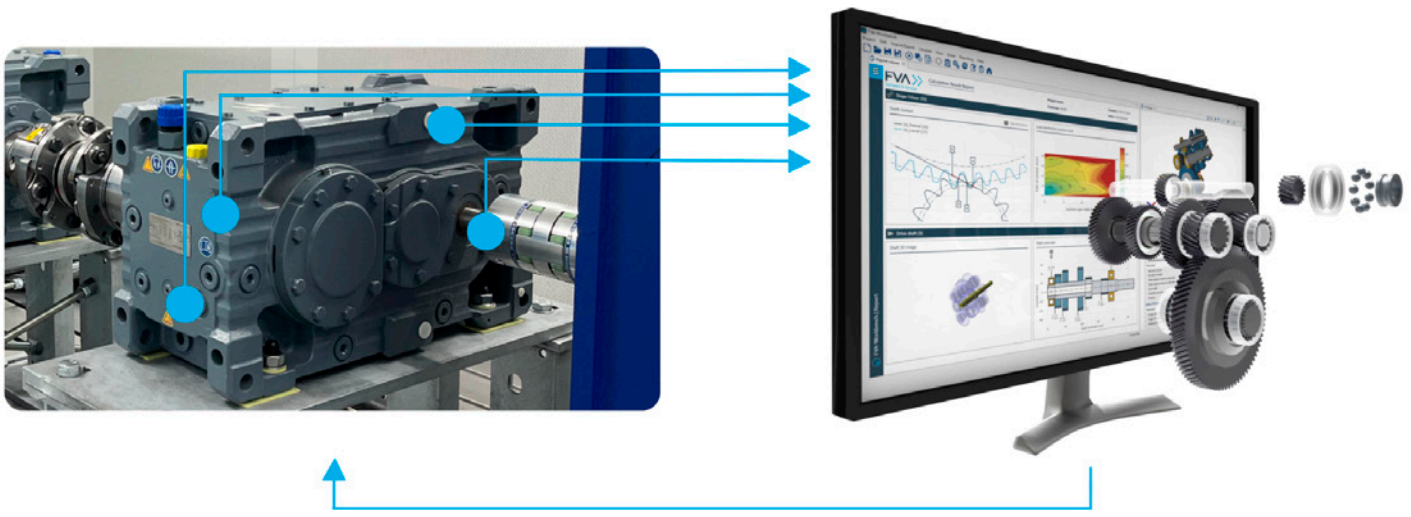
FVA-Workbench: The Foundation for Digital Twins



Software offers efficient and user-friendly solution for creating industrial gearboxes

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The digital transformation is fundamentally changing the industry, and digital twins play a central role. They enable real-time monitoring of physical systems, simulation of their behavior, and informed decision-making. A dissertation from the TU Darmstadt Institute for Product Development and Machine Elements (pmd) shows how the *FVA-Workbench* gearbox design software can be implemented as a platform for creating digital twins of industrial gearboxes. The results demonstrate how the combination of detailed modeling, continuous real-time calculations, and engaging dashboard visualization offers an efficient and user-friendly solution for the development of digital twins.

What Is a Digital Twin?

Digital twins of technical systems offer a broad spectrum of potential applications (Attaran and Celik 2023). The term refers to a digital representation of a concrete physical system. In this article, a digital twin is regarded as a digital representation of the physical model with a live data connection. During operation, sensor and operating data is continually recorded and provided to the digital twin. This data serves as input parameters for models which simulate the actual system and describe its behavior. Thus, its behavior can be calculated or simulated live, making it possible to make predictions and draw conclusions (Stark et al. 2020; Czwick et al. 2020; Wilking et al. 2021).

FVA "Digital Twin II" Research Project

The topic of digital twins and their creation is being intensively researched by the TU Darmstadt pmd together with the FAU Erlangen-Nürnberg Engineering Design KTmfk as part of the FVA 889 II—"Digital Twin II" research project. A central component of this project is developing a prototype for a digital twin of a Type X2FS100e two-stage industrial gearbox from SEW-Eurodrive *(see image above left)*. This gearbox is part of a test setup at TU Darmstadt and can be loaded with targeted speed and torque settings. Various sensors are installed in and on the gearbox to record operating data. In this case, the speed and torque are particularly relevant. The measurement data is stored in real-time on a server at TU Darmstadt.

An Overview of New Features in FVA-Workbench 10

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The *FVA-Workbench* is a manufacturer-neutral solution for modeling, parameterization, and simulation of transmission systems. *Version 10* was released on February 17, 2025, to make gearbox design even more efficient.

2D Modeler: Faster and easier design changes

The new 2D Modeler makes it possible to quickly and easily modify geometries, shafts, and positions in a single plane. This is especially useful for shaft modeling: the shaft contours can be intuitively edited and modified, which greatly simplifies design and troubleshooting. Another highlight is snap and grid functionality for efficiently adjusting component positions. For example, a rolling bearing can be moved specifically to the shaft edge – the 2D Modeler automatically "snaps" the edge of the rolling bearing to the edge of the shaft, which saves time and enables precise placement of gear elements. This makes subsequent adjustments easier than ever.

