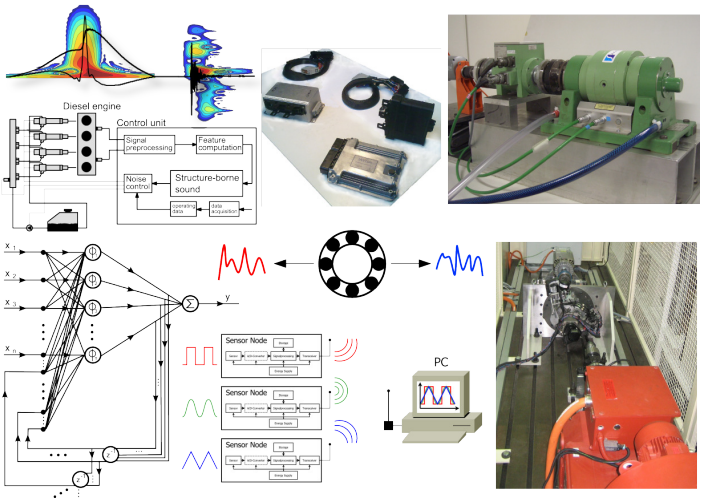
Technische Universität Berlin

Annual Report 2010



Electronic
Measurement and Diagnostic Technology

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Dear ladies and gentlemen,
dear colleagues and friends,

by tradition we would like to give you a review of the year's events. In March we started the new project VEROLAT (VERbesserte Oel- und LAgersystem für Triebwerke - Lagermonitoring/improved oil and bearing systems for jet engines - condition monitoring), which is funded by the Bundesministerium für Wirtschaft und Technologie. At the end of 2010 we finished the development of our transmission test bench. With this new test bench we can strengthen our experimental research competence in the field of mechatronics. In this annual report you will find more details about the test bench, an overview of the other projects

- Noise Controlled Diesel Engine
- Nonlinear System Identification - NoSI
- Automated Calibration and Data-based Enhancement of Electro-chemical Battery Models
- Condition Monitoring and Fault Diagnosis of Electrical Machines
- Fast Parametrization of "Grey-Box" Models of a Double Clutch Transmission
- Nonlinear Control Strategies for Automotive Transmission Systems
- Model-based Calibration of Automated Transmissions
- Integration of Driver Assistance Systems Information into the Shifting Strategy of Automated Manual Transmissions
- Hybrid Bearing Monitoring
- Sensors for intelligent Signal Processing and Wireless Sensor Networks
- Application oriented Optimization of Matrix Factorization Methods for Technical Diagnosis

and a summary of our teaching activities.

A special highlight in 2010 was the conference "Simulation and Test" (SuT). It was carried out in cooperation with the IAV GmbH. During this scientific conference 110 modeling, simulation and test experts discussed new trends and could exchange ideas.

Currently we are organizing the sixth international conference "Design of Experiments in Engine Development" (DoE) in cooperation with the IAV. In May scientists and developers from all around the world will discuss modern development methods for combustion engines here in Berlin. A special focus will be the identification of nonlinear dynamic systems. We would be pleased by your attendance.

We welcome Prof. Sibylle Dieckerhoff in our Department of Energy and Automation Technology. Since Autumn 2010 she is the head of the Chair of Power Electronics.

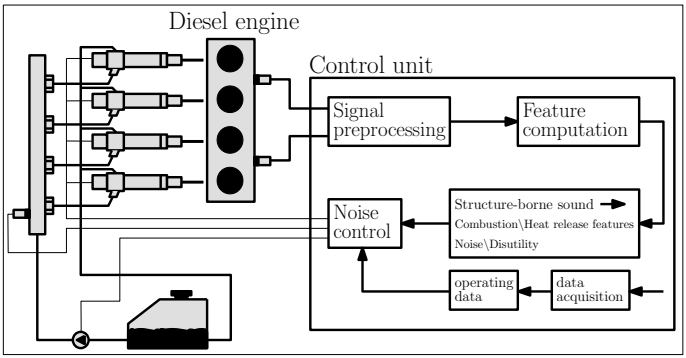
I would like to thank all partners and the whole MDT-Team. I hope you will enjoy our annual report. Please contact us if you have any questions or comments. I wish you and your families a blessed Christmas *and a Happy New Year,*

Clemens Gühmann

Noise Controlled Diesel Engine

Marco Decker (Publications 2010: [1],[2],[3],[4])

