Vehicle durability workflows-
Complementing physical testing with simulation

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IDIADA positioning on durability simulation
Vehicle Durability attribute development tasks are trending towards increased simulation prior to physical testing. Supplementing testing approaches with simulation has improved the accuracy and the completeness of the information available through the vehicle development cycle.

IDIADA is a MSC technology partner. It offers engineering, testing, and homologation services in different locations over the world. IDIADA has more than 30-years of experience on physical durability testing at the full vehicle level, system, and component level and leverages differentiated infrastructure such as two operating proving grounds in Europe and China. Over the years, it has been recognised as an expert in vehicle development tasks across different markets.

Durability attribute development process
Traditionally durability assessment has consisted of three significant steps. First is the target setting, the second the virtual development phase, and the third one is the experimental validation.

Based on this broad framework, specific tasks that best fit a particular project are defined. These specific tasks would depend on factors and constraints such as the availability of a prototype, the prototype’s maturity, the study’s objective (complete vehicle/component), etc.

Vehicle durability assessment projects usually consist of several combinations of the following applications depending on the specific project. They are: a) target setting, b) quasi-static virtual assessment, c) 4-poster / multiaxial (virtual and experimental), d) proving ground (virtual and experimental), e) (Road Load Data Acquisition) RLDA/Load cascading (virtual and experimental), and e) fatigue analysis.

1. Application review
1.1 Target setting
In terms of durability, Target setting refers to the number of miles/kilometres a vehicle has to operate over. It is necessary to define this vehicle's usage profile, which includes the region where the vehicle will be used, the road type, the speed, and the payload.

Once the target is set it is correlated with an equivalent cycle in the proving ground. There are three main approaches for this correlation: physical RLDA and virtual RLDA (3D or 2D).
1.2 Quasi-static assessment

Quasi-Static assessments consist of the definition of manoeuvres and vehicle inertias, representing the standard driving conditions. These manoeuvres are simulated in MBD simulations like Adams to generate loads that are used in fatigue analysis. This is a simplified approach used at the initial stages of development.

1.3 Virtual 4P/Multiaxial

Multiaxial analyses consist of the replication of experimental 4-poster and multiaxial configuration in an MBD simulation. The input loads for this test can come from virtual or experimental RLDA.

The outputs obtained are interface loads to be used in a fatigue analysis.
1.4 Virtual proving ground

VPG analyses consist of the replication of proving ground through an MBD simulation over scanned 3D tracks.

The outputs obtained are again, interface loads, to be used in a fatigue FEM analysis.

Notice that ‘input loads’ is a generic term and that they could be presented in different forms: 1) interface loads in time domain 2) in frequency domain 3) modal participation factors.

Depending on the form that these loads are presented in, we need the corresponding form of stress/strain. In case (1) we need the stress/strains from a unitary load case. In case (2) we need the modal stresses and the vehicle’s frequency response, and in case (3), we need the modal stresses.

2. Adams durability simulation workflow

Virtual simulation starting from Adams Car models helps durability engineers overcome some of their main challenges in the development cycle

- Unavailability of prototype vehicles for RLDA or available vehicles not being representative of the production release
- The insufficient maturity of available component information
- Inability to measure component loads, consider all vehicle variants, what-if studies for structural design proposals, components, etc.

To build a reliable model for virtual durability applications, the following components must be considered:

- Vehicle model: Sufficient level of model flexibility should be considered for all components that directly impact the vehicle response for the frequency range in the study. This is usually in the 50-75 Hz range for durability applications. It usually requires the use of flexible bodies (proper natural frequency representation of the flexible elements), proper powertrain suspension representations, representation of the bushings with the frequency content and a physics-based high fidelity tire model. A proper and detailed correlation process at different model levels has to be conducted. Starting from the component information, perform a suspension Kinematics and compliance correlation, then a low frequency (handling and braking) set of manoeuvres to compare the simulation outputs to test measurements for comfort and durability events. For this comparison, the user may start with essential mechanical signals like displacements and accelerations to compute forces, stress, and strains.

1.5 Virtual RLDA/load cascading

This application refers to the outputs that are obtained in an MBD simulation and their post-processing. The MBD simulation could be 4-poster, multiaxial, or proving ground.

This means that after MBD simulation, we have all possible measures available (displacements, accelerations, and forces) for a complete virtual RLDA. We can define follow-on activities, for example, component tests. Notice that these component tests could be conducted virtually or experimentally.

1.6 Fatigue analysis

This analysis consists of combining MBD input loads with stress/strains obtained in a FEM simulation. Users can affect this combination with commercial software like MSC’s CAEfatigue.
• Durability cycle: In general, it is a combination of track sequence run at a certain speed and a specific number of cycles for each of them. The end goal is to compute equivalent damage on the vehicle representative of a certain amount of driven distance defined in the durability standards. If these are defined at IDIADA Proving Ground in Spain, IDIADA in partnership with MSC offers the possibility to use the digitised representations of the proving ground directly within Adams.

• Fatigue Assessment: With the load histories generated at each interface point of the vehicle components under study, the durability engineer combines the load for every event considered in the durability cycle considering the number of cycles to estimate the damage of the part.

Summary

The article defines different available virtual tools used along the development project of a vehicle using an efficient combination of testing and simulation activities. Although simulation is gaining momentum for durability applications, due to the statistical nature of the vehicle phenomena, there is plenty of room for both testing and simulation techniques to complement each other.