Design, Reliability and Service Life Predictions of tribological Contacts in drive Systems

Michael Gless[1)*], Anette Schwarz[2)]
ContactEngineering.de, Stuttgart, Germany
Corresponding author: Michael Gless Contact@ContactEngineering.de

Abstract
During design process different design solutions have to be considered and compared.
In early stage fulfillment of requirements and functions, reliability and service lifetime have to be confirmed.

This presentation shows a systematic way how modelling and optimization of design helps to find robust design solutions. The practical approved reliability estimation shows three steps to find robust and reliable design, to choose best design solution and to fulfill required reliability and service lifetime.

Advantage of in early stage optimized design avoids many wear mechanisms and helps to focus on unavoidable mechanisms.

In addition to calculation and simulation, presented method also considers accelerated testing on tribometers. Furthermore, data from products in the field and production-accompanying testings are collected and evaluated.

Presented reliability estimation approach is applied to evaluate a medium-lubricated concentrated contact in high pressure pump drive. In a second example approach is applied to control and use of abrasive wear for self-sharpening effect of a blade. In a third example wear is estimated in a plastic gear drive of a toothbrush.

Engineering challenges are to choose best design in an early stage. Many requirements are addressed.

Design to cost, milestones and timeline targets. In addition, there are aims like do it right the first time. Therefore, it is essential to choose robust design and material selection in early state, to prevent use of non-robust designs, late changes or even failures (cost rule of 10^{th}).

Established are development processes for example according VDI 2222.
This is a very systematic way for development of a new design. Furthermore, this process helps to make and to document decisions.

On the other hand, reliability of chosen solution is not considered at all. Reliability standards are not available, or products are operated outside the standardized operating conditions e.g., mixed lubrication, medium lubricated or dry contacts. Potentials like data collection and smart services are not taken into account.

This presentation addresses these aspects. A systematic Design for Reliability service life and **reliability estimation** for components and connections is shown. Goal is to reach system reliability target and choose appropriate design solution.

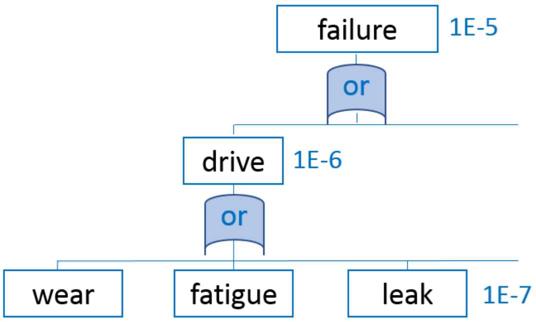

Figure 1: Fault-Tree-Analyses. Breakdown of required system reliability to component and failure mechanism.

In meantime familiar with automotive and aviation processes we had during last years in aviation important lessons learned.

Scope is to give a practical oriented overview how best design can be chosen, how reliability can be predicted and how first tests on component level preferred under accelerated conditions can be done. In short it helps to make design decisions easier, to minimize changes in late development state.

Contacts are heart pieces and Achilles' sinew in engineering. After a general picture of used processes (design, reliability) a **comparison and verification** of designs of mechanical and electrical contacts is shown.

1. First step: Requirements and Functions

In a first step requirements and functions are addressed and verified. These enables a simulation driven development, the evaluation of influencing factors, optimization and therefore robust designs.

2. Second Step: Identification of Failure and Wear Mechanism

Relevant Failure and Wear Mechanism are visualized in wear maps.

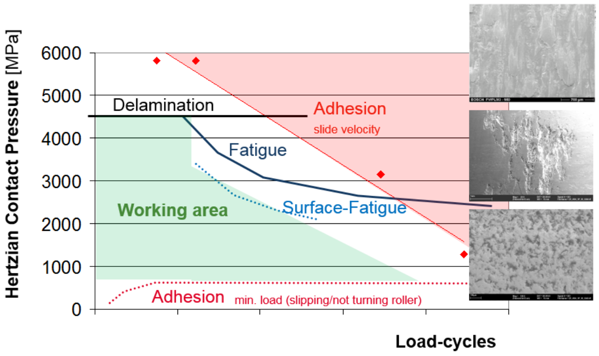

Figure 2: Wear Mechanisms of a concentrated contact visualized in a wear map. In concentrated contacts fatigue is a lifetime limiting failure mechanism and requires a closer look. All other wear mechanisms are not service time limiting.