Present diesel vehicles are already characterized by favorable fuel consumption and low harmful emissions. The research project "Noise Controlled Diesel Engine" funded by the "Forschungsvereinigung Verbrennungskraftmaschinen" (FVV e.V.) analyzes possible improvements concerning fuel consumption, noise and exhaust emissions by integrating structure-borne sound signals into the engine management system. In compliance with legal regulations a weighted optimum of consumption, exhaust emissions and airborne noise emitted is to be obtained. However, this will only be possible if the characteristic Diesel knocking which is emitted during start- and warm up phases as well as in lower rotational speed and load ranges can be reduced to an acceptable level.
This year we started with the correlation analysis between airborne- and structure-borne sound features. Based on subjective criteria, methods have been developed to classify the annoyance of airborne sound. As it is not possible to measure the airborne sound directly within the engine compartment of a standard vehicle the structure-borne sound has to be analyzed. The working thesis was, that if a correlation between the two sound types could be found, it would be possible to integrate the annoyance of the noise into the engine management system. Measurements within part-load operational range at different speeds and loads were conducted at the Chair of Reciprocating Machines at the "Otto-von-Guericke-University Magdeburg". From these tests a high degree of correlation between the airborne- and the structure borne sound features was found.



In the next step these features from a structure-borne sound signal will be used in an engine management system which will be calibrated by the IAV GmbH. The final control design shall give a weighted optimum between fuel consumption, exhaust emissions and noise emissions.

Nonlinear System Identification - NoSI

Jan Malte Riedel (Publications 2010: [9])

The NoSI Project aims at building a data driven model of a combustion engine. To increase the dynamic simulation capabilities of the overall model, multiple data based modeling approaches are tested for each of the engine parts (e.g. combustion chamber, intake tract, cooling system).
As most of the framework for the data driven modeling in the Toolbox for Dynamic Modeling (TDM) was brought into place during the last year, this year has been mostly filled with research into additional modeling structures and their implementation. A first 'practical test' was conducted by modeling various emissions of a diesel as well as a gasoline engine. As the focus of the NoSI Project is still on the dynamic modeling of engines with off- and online methods, adaptive methods have been examined for selected modeling structures - some of which will be implemented into the toolbox as well. In addition the TDM has been put to good use in various student projects: some students using the already existing model structures and learning algorithms (Mr. Unverferth, Mr. Kleinschnitker and Mr. Rudorfer); other students researching further training algorithms and/or implementations (Ms. Lozada Bello, Ms. Radtke, Mr. Xuan, Mr. Queisser and Mr. Zhao).

Automated Calibration and Data-based Enhancement of Electro-chemical Battery Models

Joachim Priesnitz

For conventional vehicle engines the model-based calibration approach can be described as state-of-the-art. By creating simulation models of a combustion engine and the use of appropriate algorithms it is possible to find an optimal engine calibration. This offline pro-

