How to Improve Fatigue Strength of Vehicle Components, Employing Different Test Methods

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1. Laboratory tests for endurance determination

New vehicles, systems (e.g. rear suspension) and new components (e.g. wheels) are tested in the laboratory and in the form of road tests. The endurance testing and component optimization processes have been laboratory-based since August Wöhler's day, in other words for over a century. Materials testing developed into component testing, which led to endurance confirmation for entire systems. In-car function testing, where the interplay of man and machine is assessed, has also of late been taking place to an increasing degree in the laboratory, in direct relation to the increasing number of objective measuring methods for subjective criteria.

Facilities for strength testing range from the classic tensile testing machine to multi-axial system test rigs. The requirements of raw material economy and weight-saving design have led to the development of laboratories with highly complex testing facilities at institutes and manufacturers. The methods used here are the three classic ones: static, sudden and dynamic.

The art of the test engineer at a car strength testing laboratory or component laboratory in the supply industries is to select the correct test method for each specific case. Which test method is correct? In addition to the obvious requirement that the correct type of load has to be selected, in some cases attention has been paid to testing frequency and now, particularly, the correct choice of multi-axial load type.

Can the conditions affecting a vehicle in operation be achieved economically, rapidly and simultaneously? The answer is: usually only in a simplified form or with restrictions. All the same, strength tests are increasingly carried out exclusively in the laboratory. It is far less economical to test components and systems comprehensively at different stages of development, from different suppliers, of different materials and/or heat- or surface-treated in different ways in a road test - i.e. in prototype form - than it is to test them on test rigs. In addition, the laboratory test lends itself to the application of time-compression methods. However, in this respect the pertinence of laboratory testing techniques with respect to actual driving is crucial, Fig. 1.

Tests on standard samples which have been ground, notched samples and "component-like" specimens can usually be carried out quickly and cheaply, but only provide limited information on component or system behaviour in the vehicle. Only the positive or negative tendency of an altered parameter (e.g. radius or heat treatment) can be determined. Component testing needs to be based on the more costly, finished part itself. A quantitative assessment of components can be obtained rapidly in one-level s-n tests. This assessment normally refers to tolerable fracture load cycles at a given load level. This test technique is relevant for parameter optimization of the geometry, type of material and method of surface and heat treatment. Yet the result is always the same: an improvement of X or Y load cycles at a constant amplitude of dynamic loading.
A further improvement is to conduct statistical confirmation of survival probability, if sufficient samples are available. Yet the design engineer wants to be able to quantify the improvement he has made to the component in terms of extra kilometres. All damage accumulation hypotheses to date, based on the Palmgreen-Miner rule, have not yet led to the desired "conversion procedure". The multi-axial operating load simulation test, which has found increasing use over the last 10 years, is of help in this respect. This test method involves subjecting a component, assembly or system to multi-axial endurance testing on a test rig with load-time signals from actual driving. This test is costly and time-consuming, but can be reproduced at any time and provides highly pertinent results.

2. Load types, sample applications

The application of each strength-testing technique is listed below, from static tensile testing to 16-axial operating load simulation testing. The examples numbered are then described in greater detail with the aid of illustrations.

2.1 Static tests

Universal testing machines are used for tensile, compression and bending tests, and a slow-running torsion drive transmission for torsion tests.

<table>
<thead>
<tr>
<th>Load</th>
<th>Specimen, component, assembly, system</th>
<th>testing reason/optimization</th>
</tr>
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<tbody>
<tr>
<td>Tensile</td>
<td>specimen</td>
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<tr>
<td>Compression</td>
<td>tie rod, push rod</td>
<td>buckling load</td>
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<tr>
<td></td>
<td>rack and pinion 'steering'</td>
<td>buckling load of rack and pinion steering, housing fracture load</td>
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