FATIGUE LIFE PREDICTION OF AUTOMOTIVE DRIVE TRAINS BY COMBINATION OF DRIVE CYCLE MEASUREMENTS AND SIMULATION USING WINLIFE

Fatigue life prediction of automotive drive trains by combination of drive cycle measurements and simulation using winLIFE

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SUMMARY

It is becoming more and more important to assess fatigue life in the early stages of developing vehicle engines – in particular for the development of transmissions. winLIFE has the necessary calculation methods for analyzing fatigue life. These can be linked to equipment for recording measured data and used for simulating the drive train.

Actual driving cycles can be measured for very different conditions. Using this data as a basis, simulations can be carried out to calculate the dynamic values in the power train (revolutions and torque). In this way it is possible to determine the fatigue life of individual components for each driving cycle.

Total driving cycles for the life cycle of a vehicle can be obtained by adding together individual driving cycles. By combining individual driving cycles to such a total driving cycle, it is possible to make a fatigue life prognosis. This method is transparent since the critical conditions for a component can be recognized in individual stretches of the journey. We describe this as a critical component collective.

It is possible to establish a system for optimizing fatigue life and reliability which enables you to use this method over a long period of time. This leads to a shortened development phase and improved reliability.

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1: Introduction

A number of demands are made on vehicle transmissions. Low fuel consumption, small size and light weight have to be considered more and more in the development phase, along with a defined fatigue life and the cheapest possible manufacturing costs. The most important characteristics of a transmission are fatigue life and reliability. If it is over-rated it will be too heavy, too large and too expensive. If it is under-rated the reclamation costs will be high and the reputation endangered.

Because fatigue life is influenced by so many aspects, it is impossible to carry out tests under all the peripheral conditions one can think of. In this presentation we show how fatigue life prediction is done considering realistic use. The goal is a procedure that takes these demands into account during the development stage of a transmission.

For the past 20 years the Steinbeis Transfer Centre has been developing simulation programs to simulate drive lines and calculate fatigue life. These programs are in use all over the world.

2: System summary

The tools for the development and the data flow are shown in the first diagram. winADAM collects data from test cars and supports winEVA for driveline simulation based on this data. Fatigue life calculations are carried out based on the simulation results.

As well as test cars, test rigs are used which are controlled according to the measured test tracks. The goal is to create the same conditions on the test rig as in reality.

The simulations system is used for further tasks such as designing the electronic shift process and checking the compatibility of the shifting data to the driveline design.