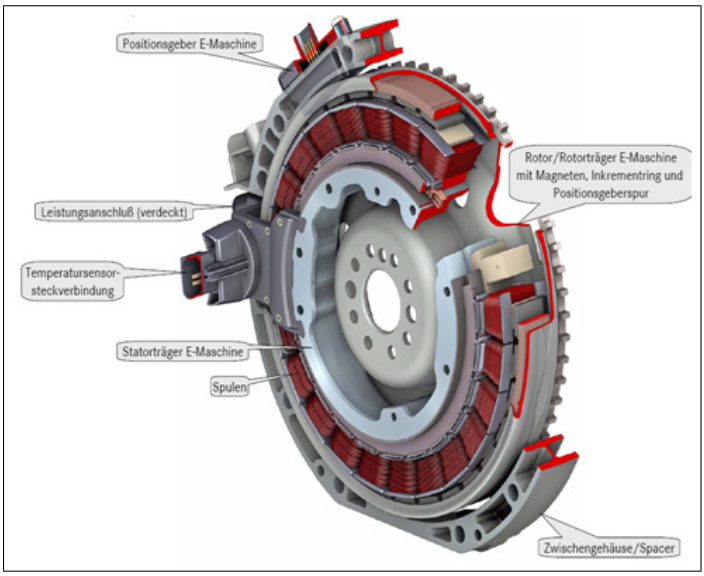
cess reduces the need for expensive test bench time significantly.
Since hybrid and electric vehicles are becoming more relevant and will soon be established in the market, new, fast and reliable methods have to be developed in order to adapt conventional development processes to the new technology.
A special and novel field in electric vehicle development arises from the need of storing energy. In addition to the research concerning chemical and physical matters efforts in software and diagnostic technology will increase. Therefore modeling and simulation of electric vehicles and its components will be required as well.
Due to this our project focuses on the modeling of energy storages. In order to acquire measurement data a small test facility was set up. With this test stand it is possible to charge and discharge different battery cells with desired load cycles. For the identification and modeling process, different approaches have been investigated. On the one hand electro-chemical relations lead to equations which can be used to simulate the electrical behavior. On the other hand representation of batteries can be based on equivalent circuit diagrams. Both of those knowledge-based methods will be combined with data-based, stochastic model approaches. This consequent enhancement will result in an extension of the knowledge-based models with data-based submodels ("grey-box"). Prior knowledge of the system yields the physical part and will present a reasonable framework for the model. The data-based parts will describe physical effects, which cannot be modeled adequately by physical equations. The physical part, however, could provide a better performance for the estimation of output values in areas where the data-based models could only extrapolate them. It will also be investigated whether the estimation quality for dynamic behavior can be improved by only using steady-state measurements (e.g. DoE test plans).
The main goal of automatic parametrization and enhancement of different models will be pursued by the use of nonlinear optimization algorithms. First experiments with Evolutionary Algorithms showed promising results. Particle-Swarm-Optimization (PSO) and other Genetic algorithms are investigated as well.

Overall there are many interesting and promising applications, which motivate the aim of realizing this methodology. In this context a request for an electric test vehicle was made, which would be used for data acquisition and evaluation.

Condition Monitoring and Fault Diagnosis of Electrical Machines

Eduard Backhach - Daimler AG

The electrical machine becomes more and more important in alternative driving concepts and is an elementary component in hybrid-, electrical- and fuel cell vehicles. The effect of faults in the electrical machine on the vehicle operation depends on the kind of fault. During vehicle operation, the occurrence of faults in the machine can cause reduced driving quality, increased emissions/ fuel consumption (in hybrid vehicles) and in the worst case unwanted breakdowns. To ensure the vehicles availability and to meet global legal requirements for environmental protection, efficient and accurate on-board monitoring algorithms are necessary. Moreover, in order to support an efficient repair in production and after sales service an efficient 'pinpointing' of faults is needed.



The aim of the current dissertation, which is carried out in cooperation between the Daimler AG and TU-Berlin, is to develop methods for the on-board monitoring of faults in electrical machines with focus on synchronous machines. Aging, vibration or overloading are the main causes of faults. Common types of faults are: insulation

faults, stator faults resulting in the opening or shorting of one or more stator phase windings, bearing failures and irreversible magnet demagnetization. Furthermore, faults in the temperature sensor and speed-sensor can occur.

The challenge of this work is to develop appropriate diagnostic methods for the detection of these faults by means of one generalized approach that can be run on an on-board computer with limited resources. This leads to the investigation and combination of different methods in order to meet the diagnostic requirements with a minimum of effort. The approach is verified by simulations in Matlab/Simulink, using real measured data of the test bench and the vehicle.

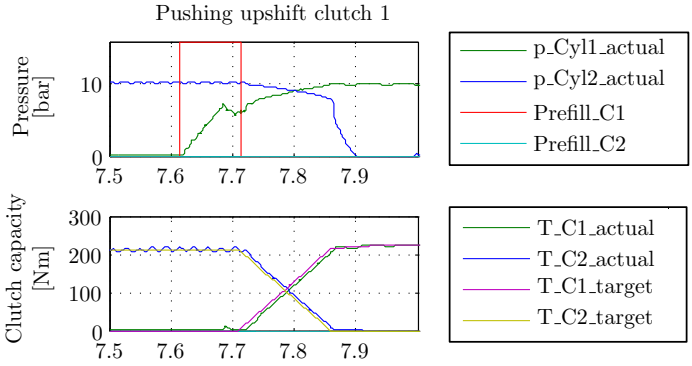
Fast Parametrization of "Grey-Box" Models of a Double Clutch Transmission

