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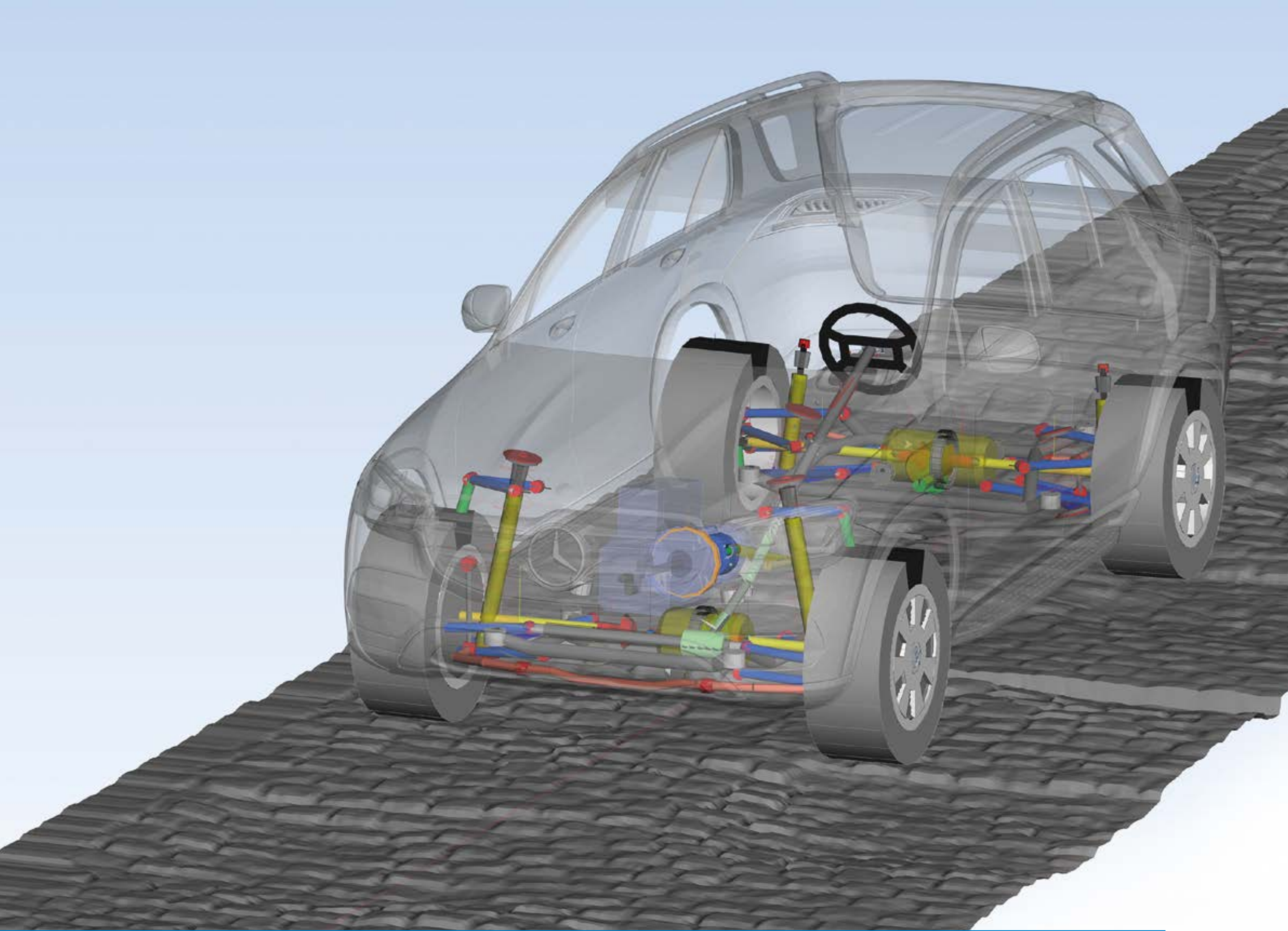
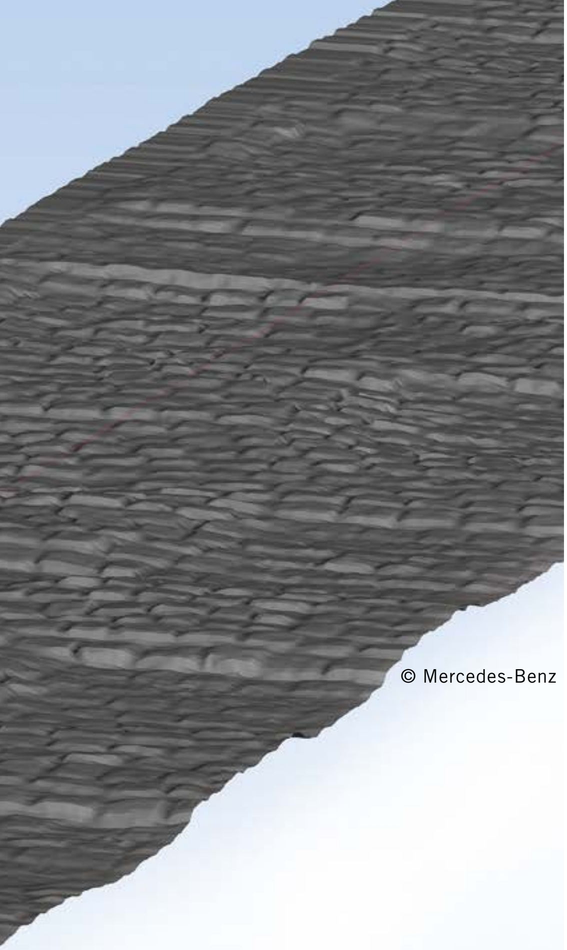
Efficiency Gains in Vehicle Development