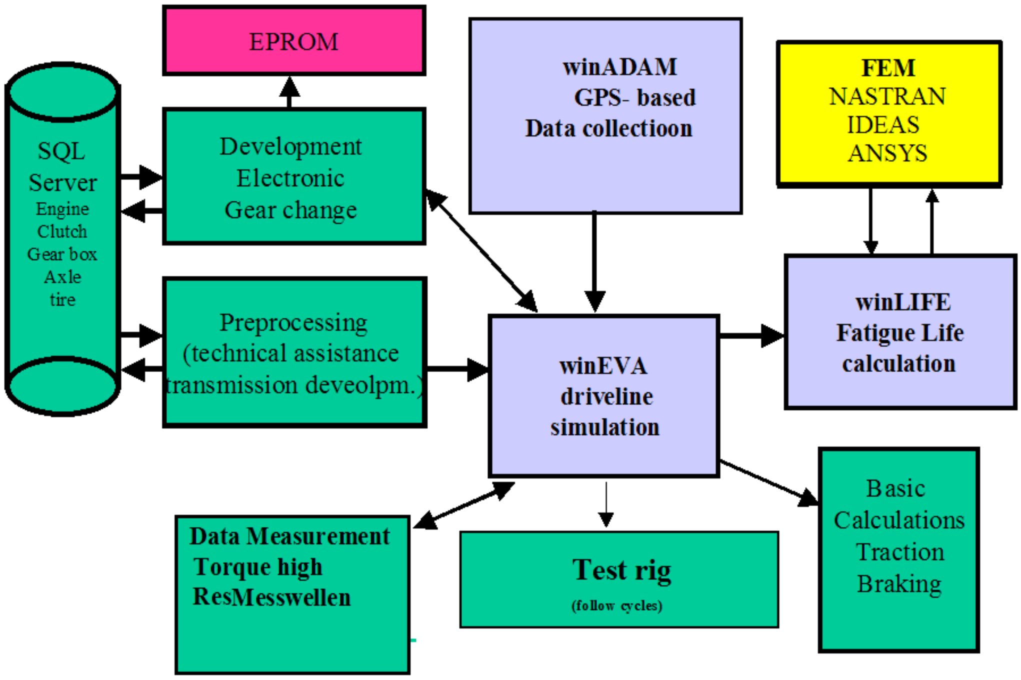

Figure 1: Tools of the development system

3: Capabilities of winLIFE

winLIFE is used in different industries such as aerospace, military, wind energy, machinery and automotive. winLIFE supports the common methods of fatigue calculations.

Proportional Loading
- Nominal stress theory using S-N-curves
- Local Strain Approach using e-N curves

Multiaxial Loading
- In the case of non-proportional loadings the critical plane approach is used
- Powerfull capabilties in accelerating the calculation process

A material data base is available, generators according to different authors are integrated and support is provided to create fatigue life curves based on static material data.

The goal of winLIFE is to support the most used and accepted calculation methods with a (relatively) simple to use user interface. Welded structures can be calculated according to FKM. Finite Element Systems can be integrated into the calculation process.

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This paper sets the focus on the automotive aspect in the transmission development.

4: Fatigue processes in a transmission and calculation models

An automatic transmission for passenger cars consists of, among other things, a hydrodynamic torque converter and planetary gears. These can be shifted under load with the help of multi-plate clutches. A modern automatic transmission, which is in our test-car, is the DaimlerChrysler 7 speed automatic gear. (Figure 2).

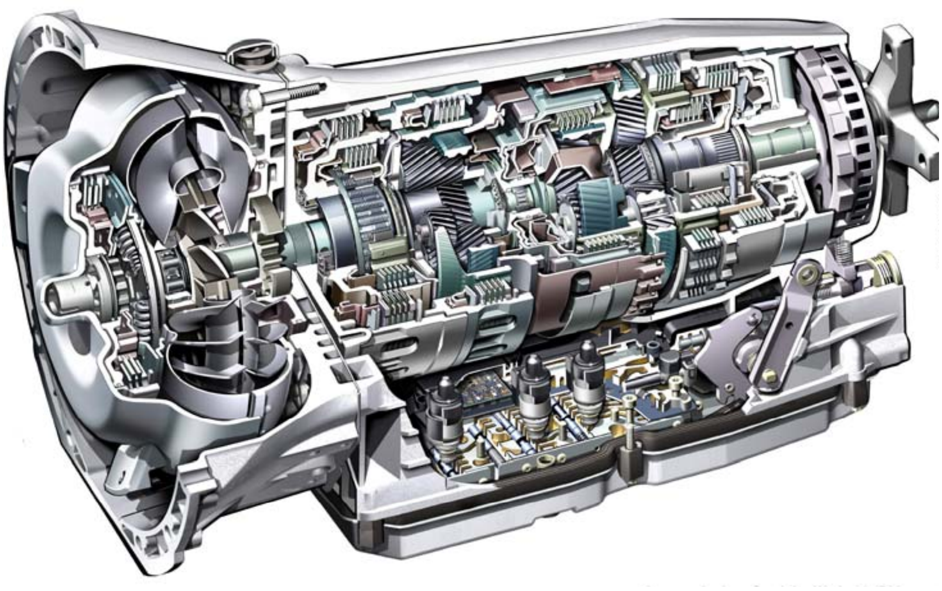

Figure 2: 7 Speed automatic transmission of DaimlerChrysler

The following machine elements are used here and they have to be dimensioned according to their fatigue:

- shafts	fracture
- gear wheels	pittings or fracture
- bearings	pittings or fracture
- clutches and brakes	wear
- casing	fracture

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The picture shows the relevant points where fatigue damage occurs.