Sebastian Nowoisky

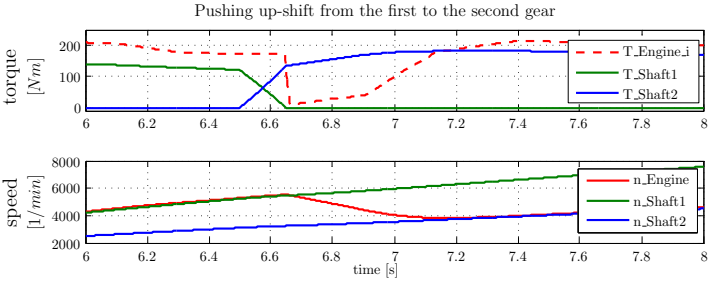
As the software development for automated transmissions is key in producing the characteristic behavior of the different powertrain types (e.g. economic, comfortable, sportive), reduction in its development time while keeping the quality constant is highly valued. Using model-based software development it is possible to test the dynamic behavior of powertrains and their software outside of an actual test bench.
Two different approaches will be tested in this project: The first is the modeling with physical equations which requires a high degree of knowledge about the process. The second is data based modeling which describes the system in a mathematical structure that models only the input-output behavior without physical interpretation of the process. Both methods will be tested and the results compared to determine the feasibility of both approaches or even a combined one.

In this year the main focus has been on developing a detailed model of a double clutch transmission based on physical equations. For that, a detailed model of the hydraulic clutch system was generated (Mr. Chi Shen). This model contains hydromechanic components like a pump and proportional valves. In the first figure the simulation results of the pressure and the clutch capacity of the new clutch model are shown.
The time delay of the clutch system is minimized by using a pre-fill function. With the increased pressure the friction plates

close faster. The clutch then starts transferring the torque which is also called capacity. Currently the development of a detailed model of a synchronization is in progress (Mr. Xi Zhang).



New software functions have been developed due to the models higher level of detail. These new functions were added to the existing basic shift strategy. As verification for the two different models an improved shift strategy had to be developed. The performance of the actual shift strategy could be increased by a mix of open and closed loop control. In the next figure simulation results of an up-shift process with the torque and the speed of the engine for each of the input shafts of the transmission are shown.



The next step is to evaluate methods for data based modeling by means of the detailed clutch model. With this model, the first algorithms of data based models will be trained and tested. This work is still in progress (Mr. Xianghui Zhao).

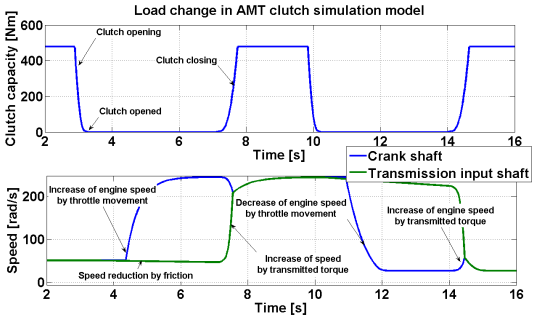
With the modeling and parameterization of friction elements (e.g. bearings), the transmission model should be finished in the near future. Afterwards the focus lies on the evaluation of the data based models.

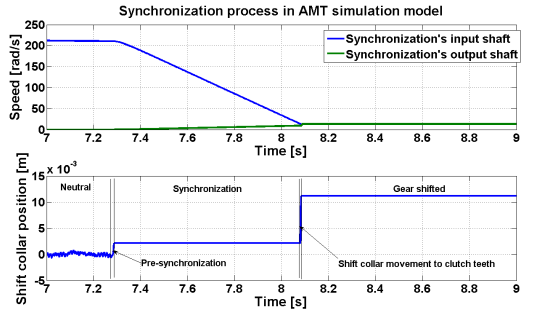
Furthermore, several projects could be finished. One of them is the successful performance check of the TestWeaver HiL-Plugin (Mr. Michael Hartmann).

Nonlinear Control Strategies for Automotive Transmission Systems

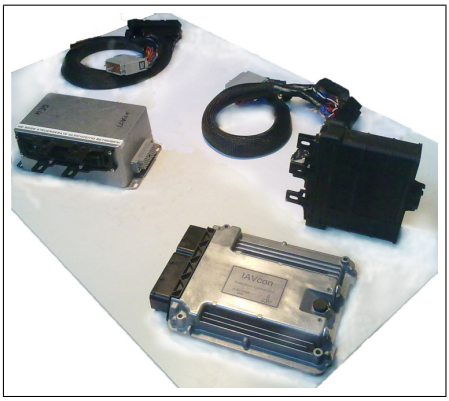
René Knoblich

The first step towards the implementation of nonlinear control strategies was the realization of a detailed simulation model of a 5-gear automated manual transmission under MATLAB®/SIMULINK®. Besides the major components of the automotive drivetrain like the combustion engine, the friction clutch and the transmission stage this model contains the electrohydraulic and the mechanical clutch actuation system and the synchronization system. Due to this model accurate simulations of load changes and the synchronization process are possible and the influences of the different nonlinearities can be observed.





