SPECTRUM

„IT`S ALL ABOUT SOFTWARE“

VIRTUAL ENGINE
Multidisciplinary approach to firing order optimization

TOPEXPERT
Quality and efficiency in the competition of modern markets

PERSIST
Enabling success through modularization

CONNECTIVITY
The car as mobile sensor
Dear readers,

In recent decades, the development of software for automotive products has rapidly gained in importance. For many solutions, around the propulsion system, in the chassis area, or in the vehicle interior, the statement “it’s all about software” has become very common. The importance of software in the area of propulsion systems development has greatly increased with the introduction of hybrid and electric vehicles. Now begins the generation “drive and surf” to make demands on the in-vehicle software. C2X and ADAS are mutually influencing systems here. “Always on” in the automobile causes “seamless automatic driving” to be a requirement in the automotive development space. As a result, “functional safety” and the testing of new systems are of great importance.

In the background, the automobile and IT industry compete for the vehicle owners as their future customers. FEV has grown in parallel with this market and does business in both the development of software for all types of propulsion systems as well as all other vehicle electronic systems. As our customer, you are able to observe this development already in many examples. Rest assured that we will continue to meet your growing needs also in the future.

Dr. Thomas Hülshorst, Vice President Electronics & Electrification
FIRING ORDER: A COMPLEX MULTIDISCIPLINARY OPTIMIZATION TASK
SELECTION OF THE FIRING ORDER IN FEV VIRTUAL ENGINE

The continuously increasing mechanical and thermal load of modern engines calls for design optimizations over a wide range of aspects. The development process of many engine components supported by various computer simulations is currently advanced and well-defined, leading to the creation of highly optimized products. However, the optimization of design variables such as the firing order, which influences engine operation with respect to several disciplines, is still challenging. To bridge this gap, the Firing Order Investigation Tool under implementation for the commercial simulation software FEV Virtual Engine can play a central role in the realization of this comprehensive task.

Firing order optimization problem
The selection of a firing order for engines with only a few cylinders is a rather simple task, as the alternatives are limited. However, the number of possible firing sequences rises sharply with the number of cylinders, and in engines such as the V16 or V20 it reaches hundreds or thousands of possibilities.

The firing order influences crank train vibration (torsional or axial), overall vibration of the engine structure including NVH behavior, performance of hydrodynamic bearings, and gas dynamics at the intake and exhaust ducts, thus making selection of the firing order a comprehensive multidisciplinary optimization problem.

New Virtual Engine tool supporting firing order selection process
The key functionality of the FEV Virtual Engine’s Firing Order Investigation Tool is the so-called crankshaft-based firing order definition procedure, which automatically generates a list of all alternative firing orders for a defined crankshaft design, preserving the desired engine balancing concept and significantly reducing the number of firing order alternatives to only the technically feasible ones.

Exemplary torsional vibratory stress amplitudes of V16 engine for alternative firing orders realized by one crankshaft design

By using the fast solver of FEV Virtual Engine’s Crank Concept Analysis (CCA) tool, which couples torsional vibration simulation in the frequency domain with quasi-static bending analysis, the full factorial investigation of the firing order influence can be executed very efficiently.

The Firing Order Investigation Tool is additionally equipped with a unique evaluator, where not only CCA results but also results derived from external software and detailed design simulations can be considered.

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QUALITY AND EFFICIENCY IN THE COMPETITION OF MODERN MARKETS

TOPEXPERT: AUTOMATED AND VIRTUAL CALIBRATION AS KEYS TO SUCCESS

To meet the strong competition in the worldwide vehicle markets, the complexity of modern engines and their respective engine control units has increased drastically over the last few decades. An exploding amount of hardware variants, several hundred function groups, and up to 40,000 calibration parameters are state of the art and define the daily work of the designated engineers. In contrast to that, development cycles and budget as well as the amount of available project vehicles have been reduced continuously.