Function Data Management for Virtual Vehicle Development

Data describing the function of components forms the basis of every vehicle development process. Function data define requirements for new components and are prerequisite for model-based systems engineering. Karakun describes the efficiency gains using an application example of function data management incorporating the FDX standard (Function Data eXchange).



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Vehicles have long been developed based on digital models [1]. However, these models currently primarily encompass geometric and geometry-related data. Function data to describe the task or mode of action of a component, such as the force-displacement characteristic curve of an elastomeric bushing, are not yet included in mainstream systems. Such data are needed in many areas of development, for example when defining requirements for new components or for the application of Model-based Systems Engineering (MBSE) methods.

FDX DATA STANDARD

If such data are digitally available at all, they lack uniform formats, and are neither consistently managed nor auditable. This significantly delays and increases the cost of the development process. For this reason, the German Association of the Automotive Industry (VDA), and later the prostep IVIP association developed the FDX standard for modeling function data [2]. Building upon this, the FDX working group continuously develops specific data models to describe the functions of all vehicle components and publishes these as standards, for example in [3]. Subsequently, these data models serve both to specify the target behavior and to capture the actual behavior of a developed component. They can also be used as input parameters in the form of characteristic data, curves, or maps for simulations. By utilizing FDX and integrated function data management within an organization, along with involvement from external suppliers and customers, the entire process chain of a development process can be closed in terms of data technology. The Exoknox software was developed to make it easier for organizations to get started with this new type of function data management. It can be used to generate and read data in the standard FDX format.

A closed data-driven development process comprises six steps: from interdisciplinary requirement definition to data delivery of actual and determination of characteristic values for the derivation of

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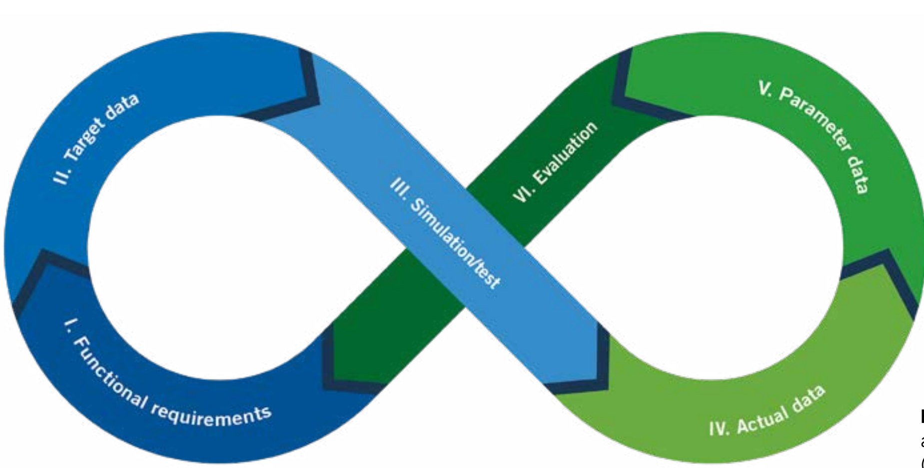