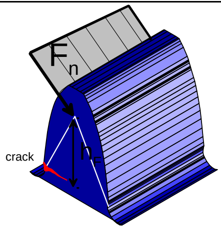

Figure 3a : Bending of the tooth and resulting notch stresses

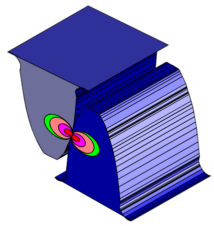

Figure 3b : Local pressing in the flank and resulting local pressure in the surface

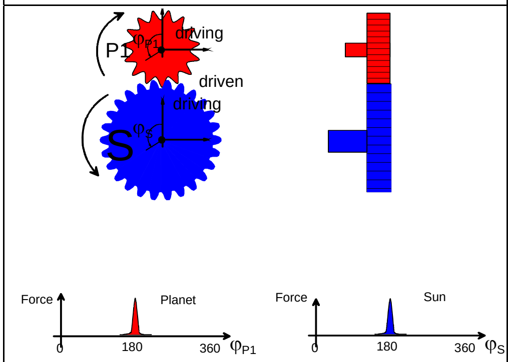

Figure 4: Two gear wheels in a simple configuration and critical points of the acting forces in a tooth

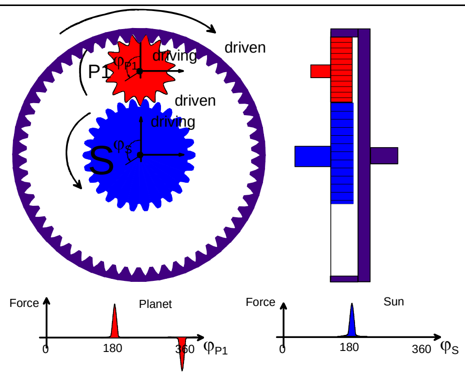

Figure 5: Simple planetary gear and forces in the planet gear and sun gear at one revolution

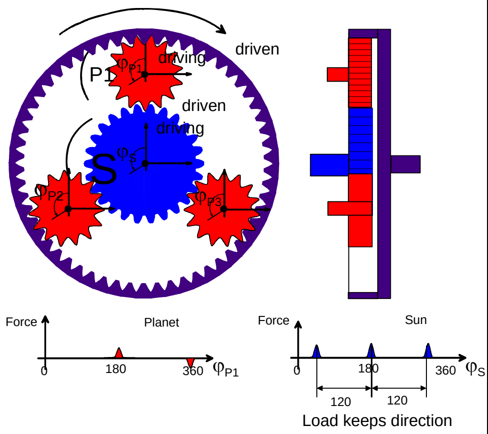

Figure 6: Planetary gear with 3 planet gear wheels and forces in planet and sun at one revolution

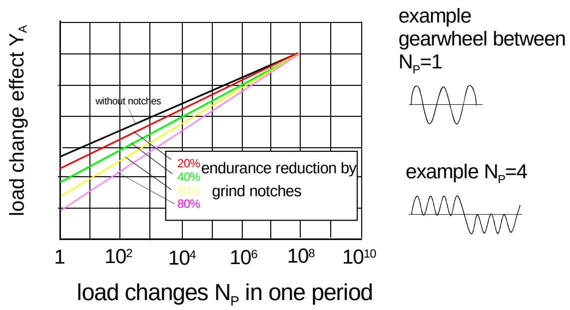

Figure 7: Load change effect factor Factor Y_A according to Niemann [5]

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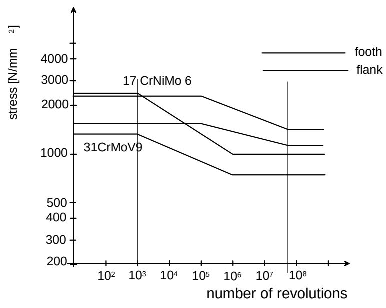

Figure 8: S-N-Curve similar to DIN 3990 for fatigue life against base bending and pittings

