REDUCING TESTING TIME BY MEANS OF FE-BASED FATIGUE-ANALYSES

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1. Introduction

For the assessment of the fatigue strength of components bench-testing is an essential aspect in the vehicle development. Multiaxial servohydraulic test benches are standard tools to reproduce operating loads in the laboratory which are close to reality.

One possible way is scaling up the test forces in order to increase the damage content. However, by applying higher loads than existing during real operation the elastic limit could be exceeded locally which might not correlate with the real vehicle.

A more accurate alternative is to cut sections with minor damage content out of the load signals. Tracks with negligible damage content can be omitted. In order to maintain the damage of the original test program the recurrence factors of the remaining tracks must be recalculated.

The most common way to assess the quality of the compressed test program is the so called pseudo damage comparison with the original load data. For each channel the damage value according to Palmgren/Miner [1] is calculated separately based on a virtual S/N curve.

As a major disadvantage of this method the virtual S/N curve has to be assumed since it is not known for all critical areas of the structure. Also, external forces can be considered only. The actual stresses, as a consequence of the applied loads, cannot be analyzed with this method.

2. Traditional Method for Compression

There are only a few options how a damage equivalent time compression of a test program can be achieved.

The complexity of such tests causes significant efforts with respect to costs and time. One single test run for the evaluation of an axle can last several hundred hours.

Within the development project of a beam axle for a pickup truck a method to reduce testing time and still assure reliable test results has been evolved. For design and process validation a 10-channel test rig was set up. With this specially designed test bench the vertical, lateral and longitudinal forces as well as the steering and braking moments could be realized (refer to figure 1).

Fig. 1: Concept for a beam axle fatigue test with 10 servohydraulic actuators

3. Adding FE-based Damage Analysis

The S/N curve and in particular its inclination have significant influence to the calculated damage. Since in reality and on the test bench all applied forces occur simultaneously, also for the damage comparison the superimposition of the forces is to be considered. Therefore the FE-based fatigue analysis was incorporated into the process of reducing the test time. Figure 2 displays the principle of the superimposition of the applied force signals [2].
Fig. 2: Principle of a multiaxial damage analysis. Linear superimposition of force signals.

With the original and uncompressed test program a FE-based damage analysis is performed. This damage result is defined as the reference.

The fatigue analysis is based on the linear superimposition of all channels, the critical cutting plane hypothesis, Rainflow classification [3] and the linear damage hypothesis according to Palmgren-Miner.

For the damage analysis S/N curves are required. Within the used software a particular S/N curve (endurance limit, cycle limit and inclination) is calculated for each FE-node based on various influences, such as stress condition, mean stress, stress concentration in notches [2], surface roughness, high temperature and others [4]. Refer to figure 3 for the principle of deriving the so called part S/N curve from the specimen S/N curve!

Fig. 3: Principle of deriving a part S/N curve from a specimen S/N curve for each FE-node.

After the compression, which is basically the cutting out of sections with lower damage content, new recurrence factors need to be found. In an iterative process, these factors are modified until the damage of the compressed test program matches the reference with sufficient accuracy.

4. Conclusion

Within a development project the additional effort for the fatigue analyses is small, since the FE-model exists already before the structure is tested.

By using the FE-based fatigue analysis software the applied forces are superimposed. Therefore the damage comparison is based on actual stress amplitudes rather than single force signals.

For the damage comparison so called part S/N curves are used for every FE-node of the structure. Therefore the inclination, which has significant influence to the damage values, does not need to be assumed.

The compressed test program can be optimized to achieve accurate results at various locations of the structure. If no test program can be found, which is accurate for the entire structure, the error can be directly evaluated.

As a consequence time condensed test programs can be significantly more accurate.

5. References


