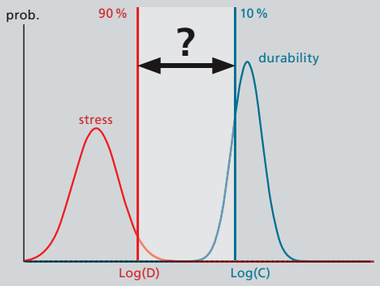

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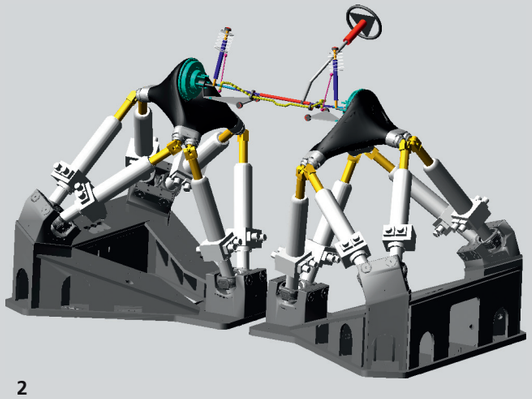

2

1 The tails of the load and durability distribution have a major impact on the failure probability, but they are usually unknown.

2 Axle test rig

Design loads and test scenarios

Release testing is usually not based on the complete load distribution expected during customer operations, but rather on a derived reference load. This has to be chosen with care, as neither the load distribution nor the durability of the component are known exactly. The problem is that the failures one wants to prevent are rare occurrences, where an extreme load is applied to a weak component. Besides the explicit addition of defined special events, we recommend using a combination of classical approaches based on experience (safety factors) with statistical methods. In this way, information about the underlying distributions is explicitly included and it becomes apparent, for example, how a higher production standard leads to lower specifications for tolerable loads. Once a reference load has been derived, various optimization and statistical methods can be employed to translate it into a driving schedule for the test track or a program for the test rig.

Planning and evaluation of fatigue tests

A traditional domain of statistics in the area of durability engineering is the planning and evaluation of fatigue tests. Because reliable statements about the failure probability of components must be derived from a few samples, the focus is on methods that make optimal use of the available data. This begins in the planning stages, i. e., we need to consider the trade-off between a few samples with long run times or more samples with shorter run times, or the question of how far a test rig signal can be compressed for a faster execution. Other typical problems are how to handle censored data, when a test is terminated before the component being examined has failed, or whether an aborted test can be »saved« by testing additional components.

JUROJIN software package

To assist in the planning and evaluation of fatigue testing, MDF supplies the software package Jurojin, which was specifically developed for statistical problems in the context of durability. The range of functions offered include, for example, balancing the number of samples versus run time, changing a test plan during testing, evaluating test results, but also more advanced applications like comparing variants, evaluating warranty data, and matching durability distributions to customer load profiles.

