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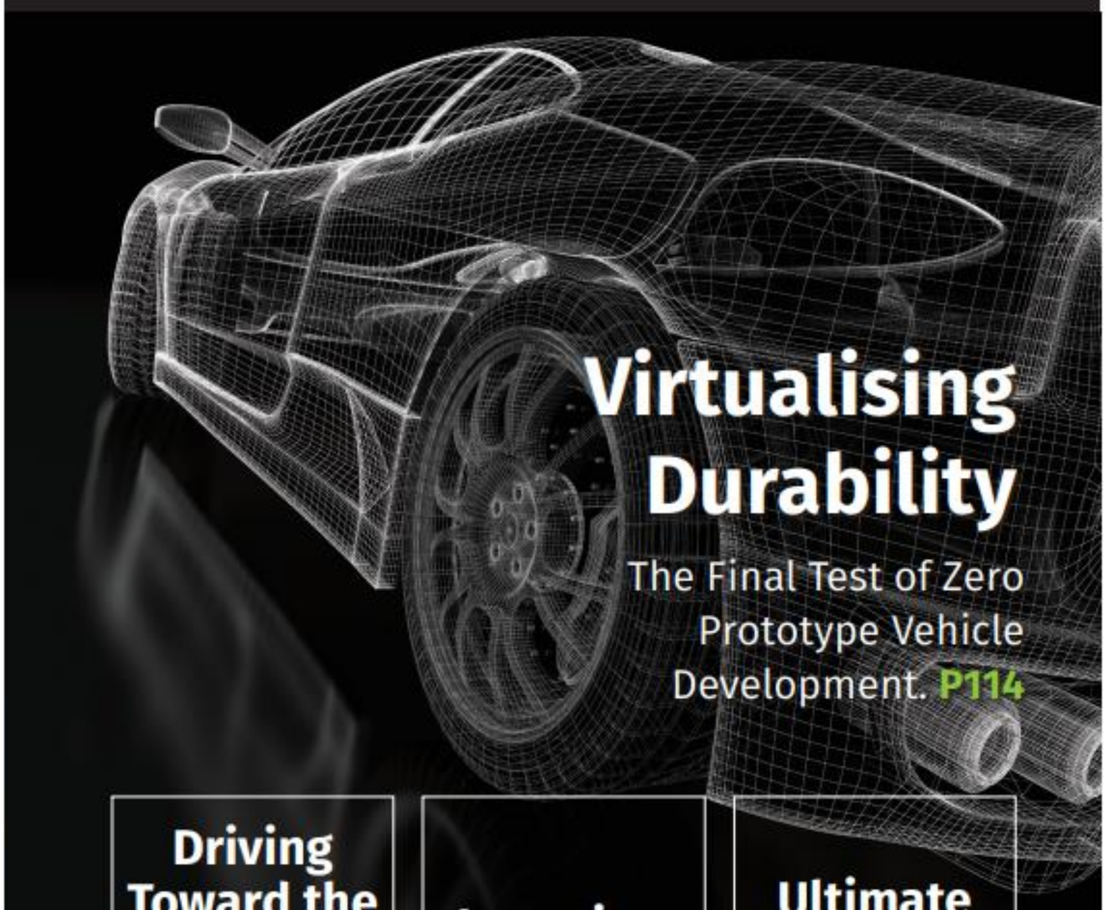

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The Final Test of Zero Prototype Vehicle Development

Many OEMs, including Jaguar Land-Rover (JLR), Mazda and Renault, have stated that their goal is to achieve zero (or near zero) prototype vehicle production. To achieve this, they require simulation to replace testing that would be covered by prototypes, as such, many have started their own investments in vehicle simulation development. BMW have built the "Driving Simulation Centre" in Munich, an investment of around €100m towards achieving this. Robust simulation is critical to any OEM in achieving a quicker, economic, and more environmentally friendly vehicle development process. But the closer to the zero-prototype goal an OEM gets, the more difficult it can be to reproduce the data they would expect from traditional prototype-based testing.