To overcome these challenges, new approaches in all contributing parts of the development process are required. It's necessary not only to do things right, but also to do the right things at the right time. This is expressed, for example, in the idea of consequently moving reasonable parts of the work to earlier stages in the development process. The concept is widely known as “Road 2 Rig 2 Desktop.”

Vehicle calibration work is shifted to the chassis dynamometer or test bed facilities. Test bench tasks are processed and solved by means of “in-the-loop” solutions - such as model-, hardware- and software-in-the-loop (MiL, HiL, SiL, etc.) or even full simulation. It is directly obvious that all of these steps require a reasonable amount of knowledge about the behavior of those components that are necessary to be removed while stepping back along the process. As a replacement, data-driven and physical models fill the gaps.

Benefits of the TOPEXPERT environment

FEV's excellence in virtual calibration additionally manifests itself in our TOPEXPERT framework. It smartly connects the diversity of all the expertise and know-how of FEV's engineers to the benefit of the user. This ranges from FEVcal, the new solution for Design of Experiment, over domain-specific tools, to the general Framework for Automated Calibration and Evaluation (FACE) and Vehicle Test Automation (VTA). All these are built on the basis of a generalized software architecture and thus ensure close integration of all TOPEXPERT tools.

The user experiences a unified handling and usability based on a guided calibration approach by means of workflows. All actions are performed in terms of activities, which are assembled in task- and domain-tailored combinations. This eases the learning and makes the interaction with the tools fluent, intuitive for the respective field of usage, and, on request, specifically adapted to directly match the customer’s needs.

Fig. 1: Actuator linearization
Fig. 2: Plant identification and parameter optimization

WITH TOPEXPERT THE USER EXPERIENCES A UNIFIED INTERACTION CONCEPT OF GUIDED CALIBRATION BY MEANS OF WORKFLOWS

Hands-on TOPEXPERT – One calibration in a day

A very important aspect of any software with a complex technological background is its capability to make the theory as easy as possible to apply, even for less experienced users. One of many examples is the interaction of VTA, FACE, and FEV’s test bench automation system TCM. It serves the goal of fully automated boost pressure governor calibration. Operation points for required step response measurements are selected by VTA automatically and the respective tests are performed with TCM. After finishing a required set of measurements, the acquired data is seamlessly evaluated with FACE. Sections of importance are determined, plant identification is performed and the final PID controller parameters are optimized. These results are pushed into smooth calibration maps and their closed loop performance is directly validated via TCM. In this way, the typically manual and iterative task of parameter tuning is solved by means of a tailored model-based solution and leads, in its fully automated fashion, to massively increased efficiency.

Written by: Matthias Krause krause_m@fev.com

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Written by: Matthias Krause krause_m@fev.com
The biggest challenge in software safety analysis is the high level of complexity in today’s software architectures. This complexity is due to the presence of various layers as well as the distributed nature of many development efforts where faults and their effects cannot be analyzed by one party alone. As a result, a common understanding of the method to be used and the necessary scope and depth of the analysis is essential. In addition, the interfaces that must be established for the analysis need to be defined. Thanks to experienced interdisciplinary project teams that also work intercontinentally, FEV is able to develop processes that meet all of these criteria. Furthermore, FEV has experience in collecting the corresponding data for any third party components, interfaces, and their specific functionalities. In the context of this interdisciplinary effort where faults and their effects cannot be analyzed by one party alone, a common understanding of the method to be used and the necessary scope and depth of the analysis is essential. In addition, the interfaces that must be established for the analysis need to be defined. Thanks to experienced interdisciplinary project teams that also work intercontinentally, FEV is able to develop processes that meet all of these criteria. Furthermore, FEV has experience in collecting the corresponding data for any third party components, interfaces, and their specific functionalities.

FEV has developed a practical approach to these analyses. Based on the example of a transmission control software, Bastian Wirges, Functional Safety expert at FEV explains the basics of safety analysis of software architectures.