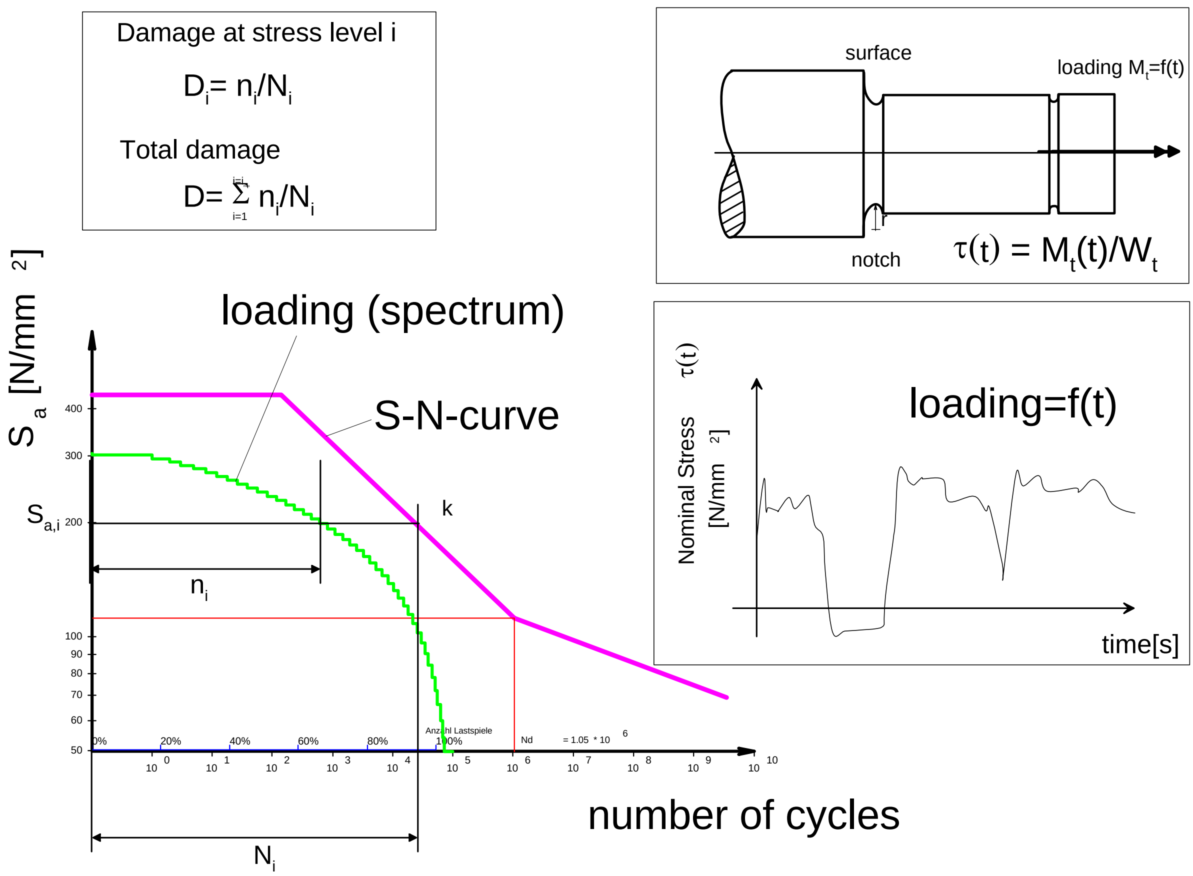

Figure 9: Schematic procedure of fatigue life prediction according to the nominal stress method

