokros, A.; Beidl, C.: Oxygenate-fuel in a diesel engine – Is a CI engine capable of Lambda 1?, 4. Internationaler Motorenkongress, Baden-Baden, Februar 2017.
- Schoenhaber, J.; Kuehn, N.; Bradler, B.; Richter, J. M.; Bauer, S.; Lenzen, B.; Beidl, C.: Impact of European Real-Driving-Emissions Legislation on Exhaust Gas Aftertreatment Systems of Turbocharged Direct Injected Gasoline Vehicles, SAE Technical Paper, 2017-01-0924, 2017
- Vadamalu, R.; Beidl, C.: Online Optimization based Predictive Energy Management Functionality of Plug-In Hybrid Powertrain using Trajectory Planning Methods, SAE Technical Paper 2017-01-1254, 2017
- Fischer, S.; Beidl, C.; Viehmann, A., Rinderknecht, S.: Potenziale der hybriden Betriebsmodi des Plug-in-Hybrid-Antriebskonzepts „Doppel-E-Antrieb mit Range-Extender" (DE-REX), Der Antrieb von morgen, 11. Internationale MTZ-Fachtagung Zukunftsantriebe, Frankfurt a. M., Januar 2017

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Publications 2016

TECHNISCHE UNIVERSITÄT DARMSTADT

- Feiling, A.; Beidl, C.: PM-Reduktion über Vanadium-SCR-Katalysatoren, ATZlive – Heavy-Duty, On- und Off-Highway-Motoren, Ulm, November 2016.
- Münz, M.; Mokros, A.; Beidl, C.: Ermöglichen Oxygenat-Kraftstoffe den Drei-Wege-Katalysator am Dieselmotor?, 14. FAD-Konferenz „Herausforderungen – Abgasnachbehandlung für Dieselmotoren", Dresden, November 2016.
- Schmidt, D.; Maschmeyer, H.; Beidl, C.; Raß, F.: Neue Verfahren zur effizienten antriebsstrangdspezifischen RDE-Entwicklung, MTZ-Fachtagung „VPC.plus", Hanau, September 2016
- Maschmeyer, H.; Beidl, C.; Düser, T.; Schick, B.: RDE-Homologation – Herausforderungen, Lösungen und Chancen. In: MTZ – Motortechnische Zeitschrift 77 (2016), Nr. 10
- Vadamalu, R.; Beidl, C.: Vorausschauendes Energiemanagement von Hybridantriebssträngen mit deterministischen und stochastischen Prädiktionsansätzen, 13th International Symposium on Advanced Vehicle Control, September 2016
- Kettmann, N.; Schöffel, St.; Feiling, A.; Kontin, S.; Hermann, T.; Beidl, C.: Combines Visualization and Thermography of Wall Film Formation and Deposit Build-Up for Urea-Water-Solution, 6th International Conference "MinNOx", Juni 2016.
- Vadamalu, R.; Beidl, C.: Online optimizing plug-in hybrid energy management strategy for autonomous guidance and drive-aware scenarios, 9th IFAC Symposium on Intelligent Autonomous Vehicles, Juli 2016
- Vadamalu, R.; Beidl, C.: Explicit MPC PHEV Energy Management using Markov chain based predictor: Development and Validation at Engine-In-The -Loop testbed, European Control Conference, Juni 2016
- Vadamalu, R.; Beidl, C.: Online MPC based PHEV Energy Management using Conic Interior-point Methods, IEEE Intelligent Vehicles Symposium, Juni 2016
- Vadamalu, R.; Beidl, C.: MPC for active torsional vibration reduction of hybrid electric powertrains, IFAC international symposium on advances in automotive control, Juni 2016
- Vadamalu, R.; Thiem, M.; Beidl, C.: Methodology for model-based development, validation and calibration of connected electrified powertrain systems, Conference on Future Automotive Technology (CoFAT), Mai 2016.
- Viehmann, A..; Fischer, S.; Rinderknecht, S.; Beidl, C.: Vergleich von Betriebsstrategien für das parallel-serielle Hybridantriebskonzept 'DE- REX', HdT-Tagung Plug-In-Hybride und Range Extender, Darmstadt, April 2016
- Vadamalu, R.; Beidl, C.: Online optimization based energy management of hybrid electric vehicles using direct optimal control method, 16th Stuttgart International Symposium, März 2016.
- Feiling, A.; Japke, E., Beidl, C.; Deutschmann, O.; Grunwaldt, J.-D.: FVV-Abschlussbericht 1146 – PM Reduktion über V-SCR, FVV-Frühjahrstagung, Bad Neuenahr, März 2016