Based on this simulation model a gain-scheduling control system for the clutch position is being designed and evaluated at present. This control structure consists of nine different linear controllers and a scheduling vector. Using the scheduling vector as an indicator the controller management structure activates switch overs between these different controllers. Two switching strategies are going to be evaluated: The 'hard' switch over by simply changing the controller parameters and the 'smooth fade over' of the control variables controlled by an appropriate fade over function (linear/gaussian).



Beyond that the tool chain for the research in the field of nonlinear control for automotive transmissions was improved: A simple transmission control unit (TCU) application software was developed for the rapid prototyping environment used on the test bench. In addition the rapid prototyping control unit was integrated into an experimental car and the test bench's control system is being enhanced by a model-based control strategy.

Wear processes in clutch and gear actuating systems

The simulation model of the clutch system mentioned above was improved by a simple clutch wear process model. The wear process model describes the loss of material caused by the sliding phase of the clutch. During the clutch's life time material loss causes a decrease of slackness in the mechanical actuation system and changes in actuation forces - the reason for possible performance problems of the used controllers. The next steps are going to be a further extension of the clutch wear process model by a friction coefficient depending on the temperature history and a wear process model for the synchronization system.

Model-based Calibration of Automated Transmissions

Hua Huang

Due to increasing vehicle emission standards and higher requirements on driving comfort and maneuverability, modern automotive transmissions such as automatic manual transmission (AMT) and double clutch transmission (DCT) have been invented, which automatically shift gears according to the driver's pedal movements to keep the combustion engines under optimal conditions. On the other hand, however, more advanced transmission systems also present more difficult challenges to researchers and technicians. The increased number of gears, more transmission variants and a tremendously expanded body of control parameters make manual calibration more time-consuming and cost-intensive.[1]

It has been noted that the method of Design of Experiments (DoE) is particularly suitable for comparing different component variations and their effects on object performance. Moreover, the model-based calibration process for combustion engines developed on both DoE and dynamic engine models has been proven to be an effective approach to significantly reduce measurements made purely for calibration purposes. So it seems natural to go further in the upcoming project by applying relevant methods[2] and bringing in important elements from other optimization methods[3] to efficiently calibrate the shift quality and gear shift points of automated transmissions on a test bench.

The first step in this is to simulate the dynamic model of automated transmission with Modelica®, followed by modeling the needed soft transmission control unit using Simulink® and Stateflow®. Subsequently they will be tested in a real-time application such as Hardware-in-the-Loop. In the last phase the strategy will be put to use on a real test bench for verification.

[1] It can be taken from statistics that at least 15,000 parameters need to be calibrated for a single automated transmission.

[2] such as evaluation of the measurements with DoE and adjacent map optimization

[3] such as gradient descent, genetic algorithms and pattern search

Integration of Driver Assistance Systems Information into the Shifting Strategy of Automated Manual Transmissions

Prof. Ruijuan Chi - China Agricultural University (Beijing)

Driver Assistance Systems (DAS) are in-vehicle systems that aid drivers in avoiding or mitigating accidents by sensing the traffic environment and controlling the vehicle. Usually DAS focus on increasing car safety. In this project DAS information (traffic lights signals and road curvature) is integrated into the shifting strategy of Automated Manual Transmissions (AMT) to cut down on pollution and fuel consumption by reducing braking and idling at stop lights or reducing braking before a turn. First, the traffic lights module and the shifting-strategy controller module are built in Simulink®. The traffic lights module can simulate the changes of traffic lights on a real road and send the information to the shifting-strategy controller. Based on this the controller can work with the information which light is on and the time when the next light will turn on. The speed of the car and the distance between the car and the stop line can be fed into the controller module as well. At this point, the controller module can decide whether the car should go or stop. The shifting-strategy of AMT is studied to reduce braking and idle time as well as to keep the car driving stably through the crossing which will reduce pollution and fuel consumption in the process. As a second step, the shifting-strategy of AMT according to road curvature is studied. To this end, we build a road curvature module which can simulate a road and give different curvatures of turns. Then the shifting-strategy controller can use a suitable gear-shift and keep an appropriate car speed to avoid braking before the turn which will also help in saving energy.