Wear limits have been found in parallel accelerated tribometer tests.

Aim of first step to describe the correct reproduction of the behavior, however, not to describe all microscopic details. Furthermore, awareness of tribological complexity, however, not to get lost in details.

Aim is to avoid wear mechanism where possible (robustness, optimization) and to focus on main service time limiting mechanism in operating. In medium-lubricated concentrated contacts is fatigue lifetime limiting failure mechanism and requires a closer look.

3. Evaluate resulting stress caused by loads vs. strength/resistance

Estimate Reliability and Service time.
Verify and quality assurance with Data from products in production-accompanying testing and field (digital twins)

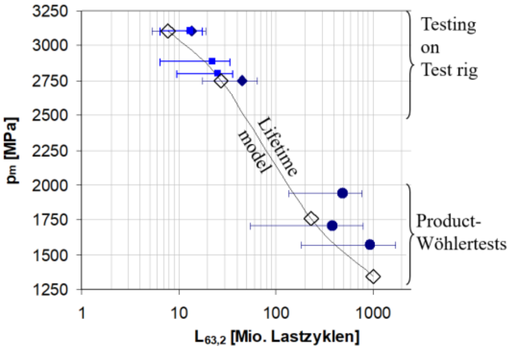

Figure 3: Accelerated lifetimes on test rig compared to field test. Lifetime limiting failure mechanisms is fatigue because of mechanical load. Lifetime-model according to Ioannides, Harris [1] allows transferability between test rig and field results.

4. Application of method on different Design-Examples

Presented method has been approved on a medium-lubricated **concentrated contact** in high pressure pump drives [3]. In addition, wear is predicted.

The cutting edge. Use of abrasive wear for self-sharpening effect of a blade

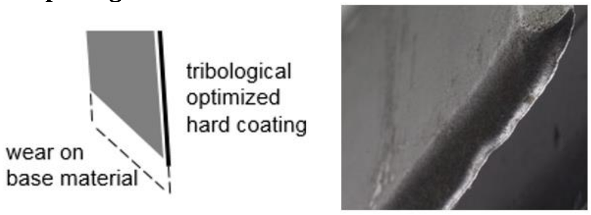

Figure 4: Design for self-sharpening. Left: Tribological system with different abrasive wear rates enables controlled wear. Base material has a higher wear rate compared to hard coating. Right: Field result on agriculture cutting blade.

Wear is estimated in a **plastic gear drive** of a tooth-brush, too. Wear is dominating and lifetime limiting. Within linear wear/steady-state wear regime extrapolation of test results is possible.

Furthermore, reliability of electrical **Contacts and Connections** is evaluated. Method enables a methodical comparison of different Design solutions, to find most robust connection.

Conclusion

A practical driven approach enables a methodical comparison of different design solutions, evaluates design components and influences with respect to reliability.

Relevant wear mechanisms are visualized in wear maps. Robust design helps to avoid wear mechanism and to focus on/evaluate service time limiting mechanisms.

Tribometer testing supports/verifies Strength and Material behavior. In addition, production accompanying, and field data are considered.

Shown approach has been successful applied in several design projects e.g.
to estimate fatigue in concentrated contact,
to control abrasive wear for self-sharpening,
to estimate sliding wear in different contacts and
to design electrical contacts and connections.

7. References

[1] Ioannides, E.; Harris, T. A.: Fatigue Life Model
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[4] FIDES Reliability Methodology for Electronic Sys.
[5] MIL Handbook 217-F
[6] IEC-61709 Electronic Components Reliability