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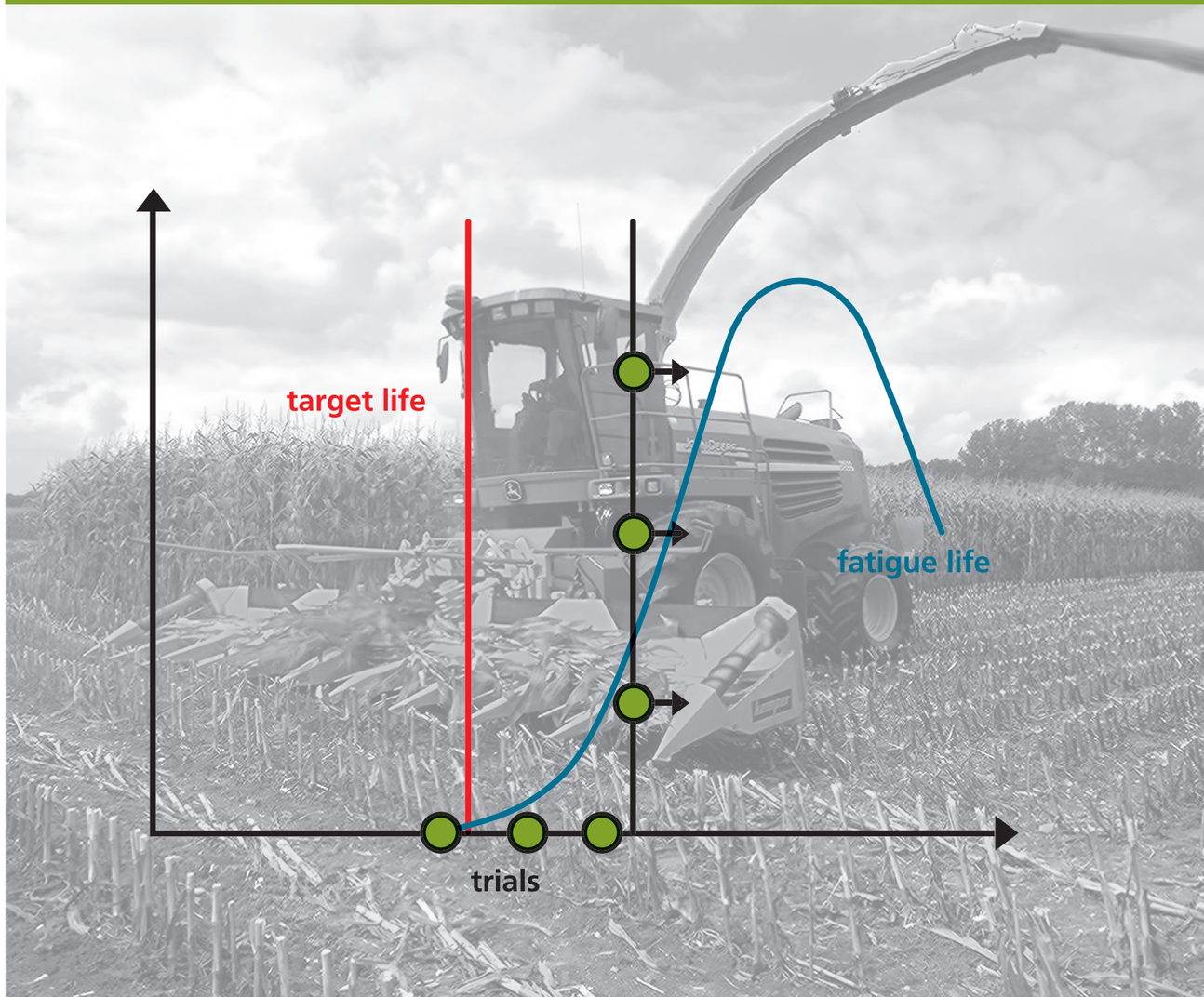
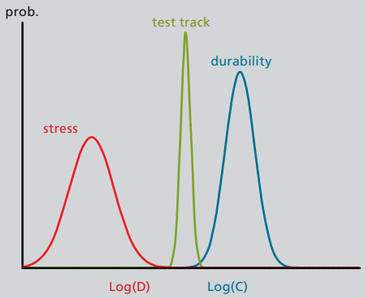
STATISTICAL METHODS FOR RELIABILITY OF TECHNICAL SYSTEMS





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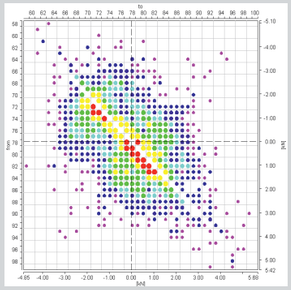

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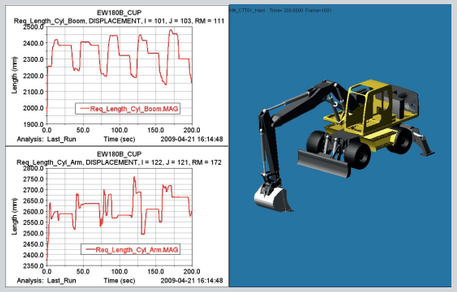

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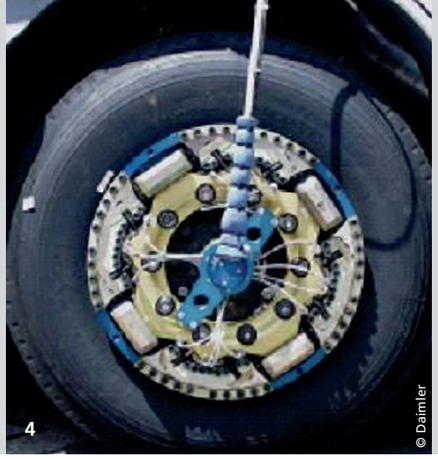