FIGURE 1 Closed process chain of a data-driven development process (© Karakun)

Function data type			NVH	Operational stability
Static				
Force-displacement	x-axis		Stiffness at operating point	Curve up to ± 15 kN
Force-displacement	y-axis		Stiffness at operating point	Curve up to ± 10 kN
Force-displacement	z-axis		Stiffness at operating point	Curve up to +5/-15 mm
Dynamic				
x-axis	Excitation amplitude	0.01 mm	Curve up to 500 Hz	
x-axis	Excitation amplitude	1.50 mm		Curve up to 35 Hz
y-axis	Excitation amplitude	0.01 mm	Curve up to 500 Hz	
y-axis	Excitation amplitude	1.50 mm		Curve up to 35 Hz
z-axis	Excitation amplitude	0.01 mm	Curve up to 500 Hz	
z-axis	Excitation amplitude	1.50 mm		Curve up to 35 Hz

TABLE 1 Data required for the MBS disciplines NVH and operational stability for a elastomeric bushing (© Karakun)

target and parameter data, culminating in automated evaluation and utilization of the data for simulations, **FIGURE 1**. The insights gained from these steps enable subsequent product optimizations.

The benefits of a standard data model and the application of software for the integrated management and manipulation of function data are illustrated using the example of a reference implementation in Exoknox. As an example of a product to be developed, the data object for an elastomer bushing is generated and increasingly enriched over the individual steps by various participants in the process. This ensures a continuous and traceable data flow throughout the entire process chain. The elastomer bushing in question is specifically a control arm bushing.

FUNCTIONAL REQUIREMENT MANAGEMENT

In step I, developers from different disciplines define the functional requirements for the new control arm bushing in a unified manner, storing them in the functional database. Such requirements encompass, for instance, force-displacement target curves and frequency value