Hybrid Bearing Monitoring

Marc Seimert

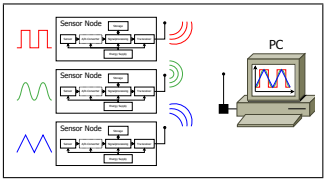
The aim of the project VEROLAT (VERbesserte Oel- und LAgersysteme für Triebwerke) is to research new bearing technologies, especially the use of hybrid bearings (ceramic rolling elements between steel races) in aircraft engines and to optimize the oil system in the bearing chassis.
In this project the following companies and research institutes are involved: Rolls-Royce Deutschland Ltd & Co KG, Dahlewitz; FAG

Aerospace GmbH & Co. KG, Schweinfurt; Universität Karlsruhe ITS - Institut für Thermische Strömungsmaschinen; Fraunhofer Institut für Werkstoffmechanik (IWM) Freiburg and last but not least our chair (MDT).
In times of climate change this project is a small step towards the development of new aircraft engines with reduced emissions. Hybrid bearings have important advantages over conventional steel bearings, including higher stiffness to achieve higher engine speed and lower friction to reduce losses. It is however much more difficult to conduct failure diagnosis or life time prognoses for them.
The objective of our project is to develop a monitoring system that detects damages and the failure progress in hybrid roller bearings. To this end an embedded system which consists of sensors and a signal processing unit usable in aircraft engines is to be developed.
Failure detection, classification and prediction should be designed in a way that they can be integrated into an aircraft engine monitoring system.
The first year was dominated by literature research on damage detection via vibration measurements, the development of first signal models of damaged bearings and the search for additional measurement techniques.
For the next year test runs on a bearing rig at FAG Aerospace GmbH & Co. KG and the Universität Karlsruhe as well as analyzing the measurement data from these tests and the evaluation of different damage detection algorithms are planned.

Sensors for intelligent Signal Processing and Wireless Sensor Networks

Jürgen Funck

Nowadays, there is a strong development towards ever more detailed process models and intelligent control strategies in the automotive industry. To this end more and more parameters are measured simultaneously. This development has led to an ever increasing number of sensors in test bench deployments as well as prototypes. As a consequence the complexity of wiring all these sensors has sharply risen slowing down the development of new systems.



This could be significantly simplified by the use of wireless sensor nodes as they do not require any wiring.

In addition wireless sensors can be put in places where the use of wired ones would be infeasible, e.g. fast moving parts.

This year a sensor platform for research in this field was built up. It is based on the intelligent wireless sensor node Preon8 of the Virtenio GmbH and the Contiki Operating System from the Swedish Institute of Computer Science (SICS).

The sensor nodes have already successfully been used for data acquisition in this year's measurement data processing lab.

In student projects the following basic signal processing algorithms were ported to and optimized for the intelligent sensor nodes:
Fast Fourier Transform (Mr. Wiktor Pronobis), FIR digital Filters (Mr. Maik Pflugradt) and Cross-Correlation (Mr. Samuel Robert Lacmene and Mr. René Lee Vás Rodrigues).

Furthermore, a module for the acquisition of analog data was designed within a student project (Mr. Erik Kallenbach and Mr. Daniel Kotschate).

Intensive research was done on preexisting algorithms for time synchronization in wireless sensor networks. An overview was compiled which was supplemented by the seminar paper of Mr. Frank Wutzler. Some algorithms have already been implemented on our sensor platform in student projects: an algorithm for the synchronization of two sensor nodes (Mr. Sven Garrit Czarnian, Mr. Jakob Glienke and Mr. Stefan Jacobi) and an algorithm to synchronize a sensor node to the ntp-time of a computer network (Mr. Birtan Özel).

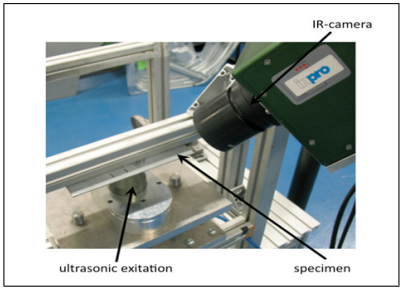
The next step is to equip our testbed for three-phase electrical engines with a wireless network and to develop algorithms for the synchronized data acquisition in this setup.