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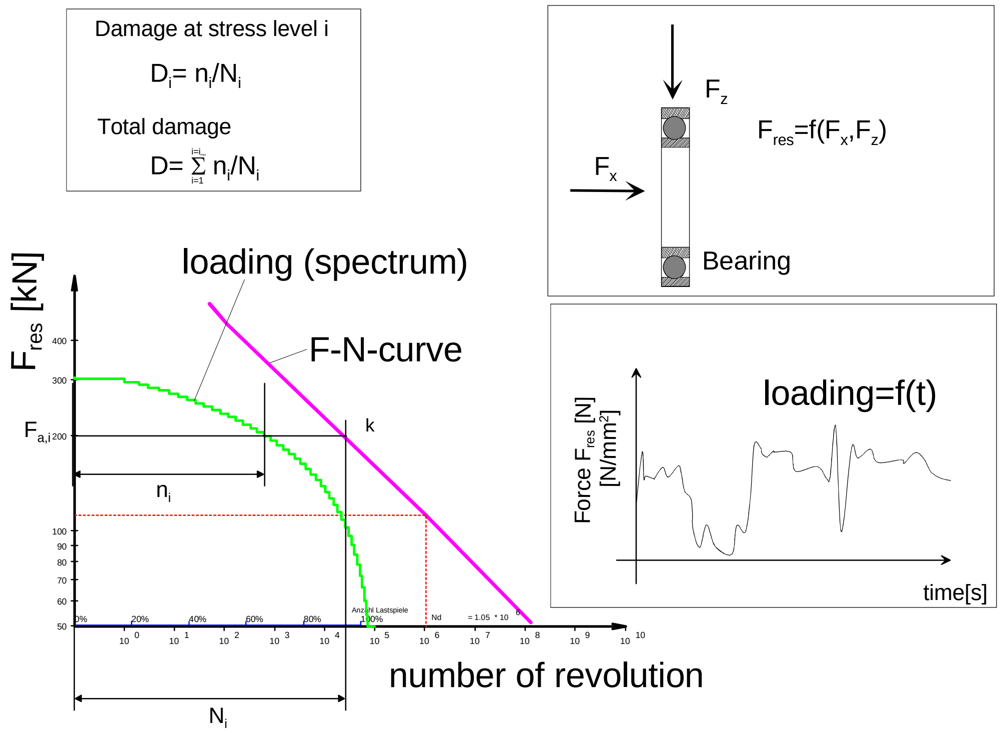

Figure 10: Data for Fatigue Life prediction of bearings

5: Fatigue life prediction using realistic driving cycles

The results of a fatigue prediction can only be as good as the computer input. For many years now, we have been recording the most important characteristics of usage in different passenger cars, among other things by measuring speed and topography. A GPS-based measurement system was used which collects beside the position dynamic data like speed, acceleration and the inclination of the road (topography).

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Figure 11: Data collection by in-car measurements

Based on these data of real cycles a driveline simulation system (Figure 12) is now used to calculate in detail the physical properties such as speed and torque inside the transmission. This data is needed for fatigue calculation of components.

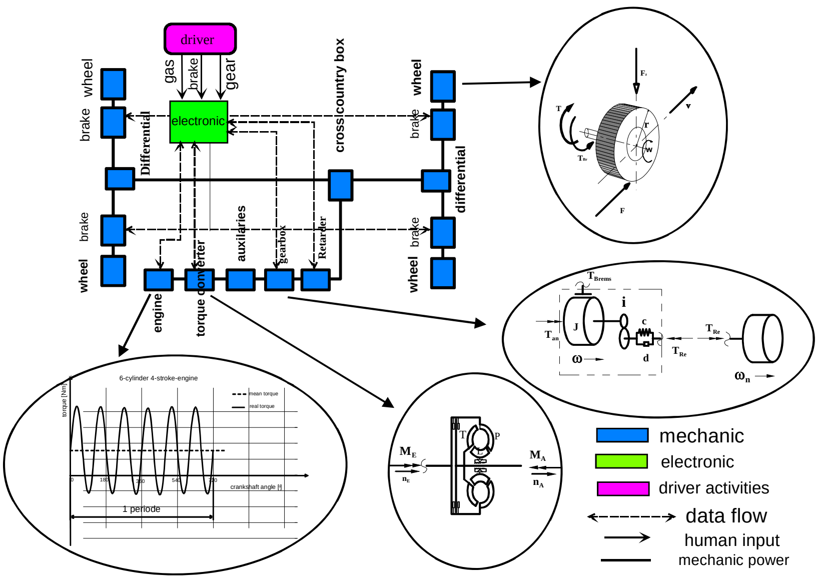

Figure 12: Simulation system of the driveline winEVA

The information obtained from winEVA forms the basis of the following calculations (Figure 13). A real cycle consists of many different routes. Furthermore, many different situations must be considered, e.g. how the car is loaded or the type of driver.