ISO26262 requires various safety analyses on software architecture, posing a huge challenge to developers. On the one hand, evidence must be provided indicating that all software elements that are required to fulfill the system level safety mechanism are developed in accordance with the assigned ASIL (Automotive Safety Integrity Level) and are effective. The second safety analysis demonstrates the freedom of interference and sufficient independency by analyzing common causes and cascading failures originating in the design of the software architecture.

Mr. Wirges, could you explain your approach with the help of a simplified part of the software architecture?

Let’s have a look at an operation where our aim is to determine and actuate the next target gear for a transmission. At the transmission system level, the functional chain must be analyzed using the HAZOP guide words such as: “too high,” “too low,” “too early,” “too late,” “too fast,” “too slow”. A “too low” gear could lead to the wheels locking up, which is a violation of a safety goal on the vehicle level. Therefore, a safety mechanism must be defined to monitor a potential actuation of a “too low” gear.

And then?

For the analyses of the software architecture, the entire architecture has to be analyzed along the control- and dataflow, with a focus on the interaction between different software components and common resources. At this level of analysis, software specific guidewords according to the Software Hazard Analysis and Resolution in Design Method – SHARD – are used. These aspects include guidewords such as “omission,” “commission,” “coarsely incorrect,” “subtly incorrect,” “wrong timing.”

What does this mean for the example of our transmission?

If the information about the lowest allowed gear is received “incorrectly,” the monitor will not be able to work effectively. This is, therefore, a cascaded failure. If the information is “omitted” or contains the “wrong timing,” the monitor will not be able to work at all. Therefore two additional safety mechanisms need to be added to the system: a protection of the information exchange and a monitor that checks whether the generation and transmission of information is handled properly and in a timely manner.

How do these analysis results impact the whole development process?

In the example, the results ended up in a design decision, namely the implementation of parts of the information protection in one central software component. A fault in this component is, therefore, a common cause failure, which leads to another safety mechanism that monitors the protection handling itself. The analysis stops at this level, as the system has to be capable of handling double faults or latent faults only.

FUNCTIONAL SAFETY
FROM THEORY TO PRACTICE
SAFETY ANALYSES OF SOFTWARE ARCHITECTURES

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In SPECTRUM, Dr. Thomas Hülshorst, Vice President Electronics & Electrification, and Dr. Axel Schloßer, Director Software Solutions, explain the challenges in development.

Dr. Hülshorst, what makes integrated systems so important in automotive applications?

As a cross-sectional technology, integrated software systems are a key enabler. Today, modern vehicles already have up to 100 million lines of code in their software, which is seven times more than in a Boeing 787 Dreamliner, for instance. Making this scope of software available with a sufficient level of quality is one of the key challenges for the future.

Dr. Hülshorst: Based on empirical evidence, we have to assume that, per 1,000 lines of code, there are between 0.5 and 20 errors in the software. If you take the aforementioned 100 million lines of code, this means that you have to expect at least 50,000 errors.

Schloßer: This highlights the importance of quality assurance measures – be it through processes, methods, or tools. In the area of automated driving, it is expected that the time and effort for validation increases by a factor of 10^6 to 10^7. Accordingly, new approaches also have to be systematically pursued in the area of integrated systems testing. Additionally, the agilization of proven processes in compliance with defined milestones plays a large role.

What tools do you use to respond to these challenges?

Schloßer: At FEV, we have established a dedicated test center for integrated systems for this purpose. It is known within the company as FEST, it makes secure testing operations possible 24 hours a day, even across continents.

Hülshorst: The reason this is so important is that, for connected vehicles, for instance, entirely new partners such as telecommunication companies, network providers, and telematics companies also have to be involved in the end-to-end consideration of the development process. FEST bundles all activities regarding the verification and validation of integrated systems. This promotes the creation and exchange of the knowledge basis and enables us to react very flexibly to even the most diverse project requirements.