Application oriented Optimization of Matrix Factorization Methods for Technical Diagnosis

Boris Zubert - INPRO mbH (Publications 2010: [10])

Pulse thermography is an imaging measurement method in which a body in thermal equilibrium is stimulated by a thermal pulse. The infrared radiance of this process is then recorded by an IR camera.

This transient follows Fourier's law of heat conduction. On the right an experimental setup is shown, where ultrasonic excitation is used to apply the thermal pulse to a specimen of two steel sheets that have been adhesively bonded and spot welded.



Pulse thermography has a high capability for non destructive inspection[4], because of its ability to detect structures like defects behind the inspected surfaces. To realize an automated method of inspection, the information whether a specimen is defective or flawless has to be extracted form the IR-Film. This is usually done in several processing steps which contain the reduction of the film to an information bearing representation - a gray scale picture - as one of the first steps followed by feature extraction and decision making. These representations can be calculated by pixel wise applying Fourier analysis, principal component analysis or other matrix factorization methods. This provides a variety of more or less redundant representations.

In this work an algorithm is developed and explored to combine information bearing representations of an IR-film for NDE. A fusion method using cluster analysis is developed and applied. The second picture shows a ground specimen (destructive testing) with gaps of adhesive in the upper part and a representation of the IR-film of this specimen in the lower part. This representation is a fusion of 5 basic representations generated by Fourier analysis, principal component analysis and non-negative-matrix-factorization. The goal of this work is to enhance the accuracy for pulse thermographic inspection of join connections as applied in automotive industries.

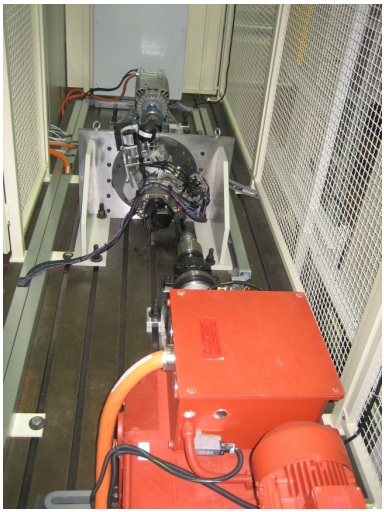
[4] also called Non Destructive Examination (NDE)

Center for Automotive Transmission Systems

Sebastian Nowoisky

René Knoblich

At the end of 2010 we are proud to present the new transmission test bench infrastructure of the MDT. The year started with the delivery of the drive engines as well as the commissioning of the fundamental electrics and the control software. In May test bench components like the gearbox carrier, the crank shaft bearing, overload protection clutches and the torque measurement equipment were integrated into the setup and tested.



During the following two months we developed a test bench control program under LabVIEW® and implemented a basic TCU software for the control of the coupling and shifting process. On the 5th of July we obtained the opportunity to present the test bench and the first results of our work to the public at 'Die Lange Nacht der Wissenschaften'. About 150 interested visitors joined our tour through the automotive transmission technology and the demonstrations of the launch and the shifting process on the test bench.

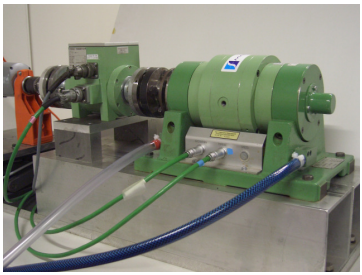
Furthermore, the electrical installation was under way. More than $600\ \mathrm{m}$ of cable with different profiles ranging from 0.15 to $90\ \mathrm{mm}^2$ were installed. After a review of the electrical circuit diagram, the CAD drawing was extended to more than 110 pages. In August and September the mechanical setup was improved. Additionally the implementation of the safety functions for the safe test bench control was started.

The safety fence was installed in the end of October. One month later, the safety functions were tested and recorded by the safety engineer of the TU Berlin. The tests included an emergency stop from 2800 to $0\ \mathrm{rpm}$ within $2.25\ \mathrm{s}$. With all safety nets active each

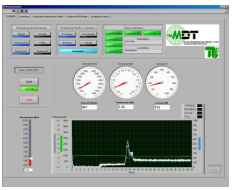
drive is monitored for the safe limited speed (SLS) and the whole testbed can be shut down in case of an emergency stop (NOT-HALT) within three seconds (SS1) which includes putting the engines in a secure mode (safe torque off - STO).
In 2011 the development of a model-based control strategy for the transmission test bench containing models of a simple combustion engine and a chassis is planned. Moreover, to simulate different test cycles a detailed model of the test bench with the mechanical and the electrical components will be developed.
We'd like to thank everyone, who supported the development and the installation of the test bench.

