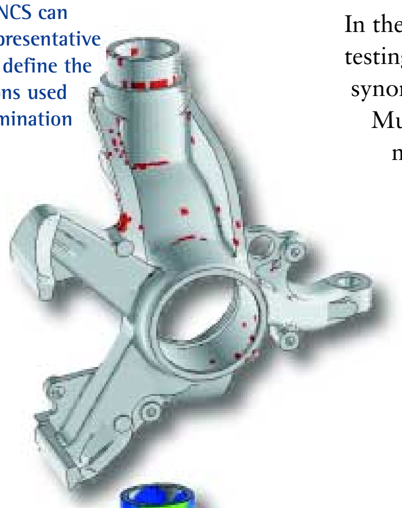
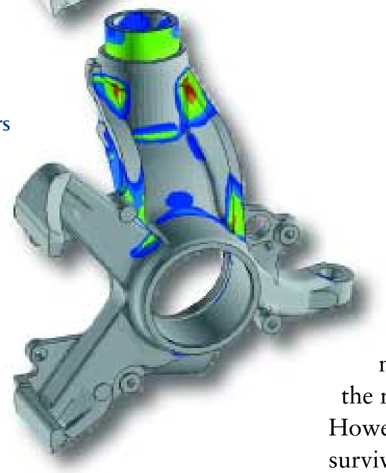
Application Case

Volkswagen Improves Durability Testing with Virtual Prototyping Tools



Uniquely, FALANCS can compute the representative elements which define the load combinations used in the nodal elimination scheme



Damage contours for VW knuckle

In the automotive industry, durability testing in the laboratory often seems to be synonymous with road simulator testing. Multi-axial loading histories previously measured on test tracks are replayed on test rigs, which often have 16 independent actuators.

However, although the road simulator is ideal for verifying the durability of the full vehicle or of large subsystems, it has two disadvantages:

- The prototypes of the full vehicle or of large subsystems required by road simulator testing necessarily become available much later than individual components. Testing components early in the development cycle can prevent surprises in later (critical path) testing, and thus speed up development.
- The reliability of components not failing in the assemblies tested on the road simulator cannot be assessed. However, knowledge of the probability of survival of each component is essential for the commercial success of current car lines selling millions of cars.

Thus, car manufacturers interested in maintaining and even further improving a high quality standard, such as Volkswagen, have to perform extensive component testing in addition to road simulator testing. The simpler these component tests are, the more tests can be performed, thus improving reliability analysis. The simplest test, of course, is a test with uniaxial loading (one actuator).

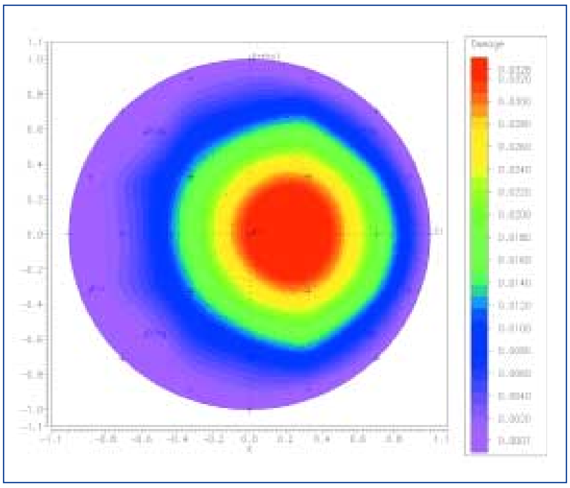
How can such uniaxial tests be designed? Imagine a steering knuckle: it is not only loaded by spindle forces, but also by free body forces acting on the connections with the shock absorber or the control arm. There may be 16 different forces acting non-proportionally on such a component. Also, several independent crack initiation locations may exist. Each of these locations may be particularly sensitive to a specific load component. If it is possible to come up with a uniaxial test that shows the same critical locations and the same life as the road simulator test, then such a test can be used for component testing. Of course, it may not always be possible to define such a test.

Based on unit load finite element analysis, LMS LMS FALANCS can predict the fatigue life for each node of the finite element mesh, thus implicitly determining crack initiation locations. Therefore, LMS LMS FALANCS could simulate various uniaxial tests set up in a trial and error fashion and compare them with the multiaxial test.

However, LMS LMS FALANCS can do even better: it can eliminate the trial and error test setup and find a suitable uniaxial loading history, if it exists, or else determine that reduction to a uniaxial test is impossible. LMS LMS FALANCS finds ‘representative elements’ of the finite element mesh. Imagine comparing stress or strain histories at two adjacent elements: very often, the histories will be very similar - mostly the histories are proportional to each other, just the amplitudes may vary. A simple case is a hinged beam with loads acting on the free boundary: intuitively, we look for critical locations just at the hinge, because we know that the stress histories at other locations are proportional to the one at the hinge, but have smaller amplitudes.

LMS FALANCS is able to automatically find groups of elements loaded by similar stress and strain histories. It can then represent such a group by the element with the largest amplitude - the most critical one. The first figure shows representative elements for a Volkswagen knuckle. When comparing with the damage contours for the same knuckle, it becomes obvious that not only critical locations were chosen, although they are included, but also elements that are influenced differently by the loads, such as the ring of elements at the shock absorber connection on the top. Those elements have to be considered as well, because they might become critical when reducing the number of load components acting on the knuckle.

In the next step, MultiRain is used to determine a ‘load influence sphere’. In this three-dimensional display, axes correspond to the influence of the longitudinal, lateral and vertical (out of plane axis) spindle forces. Representative elements are then entered on the so-defined sphere according to which force, or combination of forces, dominate the local stress history. An element dominated by lateral loads is found on the top or bottom, an element dominated by vertical forces is found in the middle. The color of each element corresponds to its damage level: red means severely damaged, purple indicates almost no damage. If the most severely damaged elements all show up in the same area of the plot forming one red ‘hot spot’, they are all dominated by the same combination of load components, which can even be read off the plot. This load combination can then be used in the uniaxial test. If several hot spots are displayed on the load influence sphere, reduction to a uniaxial test is impossible. In the case of the Volkswagen knuckle analyzed here, reduction to a uniaxial test was indeed possible.



Load influence sphere shows that a uniaxial test is possible.

Concluding the analysis results, Gerhard Mäscher, Head of the Durability Department of Volkswagen points out: “We have, of course, run uniaxial component tests before, setting up the tests with engineering judgement and from previous experience. LMS FALANCS and MultiRain have confirmed these setups. However, we are much more confident with the additional numerical analysis. Combining numerical simulation and physical testing is the key for successful design for durability, and the LMS tools are well-suited for this.”

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