What would appear to be the key question in development is HOW the software is developed.

Schloßer: Exactly. Over the past few years, we at FEV have systematically built up core skills to respond to this very question. The basis for software development is consistent, modular, and reusable architecture.

Hülshorst: Even at this early phase, the requirements regarding safety and security are taken into account. On this basis and using additional standards, the automation of software development is advanced as much as possible. Here as well, FEV has developed an automated tool chain named ASSIST. Such an automation is not only necessary in light of increasingly complex software, but also because there is already a lack of personnel with the corresponding qualifications. The competition for the best and the brightest will be considerably tougher in the future and can be at least softened a little through the measures we have taken.
ENABLING SUCCESS THROUGH MODULARIZATION

PERSIST: DOMINATING THE COMPLEXITY OF SOFTWARE DEVELOPMENT

Embedded software development is highly challenged by system complexity as well as variant diversity. Intelligent system and software architectures are required to provide timely and safe control features to the end customer. A modular function library plays a key role in mastering these challenges. FEV has developed a software solution to these challenges that can be applied throughout the entire development process.

Incomplete standards

FEV has been collaborating with global car manufacturers and suppliers to standardize functions according to the Automotive Open Software Architecture (AUTOSAR) consortium. Nonetheless, significant standardization gaps have been detected when developing series software in a real world project context. Basic layer functions only partially comply with requirements for diagnostics and safety, not to mention the integration of other systems (e.g. infotainment). In parallel, supporting tools need to be extensively adapted to profit from standardized tool interfaces. Finally, application-specific control features are heavily underspecified and still very specific to each manufacturer and supplier. The problems of complexity, variability, and compatibility remain unsolved.

Object-oriented design of control functions

PERSIST is the consequent approach to the consistent application of the AUTOSAR architecture concept at the application layer. Architecture guidelines were defined on the basis of vast experience in a diverse number of series software projects. These guide the developer from requirement definition to implementation. Control functions are reflected in an object-oriented approach where the system is divided into its physical properties and software is compiled based on a library that depends on the system properties. The PERSIST library includes functions for both gasoline and diesel engines, transmissions, and various configurations of electrified powertrains, including battery management.

Performance and efficiency proven in projects

“We have applied PERSIST within over 20 projects over the past 5 years, enabling us to build up a function library that enables us to dominate complexity and increase testability,” explains Dr. Thomas Hülshorst, Vice President Electronics & Electrification. This has become a basis on which multiple drivetrain control projects have been successfully realized. Additionally, FEV’s experience across projects with varying maturity targets from prototype up to highly safety-critical systems can be efficiently provided to each developer. FEV’s process and automation framework, ASSIST, also includes variant and release management using a database-centered approach.

“Through PERSIST we not only enable complexity handling but also the management of rapidly growing numbers of variants and efficient reuse of control functions over multiple projects and applications,” says Hülshorst.

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Performance and efficiency proven in projects

FOR DEVELOPING SERIES SOFTWARE, AUTOSAR STILL HAS HUGE GAPS

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Less time and costs through reuse: The PERSIST toolchain enables tailor-made embedded software services within one common and reusable framework for all development steps.
Modern process model: The classic V-Model was extended to optimally apply the technology of model-based software development. Development is shifted from the code level to the model level wherever possible.

Seamless development process: The process model is complemented by responsibilities, interfaces with milestones, and process instructions. The superordinate process is stable, and the individual process steps can be tailored based on the project context.

Consequent automation: All development steps are supported by automation. The degree of automation is increased continuously.

Higher quality: A block library combines recurring operations and ensures hundred percent coverage – from Rapid Control Prototyping to safety-relevant series software.

Lower costs: Development efficiency increases sustainably, because the software is already textually described within the model. Fully automated formal documentation occurs including the model as well as parameter description from a database.