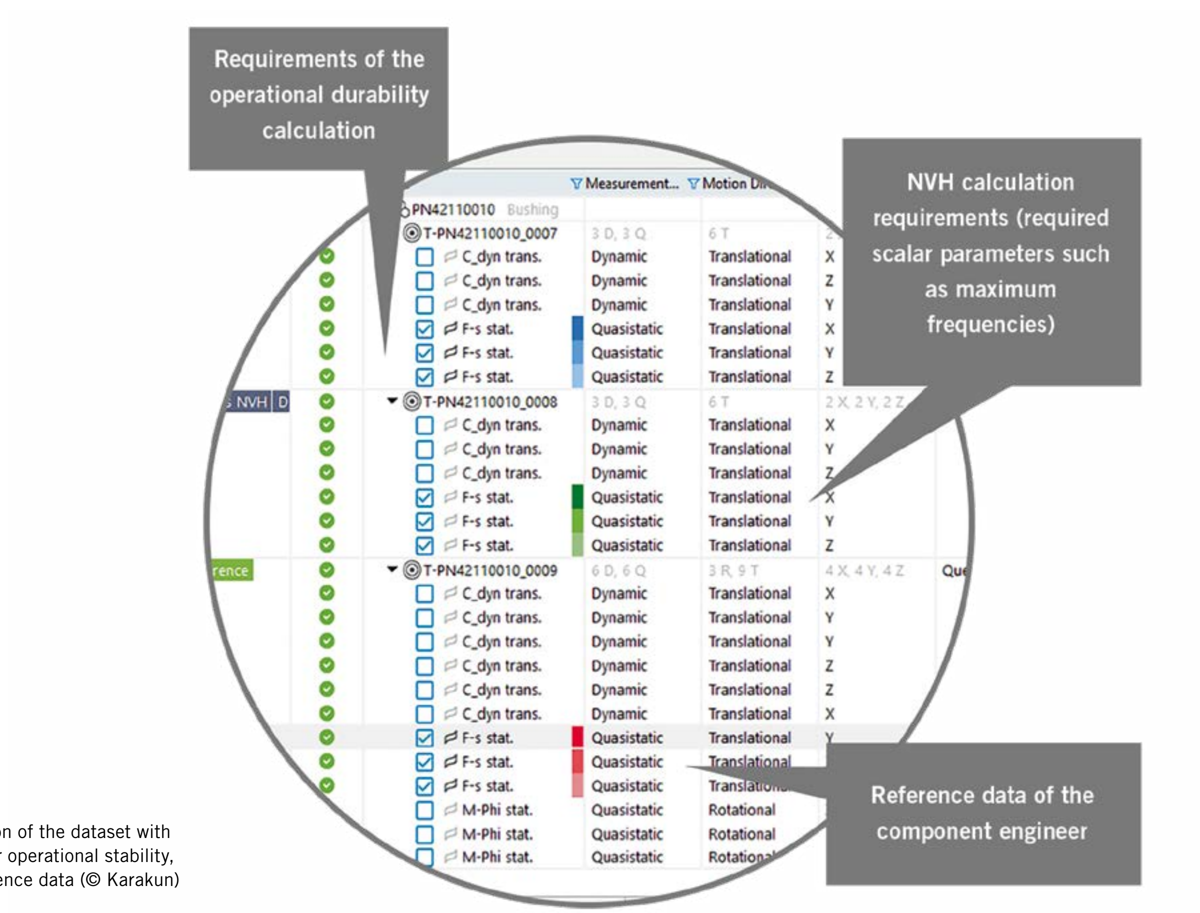

FIGURE 2 Section of the dataset with calculations for operational stability, NVH and reference data (© Karakun)

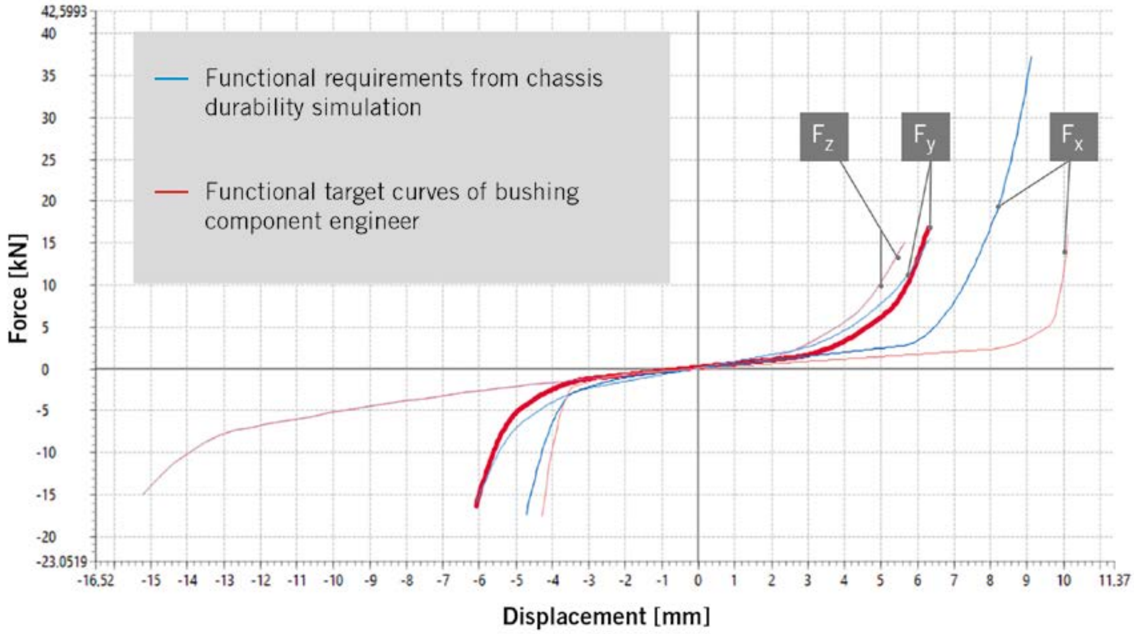

FIGURE 3 Curves of simulatively determined functional requirements for the operational stability of the chassis and target specifications for the control arm bushing (© Karakun)

ranges between which dynamic characteristic curves must lie.