Motor Test Bench with a Powder Brake Dynamometer

Frank Baeumer



Thanks to the work carried out by Mr. Schmidt in his diploma thesis and the assistance of our workshop our powder brake is operational again. Our Chair is now able to determine the characteristics of an electrical motor in a torque range from 0-10 Nm and a speed range from 0-4000 $\frac{1}{min}$ on our own test bench. The powder brake provides full torque at zero speed and the calibration of the torque measurement unit can be done anytime by placing calibration-weights on a lever.

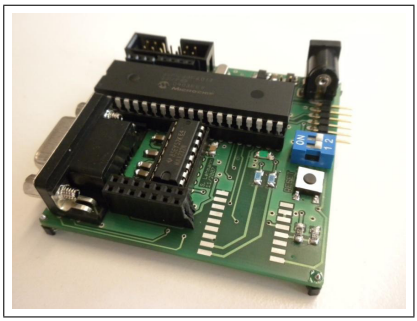


The new software for the control and operation system of the powder Brake was realized with the visual programming language LabVIEW®. You can see the LabVIEW® control panel in the figure to the left. The test bench also includes a separate speed and torque measurement device. Both actual values of that device are read in and displayed by the central control and operation system.

A new water cooling system with a 10 liter tank and a circulation pump was installed to provide the necessary cooling for the powder brake.

International Engineering Summer School

Jürgen Funck, Joachim Priesnitz



This year two groups of students from the University of Michigan joined researchers at the TU Berlin for a summer school course. One group stayed with the Chair "Energieverfahrenstechnik und Umwandlungstechniken regenerativer Energien" of Professor Behrendt while the other joined the MDT research laboratory. The program was mentored by Professor Sick (University of Michigan). The overall aim of the course was to give the students an insight into an field of science where they usually can't get hands on experience during their studies as well as to learn about German culture, language and industry.

This year the 8 students at MDT had the task of building a digital instrument tuner for the tuning of a guitar's strings. This included the assembly of a microcontroller board with a microphone module as well as the implementation of software for the acquisition and analysis of sound signals. Through this they were introduced to soldering of electronic components, the programming of microcontrollers in the C programming language as well as the theory of the discrete Fourier transform. The course ended with a presentation for all people involved in this years summer school were the students showed the capabilities of their freshly build digital instrument tuner in a live demonstration.

Publications in 2010

[1] M. Decker, M. Ebel, P. Schmiechen, C. Haukap, and C. Gühmann. Analyse und Bewertung des Dieselgeräusches aus Körperschallsignalen. In *Fortschritte der Akustik : DAGA 2010 ; 36. Jahrestagung für Akustik*, 2010.

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Dissertations in 2010

Stephan Rein:

Low Complexity Text and Image Compression for Wireless Devices and Sensors
Day of the PhD defense: 27. Januar 2010

Steffen Kühn:

Stochastic Engineering - Berechnung, Bewertung und Modellierung bei unsicherer Information
Day of the PhD defense: 20. Mai 2010

Nicolas Lewkowicz:

Simulationsgestützte Untersuchung verschiedener Umrichtertopologien im mechatronischen Verbund hybridelektrischer Straßenfahrzeugantriebe
Day of the PhD defense: 5. Oktober 2010

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Courses

summer term 2010

Measurement Data Processing	Lecture & Laboratory
Model-Based Software and Function Development	Lecture & Laboratory
Control and Regulation of Automotive Powertrains	Lecture
Graduation seminar on Measurement Technique	Seminar
Measurement Data Processing	Projects
Simulation and Technical Diagnostics	Projects

winter term 2010/2011

Basics of Electronic Measurement Techniques (MT I)	Lecture & Laboratory
Basics of Electronic Measurement Techniques (MT I)	Tutorial
Introduction to Automotive Electronics	Lecture & Laboratory
Modelling and Real-Time Simulation	Lecture
Graduation seminar on Measurement Technique	Seminar
Measurement Data Processing	Projects
Simulation and Technical Diagnostics	Projects