Reduced risk: Automatic code generation, compilation, documentation, and substantial model checks can be executed by the developers as well as within a continuous integration system. Quality risks are detected at least daily, to allow for early countermeasures.
structured and efficient
integrated verification and validation of embedded systems

Automotive innovations are increasingly derived from advances in control software. As quality requirements remain constant within a growing software environment, more encompassing test activities are required. With the FEV Embedded Systems Test Center (FEST), FEV is pursuing an integrated approach for the verification and validation tasks demanded by embedded systems. FEST scope of activities includes not only the application of various test methods, but also the creation of real-time capable simulation models and the execution of the associated test management methods.

“Test management is among one of the most important disciplines and comprises not only the scheduling of tests along project milestones within the Design Verification Plan & Report (DVP&R),” explains Ralf Maquet, team leader of the FEV Embedded Systems Test Center. “It also includes the subsequent tracking of quality defects as well as the selection of the test methods that are to be applied.” The test manager can access an FEV-developed test catalog that enables a customized selection of test methods for a project on the basis of parameters such as software maturity level or safety classifications according to ISO26262.

Automated testing
As development periods become shorter, an increasing demand is placed on the automated execution of test cases. Testing of software models is accomplished by static analysis or functional unit tests as part of continuous integration. For the automation of Hardware-in-the-Loop tests, the required test scripts can be created from test specifications with an in-house developed toolchain. Project-specific efforts for manual test execution as well as for automation will be minimized. All results will be stored in databases and can be provided to the developer automatically.

Global networking
By involving national and international subsidiaries on several continents, verification and validation tasks can be done not only offshore, but also closely located to the customer. Including international locations not only enables the potential of cost reduction, but also a continuous testing process across various time zones and thus shorter development cycles along with constant test quality.

Virtual Verification and Validation
The already precise simulation models of today allow for the future relocation of applications to a virtual environment. Thus, calibration activities can be started even sooner in the development cycle. Additionally, driving maneuvers can be reproduced exactly and parameters automatically optimized.

Within the FEV Embedded Systems Test Center, FEV is testing a wide variety of automotive control units – for example from the areas of powertrain, infotainment, or telematics. The activities are increasingly focused on the verification and validation of collaborative system networks. The basis for this is the strong crosslinking of various systems – from advanced driver assistance systems to Car2x communication and autonomous vehicles.

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Software is the key innovative solution for the automotive industry. But successful development of embedded software can only be achieved through a clear appreciation for the continuous social and economic changes that occur as soon as the industrial development evolves. In the foreground of the changes to which the development must flexibly react are the customer’s requirements. Commitment to mobility behavior and change to a digital technology is also equally important.

**Diversified teams for excellence**

In addition to proving the latest serial products and innovative functionality on demonstration vehicles, FEV has long-term experience in powertrain development and software engineering. Established organizational structures at FEV ensure that software development teams have the essential professional know-how in every discipline, for example, for Automotive Electronics, car2x communication, infotainment applications and telematics.

FEV also has the ability to develop software in conjunction with global cooperation in a customized and cost-efficient way. The worldwide network of FEV locations is a key strength. In this case, the development teams can be formed independent of the location, in order to create high-quality products with a competitive budget.

**INFO**

**FEV key factors in software development:**

- Organization and processes: combination of mature and agile processes, aiming at mature developed strategies
- Integrated development: systematic approaches regarding architecture development and test strategy that realize the benefits of front loading due to a continuous automated tool chain
- Excellence in the area of application: the combination of outstanding skills in software development with excellent knowledge of the driveline, in order to provide outstanding functional quality

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Onboard telematics systems form the foundation for connected mobility solutions. These systems collect, aggregate, and facilitate the exchange of the data generated in the vehicles with third parties. “We are deeply involved in the development of such systems and provide solutions for many different facets of connected mobility,” explains Dr. Thomas Hülschorst, Vice President Electronics & Electrification at FEV. “Our subsidiary, DGE Inc., has been an industry development partner for tailored telematics solutions for more than a decade. Thanks to the addition of this expertise, we can now offer a broad range of services from design to end-to-end-validation.”