The discipline of "driving dynamics" therefore requires both static curves as well as the dynamic curves of up to triple the axle's natural frequency. The "NVH" (Noise, Vibration, Harshness) discipline demands dynamic curves at high frequencies. Conversely, in "structural durability," static curves are expected, measured up to stops, alongside dynamic curves, again up to triple the axle's natural frequency. **TABLE 1** concisely illustrates the resultant requirement specification for the control arm bushing.

CREATION OF A TARGET DATASET

In step II, the requirements from various disciplines are now consolidated, potential conflicts of interest are identified and subsequently resolved. Frequently, this task falls under the responsibility of a dedicated individual for a specific component. After resolving any conflicts of goals, the component owner creates a dataset serving as a reference for all developers and releases it for use. All the results of the calculations for structural durability, NVH and the reference data are thus available in the dataset of the component, **FIGURE 2**. The simulated requirements for the durability of the chassis and the targets for the control arm bushing can also be checked visually, **FIGURE 3**.

METRIC DETERMINATION

Following the approval of the requirement dataset in step III, a task for metric determination can now be generated, either within internal departments or through external suppliers. Tolerance specifications can be added to the dataset, serving as the basis for subsequent automated quality checks. As for the control arm bushing, these might include tolerance requirements for the nominal stiffness of all six degrees of freedom, and for the force ranges the tolerances, within which static characteristic curves are to be supplied. Once the task order for metric determination is assigned, the dataset enriched with tolerances can be digitally transmitted directly to the component suppliers. This enables various technical options depending on the infrastructure available within the participating companies (for example, e-mail delivery or access via a data portal).

CREATION OF AN ACTUAL DATASET

Step IV is undertaken by the data provider. Typically, the actual data for the component under development are generated on a test bench or through simulation tools in early developmental stages. The FDX-based data model requires the specification of crucial boundary conditions, aiming to, for instance, eliminate the Mullins effect in the control arm bushing. Utilizing the tolerance specifications defined in step III, the generated actual data can undergo automatic verification. Only upon passing the quality assessment can the actual data be returned to the vehicle's development department, **FIGURE 4**. Similar options are available for task assignment.

AUTOMATED PARAMETERIZATION WITH EXOKNOX

Upon receiving the actual data, these can now be utilized for the further development of the product in step V, such as parameterizing Multi-body Simulation (MBS) models. A significant advantage of a data-driven development approach using FDX and Exoknox lies in the ability to automatically generate the necessary parameter dataset from the acquired actual data. In the case of the control arm bushing, an employee responsible for vehicle dynamics simulation would execute a script previously created in Exoknox to automatically generate model parameters and curves for parameterizing a Kelvin-Voigt model. Other model approaches can be supplemented individually.