Shorter calculation times thanks to modularization of ISO 10300 calculations

Bevel and hypoid gear load capacity calculations have been greatly accelerated. Standard bevel gear load capacity calculations are now up to 10 times faster thanks to modularization of calculations according to ISO 10300 – ideal for optimizations and automated calculations.

Advanced pitting calculations according to ISO 6336 and FVA 411

The local pitting calculation was extended to cylindrical gears based on findings from the FVA 411 research project. This makes it possible to determine the safety factors for each point of the flank across the mesh and compare them with damage from tests or the field.

Variant generator: Easily calculate and compare variants

The variant generator helps users to quickly calculate different gearbox variants. For example, gearing parameters or bearing concepts can be freely varied for drive optimization. The results are saved and can be easily evaluated using the new variant comparison function, allowing you to quickly find the optimum solution.

Gear skiving: Cost-effective cylindrical gear production

The gear skiving feature enables you to generate the deviation-free nominal profile for skived cylindrical gears and to calculate the gear stresses on the tooth flank and in the tooth root. This makes it possible to precisely analyze the load capacity of cylindrical gears produced with this cost-effective manufacturing process.

Bevel gear calculations: Integration of the latest calculation kernels

Bevel gear calculations can now be performed even more reliably with the new version of the software. New features enable more precise analysis and representation of tooth flank curvatures. Extended calculation options are also available, such as determination of the local flank fracture and optimization of parameters for special compensation surfaces, allowing for even more accurate contact calculations - even with flank modifications such as tip or end relief. Current standards, such as ISO TS 10300-20:2021 and ANSI/AGMA 2003-D19, have also been integrated into the software.

Quick Results View: Instant analysis of calculation results

The Quick Results View makes it possible to see key results immediately after the calculation. This allows you to immediately recognize the effects of changes to your model, enabling you to quickly determine modifications and accelerating your development processes.

Three Steps to Creating Digital Twins with the *FVA-Workbench*

The digital description and representation of the gearbox is addressed by modeling and calculation of the gearbox in the *FVA-Workbench*. This was implemented as part of William Gunawan's dissertation on "Creation of a Digital Twin through real time integration of the *FVA-Workbench*" at the TU Darmstadt pmd. The thesis was supervised by Prof. Dr.-Ing. Eckhard Kirchner and Michel Fett. The project can be divided into three steps: modeling the gearbox, establishing live calculations, and visualization in a dashboard. The following is an overview of the project and the knowledge that was gained.

Step 1: Modeling

First, the gearbox was modeled in the *FVA-Workbench*. The two gear pairs of the two-stage gearbox were used for this purpose. The geometry of the individual gears was described along with the material parameters. This includes, for example, the number of teeth (z), module (m), helix angle (b), tip diameter (d_a), and reference diameter (d) of the individual gear stages. The three shafts of the gear stages were also described by defining the material parameters, center distances, and geometries of the individual shaft shoulders, among other things. The bearings and the gear oil could be selected as standard components from the *FVA-Workbench* library. The gearbox casing was not modeled, as CAD data for the casing was not available in the project.

Step 2: Live Calculations

Typical use of the *FVA-Workbench* involves one-time simulation of the behavior and characteristics of the modeled gearbox and creating a report from the results. However, digital twin functionality requires continuous, cyclically recurring live calculations. This can be achieved using the *FVA-Workbench's* scripting feature, which can automate the execution of calculations. To do so, a script was created which uploads the latest measurement data from the sensors mounted in the gearbox to the TU Darmstadt server in 10 second increments. This measurement data includes the current torque and speed values, which are then used as input variables for calculations in the *FVA-Workbench*. Thus, the current behavior and status of the gearbox are calculated every 10 seconds.

Step 3: Visualization

Creating a results report every 10 seconds is not useful for the purpose of a digital twin. Instead, the *FVA-Workbench* exports the calculation results as *Excel* files. A live dashboard was created directly in Excel using VBA (Visual Basic for Applications), which is updated regularly with the latest calculation results and shows the current status of the gearbox. For example, the load distribution on the tooth flanks and the load ratio C/P of the bearings are visualized. The plots in the dashboard are updated after each new calculation in the *FVA-Workbench*.

The *FVA-Workbench*: A Versatile Tool for Gearbox Design and Industry 4.0 Applications

The *FVA-Workbench* goes far beyond the basic functionality of typical gearbox design software, offering a number of expansion options that increase its versatility in various application scenarios. Users can implement their own scripts to automate specific calculations and develop customized solutions. This makes the *FVA-Workbench* a key component in the lifecycle management of gearboxes. Furthermore, combining the *FVA-Workbench* with modern data acquisition methods enables deeper analysis of sensor data from physical systems. This makes it possible to detect anomalies in operation at an early stage and quickly identify the effects of system changes, which opens up new potential for predictive maintenance and machine optimization. Thus, the *FVA-Workbench* proves itself to be not only a powerful tool for the design and calculation of gearboxes, but also a foundation for innovative applications within the context of Industry 4.0. The integration of live data, for example via OPC UA, allows for more precise calculations, as measurement data for individual gearbox elements is fed directly into the *FVA-Workbench*, making it possible to perform calculations using actual data instead of just nominal values. These new models along with the evaluation of live data can be used to create digital twins which contain data from across the entire product lifecycle.

References

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