FEV - CONNECTING VEHICLES
THE CAR AS MOBILE SENSOR

What is the current traffic situation? Are there any hazards ahead? What is the traffic light phasing? What is the current charge state in my electric vehicle? The continually expanding networking between vehicles and their surroundings is an important trend in future mobility. Novel driver assistance systems and value-added services are greatly assisted by an intensive exchange of data via Car-to-X communication, making tomorrow’s mobility safer, greener and more comfortable.

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Mastering the complexity of modern telematics systems
Automatic test systems such as the FEV Telematics System Tester are instrumental in mastering the complexity of contemporary telematics systems in combination with back-end and internet services. “Our test systems can simulate both GPS and cellular radio signals. Additionally, the FEV Telematics System Tester can reproduce the complete communication chain from a smart device to the back end, on to the head unit and then further into the vehicle’s CAN bus. This allows easy validation of arbitrary scenarios.”

Data, data, data
The distribution and storage of the data being exchanged is another important aspect of connected mobility applications. The main challenges are the sheer volume of data generated, the data rates, as well as the heterogeneity of the data. IBM has estimated that, already in 2015, there will be more than 200 million connected vehicles in the world exchanging more than 400 billion GB of data. In parallel, the security of the data must be ensured at all times.

Platform independent and proven: telematics solutions by FEV
Based on the experience gained in various projects and many years of expertise in automotive development and software engineering, FEV engineers are able to support the development and implementation of powerful connected mobility solutions.

Since 2010, FEV has operated a fleet of connected electric vehicles for which all of the important vehicle parameters have been continuously collected and evaluated while operating in the field, using cloud-based services. One example of this is an FEV developed, cloud-based application that calculates the remaining range of an electric vehicle, based on vehicle data and other sources. “Other examples from our ongoing development projects include an application for cooperative detection and warning of hazard areas via car-to-cloud and car-to-car communication and an information service for localized, high-resolution weather data based on collected vehicle information,” concludes Hülschorst.

In addition to the design of back-end systems, data transformation and routing services, FEV also supports the user front end development which is an important element in using these telematics applications and enabling the configuration of the services from within as well as outside of the vehicle. In this field, FEV engineers focus on platform-independent web technologies to realize the corresponding apps and ensuring seamless integration with a variety of devices.

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FEV software is delivered with detailed manuals, tutorials, and workshops. For support, individual technical requirements or special training please don’t hesitate to contact the service hotlines.

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Detroit, Michigan, USA
Vienna, Austria
28.04.-29.04.2016 8th TM Symposium China (TMC 2016)
Beijing, China

MAY
May 2016
May 25.-27.05.2016 FEV Tech Day Stuttgart
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25.05.-02.06.2016 Automotive Testing Expo 2016
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01.06.2016 FEV Virtual Engine Day China 2016
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01.06.-02.06.2016 SIA Powertrain - Rouen 2016
Rouen, France
06.06.-10.06.2016 28th CMAC World Congress 2016
Helsinki, Finland
08.06.2016 MSC Software 2016 Users Conference
Tokyo, Japan
14.06.-15.06.2016 FEV Conference: Diesel Powertrains 3.0
Leipzig, Germany
21.06.-23.06.2016 International VDI Congress: Drivetrain for Vehicles
Friedrichshafen, Germany
29.06.2016 FEV Day of Powertrain China 2016
Yanjiao, Beijing, China
29.06.-01.07.2016 JSAE Automotive Engineering Exposition 2016 Nagoya
Nagoya, Japan

On June 14 – 15, 2016 “Diesel Powertrains 3.0”, FEV’s major exchange platform for Diesel Experts will take place in Leipzig, Germany. By providing in-depth topics illuminated by international industry peers the conference will give insights into the future of modern Diesel powertrain development.

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DIESEL POWERTRAINS 3.0
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