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5

1 *Operating loads, test loads, and component durability vary according to certain distributions.*

2 *Rainflow matrix*

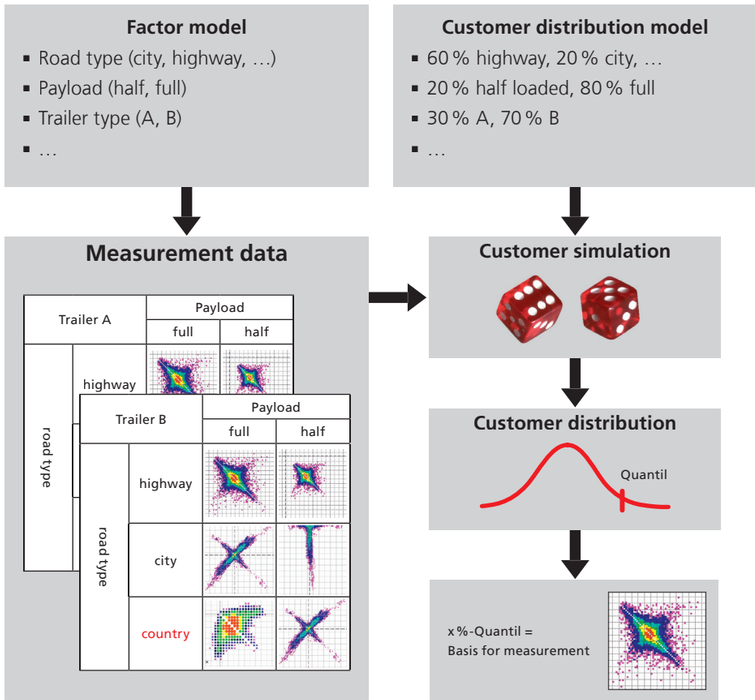
3 *Load determination via multi-body simulation*

4 *Wheel force transducer*

5 *Test track*

Mathematical methods in dynamics and durability

One focus of the research effort at the Mathematical Methods in Dynamics and Durability Department MDF is durability engineering for technical systems and their components. We use and develop methods that encompass the entire development process, as well as quality control and warranty data. The majority of projects derive from the vehicle industry and related suppliers, but the processes are generally applicable to all technical systems with highly variable loads.



Methods of load data analysis

Load data for systems and components from field measurements, rig tests, or simulations is initially available in the form of time series. Important information about the loads is generally obtained from the amplitudes (rainflow count) or frequencies (PSD) of a load sequence. Which of these measures are relevant in a specific situation depends on the component and its damage characteristics – an issue that needs to be considered already in the planning stage of a measurement campaign. When the damage mechanism is known, loads can be converted to scalar values using an appropriate (pseudo-) damage law, which enables, for example, quantitative comparisons between customer operations and the test track. If loads cannot be measured directly on the component of interest due to technical constraints, they can be calculated with the aid of a system model (Finite Element or Multi-Body Simulation). For all of these tasks, MDF employs both commercial engineering software and self-implemented methods customized for certain applications.

Modeling customer usage

Field measurements alone are usually not sufficient to make realistic assessments about system loads during customer operations. The first problem is that measurements are short and there is a desire to extrapolate to longer run times, which would result in more extreme events than those actually observed. Methods from the fields of extreme value statistics or non-parametric smoothing of distributions are helpful in this context. Another problem is the large number of potential applications or vehicle missions, which means that the frequency of certain tasks in the field is usually not related to their proportion among the available measurements. The data can still be used effectively if it is first classified according to distinguishing factors and then recombined according to the expected mission profiles.

Classification of measurements is based both on technical considerations and statistical analysis of the data. If it is independent of the system, i.e., based on external conditions like environment or mission, classification also provides a description of the customer usage spectrum that can be used to evaluate and compare variant systems.

Customer models beyond durability

The methods used for the analysis of field data and for description of customer behavior are not only of interest in the area of durability. Conclusions about other properties of a technical system can be drawn from appropriate measurements, for example, we may derive fuel consumption or vibrational comfort for different vehicle missions. If the necessary calculations are not too expensive, they can also be used for the purpose of online monitoring, perhaps for warning systems or to collect customer data for further analysis.