The following table contains all the parts of the total cycle which are considered relevant. A calculation is carried out for each individual part of the cycle and the relative damage proportion is determined for each component of interest. The simulation provides us with the total damage.

As well as the damage, the collective which occurs can be entered for each calculated component. Particular attention must be given to the collective within an individual route which has created the most damage to the component. We call it the critical component collective.

The process described leads to a transparency of the relevant damage mechanics which has proved to be helpful.

It is very difficult to calculate a fatigue life prognosis exactly and only a combination of experimental and statistical analyses can form a basis of knowledge with which an increasingly certain statement can be made regarding the dimensioning (Figure 14).

The calculated analysis and the ascertaining of the critical component spectrum is one of the most important factors, since the costs are relatively low and it becomes clear which influence variables are important for the fatigue life and which are not.

6: Conclusion

When dimensioning and testing components, it is helpful to carry out fatigue life calculations to obtain information on the damage proportion of individual routes. The critical component collective also helps to identify critical parts.

As well as the fatigue life calculation, fatigue tests with indoor test rigs and outdoor vehicle tests also help. This is complemented by damage statistic tests of components used by customers.

However, after many years of use and comparisons between test and actual results it is possible to improve the calculation tools to such an extent that even a quantitative fatigue life prognosis with relatively exact results can be achieved. This leads to an improvement of existing transmission, helps with the development of new products and helps to optimise customer relations.

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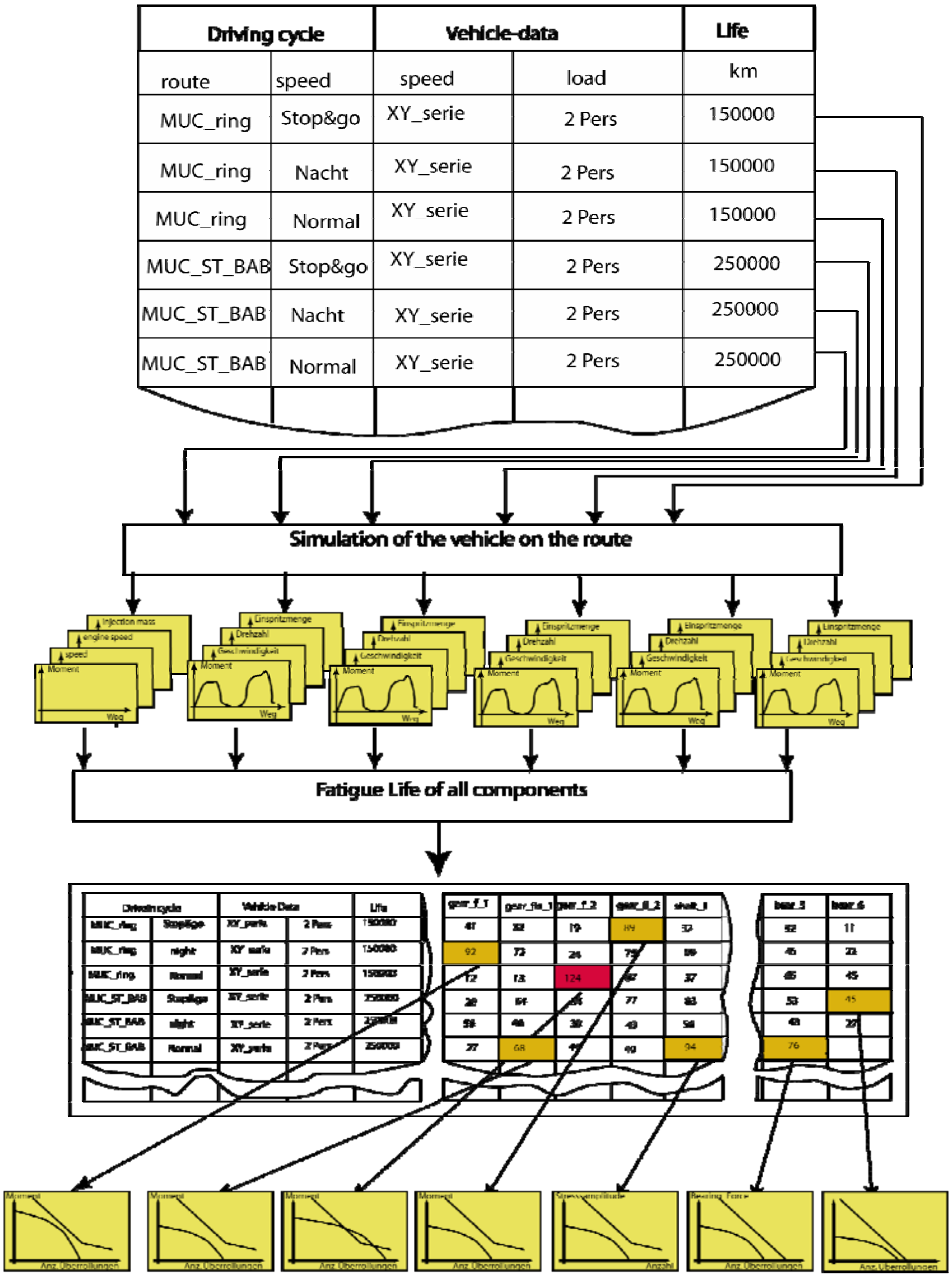