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Publications 2016/2015

TECHNISCHE UNIVERSITÄT DARMSTADT

- Münz, M.; Feiling, A.; Beidl, C.; Härtl, M.; Pélerin, D.; Wachtmeister, G.; Lehrstuhl für Verbrennungskraftmaschinen (Ivk), Technische Universität München: Oxymethylene Ether (OME1) as Synthetic Low Emission Fuel for DI Diesel Engines. 3. Internationaler Motorenkongress. Baden-Baden. Februar 2016
- Münz, M.; Feiling, A.; Beidl, C.: Potenzial des synthetischen Kraftstoffs OME1b für den rußfreien Dieselmotor. Artikel in MTZextra „Kraft- und Schmierstoffe der Zukunft". Springer Vieweg. Februar 2016
- Beidl, C.; Waldhelm, A.; Rathgeber, C.; Hipp, J.; Hohenberg, G.; IVD Deutschland GmbH; Grisstede, I.; Noack, H.; Spurk, P.; Göbel, U., Umicore AG & Co. KG, Hanau-Wolfgang, Germany: Challenge Clean Diesel: Robust Exhaust Aftertreatment Fulfilling RDE and CO2, 9. Internationales Forum Abgas- und Partikel-Emissionen 23. und 24. Februar 2016 „Forum am Schlosspark" Ludwigsburg
- Feiling, A.; Münz, M.; Beidl, C.: Potential des synthetischen Kraftstoffs OME1b für den rußfreien Dieselmotor, MTZextra 01/2016 „Kraft- und Schmierstoffe der Zukunft", Springer Vieweg, Januar 2016
- Beidl, C.; Hipp, J.; Hohenberg, G.; IVD Deutschland GmbH; Göbel, U.; Grißtede, I.; Noack, H.; Welchsc, F.; Umicore AG & Co.KG: Clean Exhaust Gas and Low Fuel Consumption: Exhaust System Concepts for the Diesel of Tomorrow, 8. Emission Control 2016 Dresden
- Maschmeyer, H.; Schmidt, D.; Beidl, C.: Simulations- und Testmethoden für die Entwicklung von Fahrzeugantrieben unter Real Driving Emissions Randbedingungen, 6. Internationales Symposium für Entwicklungsmethodik, November, 2015
- Vadamalu R.; Beidl, C.: Methodik zur funktionalen Evaluierung und Robustheitsanalyse einer online-optimierenden Längsführung in einer vernetzten Umgebung, 17. MTZ-Fachtagung, VPC – Simulation und Test, Oktober 2015
- Vadamalu, R.; Buch, D.; Xiao, H.; Beidl, C.: Energy Management of Hybrid Electric Powertrain using Predictive Trajectory Planning Based on Direct Optimal Control, 16th IFAC workshop on control applications of optimization, Garmisch-Partenkirchen, October 2015
- Münz, M.; Beidl, C.: Indizierung am Einzylindermotor mit alternativem Kraftstoff OME (Oxymethylenether). AVL Tech Day „Indizierung". Darmstadt, September 2015
- Buch, D.; Beidl, C.; Hohenberg, G. (IVD): Möglichkeiten der Drehschwingungsberuhigung bei Parallelhybriden mittels E-Motor; VDI- Tagung: Schwingungsreduzierung in mobilen Systemen 2015, Karlsruhe, April 2015
- Dr.-Ing. F. Atzler, Dipl.-Ing. M. Wegener, Dipl.-Ing. (FH) F. Mehne, Dipl.-Ing. (FH) S. Rohrer, Continental Automotive GmbH, Regensburg; C. Rathgeber, M.Sc., S. Fischer, M.Sc., Institut für Verbrennungskraftmaschinen und Fahrzeugantriebe, TU Darmstadt: Kraftstoffverbrauch und Emissionseinflüsse der „Phlegmatisierung" von PKW-Dieselmotoren, HdT-Tagung Motorische Verbrennung, Erlangen-Nürnberg, April 2015
- Dr.-Ing. F. Atzler, Dipl.-Ing. M. Wegener, Dipl.-Ing. (FH) F. Mehne, Dipl.-Ing. (FH) S. Rohrer, Continental Automotive GmbH, Regensburg; C. Rathgeber, M.Sc., S. Fischer, M.Sc., Institut für Verbrennungskraftmaschinen und Fahrzeugantriebe, TU Darmstadt: Fuel consumption and emissions effect from the „phlegmatisation" of a passenger Car Diesel engines, SAE World Congress 2015, Detroit (USA), April 2015

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Education

TECHNISCHE UNIVERSITÄT DARMSTADT

Institute for Internal Combustion Engines and Powertrain Systems

- **Lectures**
  - Verbrennungskraftmaschinen I + II
  - Konstruktion im Motorenbau I + II
  - Berechnungsmethoden im Motorenbau I + II
- **Bachelor and Master theses**
- **Tutorial for students**
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