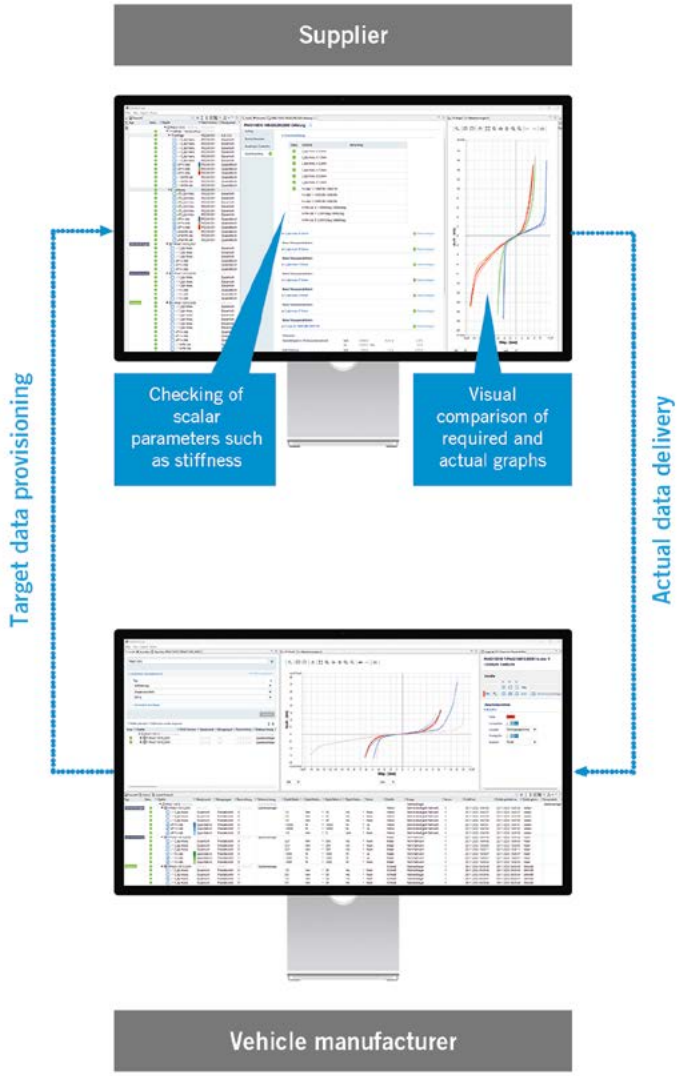

FIGURE 4 Quality inspection and visual comparison of characteristic curves between target and actual data on the part supplier's side and data exchange with the vehicle manufacturer (© Karakun)

Such a script can, among other tasks, generate the hysteresis-free skeleton curves needed for the static model component in all six degrees of freedom. This is achieved by optimizing the parameters of an algebraic approximation function. It ensures, for instance, the availability of curves for the discipline of structural durability, even in high load ranges. Additionally, the necessary parameters for loss angles and dynamic hardening factors in all six degrees of freedom are computed from the ascertained dynamic curves via linearization at specified operating points.

For traceability purposes, the parameterization dataset is linked to the source data (actual data from steps III and IV) and stored in the database. This enables other analysis methods to use the same parameter set if needed. However, it is also possible to create specific parameterization data sets using dedicated automation scripts. They can also be linked to the source data sets and can be used directly in an MBS tool.

MODIFICATION OF REQUIREMENTS AND TARGET DATA

In step VI, the evaluation of results obtained from simulations or tests takes place. This can lead to adjustments in requirements and related target data. For example, it may be necessary to adapt the behavior of the control arm bushing. Such alternations can now be made directly and comprehensibly within the function data management system. A duplicate of the original target data is created and linked to its source. This duplicate allows, for example, adjustments to the static force-displacement curve concerning its basic stiffness, linear range, and progressive behavior in the primary direction.The data generated in this manner serve as initial values for the subsequent development loop.

ENRICHED PRODUCT DATA AND CLOSED PROCESS CHAIN

With FDX as a data standard and a corresponding software solution like Exoknox, suppliers can be integrated into the data procurement process for populating product data management systems (upstream process). On the other hand, it enables a novel utilization of functional data within a fully digitized closed process chain of a development loop (downstream process), specifically, their massively automated analysis and further processing. The evolution of data can be traced and audit-proofed through suitable software solutions – an essential prerequisite for certifications.

Function data management translates into significant efficiency gains in developing new products, a fact confirmed through initial practical experiences in digital vehicle verification at Mercedes-Benz. In specific applications in chassis simulation, the company's development department was able to significantly reduce the time and effort required for parameterization. Overall, an improvement in the quality of the development outcomes and comprehensive traceability of the entire development process related to function data was observed.

In the future, prostep IVIP will increasingly provide component models as standards integrated into Exoknox. Additionally, the authors anticipate for the market the emergence of yet more software solutions based on FDX.

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EXOKNOX

EXOKNOX is the first fully comprehensive and future-proof data management platform for function data. Developed by calculation engineers from the automotive industry, the software solution closes a gap in the development of components: While there are already very good CAD product data management systems for geometric or geometry-related data, component and system properties such as stiffness, damping, pressure loss or torque behaviour can only be reliably managed and exchanged with all parties involved with EXOKNOX. These properties in particular significantly determine the DNA of an entire vehicle.

EXO:FDM	Data management for function data
EXO:FDX	Simple, cost-effective exchange of function data
EXO:RDM	Highly scalable management and analysis platform for results data
EXO:ODS	ODS Server basis for EXO:FDM and EXO:RDM
EXO:VIZ	Advanced visualisation, reports and comparisons

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