Figure 13: Process to ascertain the critical component spectrum

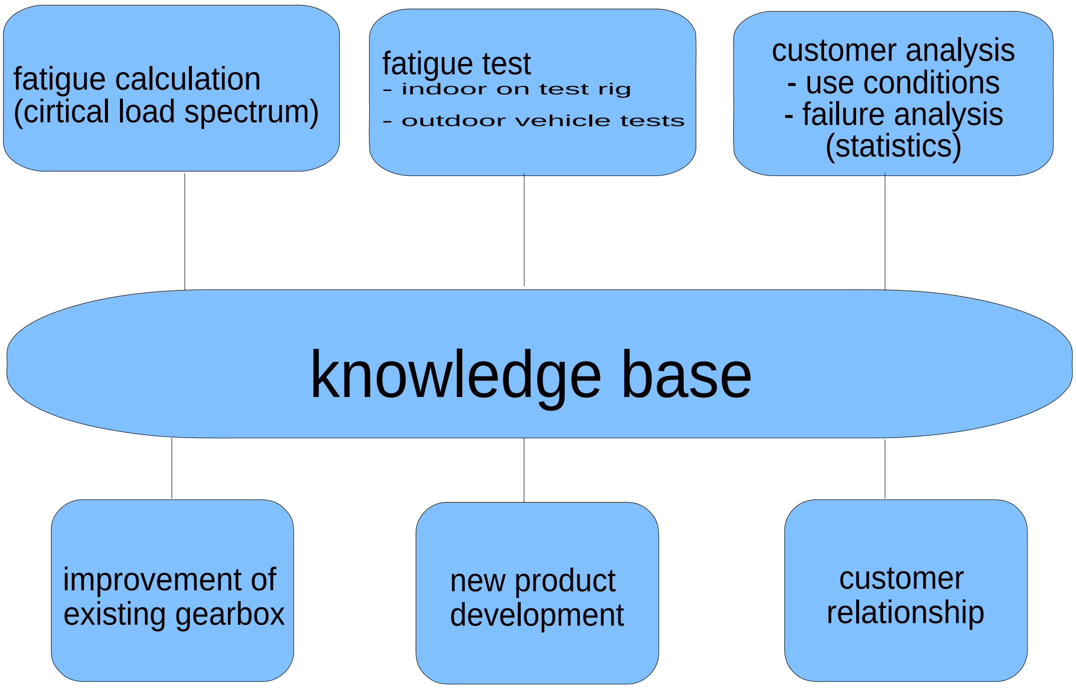

Figure 14: Fatigue life optimisation as part of the development process

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