Simulation already forms an essential role in the early stages of vehicle development, aerodynamics simulation improving vehicle drag, powertrain analysis to gain vehicle efficiency and suspension optimisation to make the ride comfortable and achieve the handling targets. A great number of tools are available for development and refinement, but many predominantly work in isolation from each other. Most specialise in their own aspect of vehicle analysis and produce results for one element of the vehicle. Data from each tool feeds another but as the vehicle design mutates during development the inputs to each test must change with it. For example, an alteration to the bodywork at the front of the vehicle could affect the cooling of the powertrain, the drag and average torque load on the motors and vertical load on the suspension and tyres. This can cause a cascade of reviews and modifications to accommodate the change but that in turn can have its own effect on every other system.

While obvious changes can be earmarked as potentially influential and investigated ahead of this problem, some issues are only found when full vehicle durability testing is carried out. Problems in component wear is a problem that many OEMs have difficulty in predicting but critical to achieving vehicle longevity. In almost all cases, prototype vehicles, their drivers and the subsequent component evaluation have the final say in whether the vehicle is working correctly and ready for sale.

What Is Durability Testing?

Durability testing is an investigation into the long-term degradation of a vehicle after experiencing the expected obstacles it should expect to see through its lifetime. Most durability testing is carried out at vehicle proving grounds and encompasses both what most would consider normal driving conditions and the less common events that a normal driver would see irregularly. This can include sustained high speed, laps around racetracks and kerb strikes. Each OEM will have durability routines which are tailored to include what they anticipate the vehicle will encounter given the vehicle type and the target market.

The information gained from durability studies come in many different forms, both measurable, from the vehicle, and objective feedback, from the drivers who conduct the studies. Information is gathered during and after a durability test where the vehicle can be examined and any component exhibiting failures or performance degradation identified and investigated. The subjective feedback can be regarding many elements of the vehicle, including vehicle comfort and handling characteristics.

Problems With Existing Development Programs

Up to 70 prototype vehicles are produced for a new vehicle program,

Durability

with earlier prototypes potentially costing over £250,000. As these vehicles can only be produced in late stages of development, the very earliest the point at which an approximate full system can be fully tested is after the one-off first vehicle is constructed. In the early stages of testing, proxy vehicles can be adapted to include components of interest and early investigations carried out. While these give a lot of useful results, the time and cost for both modifying and testing the vehicles allows a limited number of tests.

There is of course an environmental cost to prototype testing. Involving thousands of miles of driving, using a larger amount of energy over normal driving conditions. Often needing tests performed in many locations, in all conditions, the transport between test facilities also increases the time, cost and environmental effects.

Once full-scale production is on the horizon, the ability to modify components reduces. With lead time needed to produce production tools such as panel press forms, there is little that can be modified in the event of a design fault emerging during durability testing, as durability tests are often performed with late stage prototype vehicles once the tools have already been produced. Finding these issues before the tool designs are set is critical in improving efficiencies. But this requires a durability study to be conducted before first tool production. This can only be achieved with virtual durability testing.

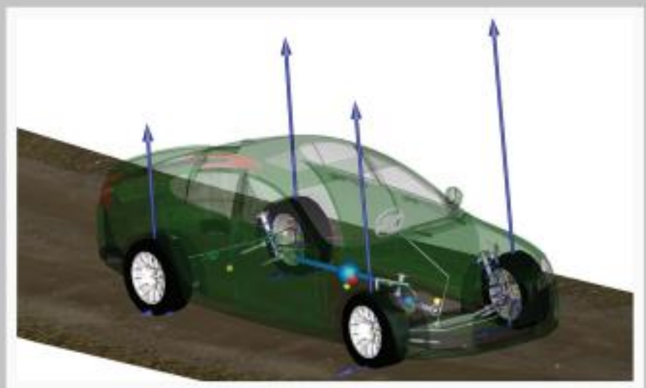
Development Of Durability Simulations

Claytex, a global modelling and simulation solutions developer for the automotive and motorsports markets, has been working with an international OEM to recreate their specific durability studies in Dymola, a simulation package with the ability to simulate mixed media experiments. This means that the multibody of the suspension, heat, and fluid dynamics of the cooling system and the controllers, can all be modelled in the same program. Libraries are available that specialise in specific system modelling, normally focusing on particular areas of investigation, such as suspension, engines, or electric motors. Effort has been made to create simulations with future vehicles and adaptability in mind. The setup has been developed such that test sequences are not vehicle specific. This allows any new vehicle to be tested by replacing and simulating.

Using the Vehicle Systems Modelling and Analysis (VeSyMA) simulation libraries as a base provides vehicle templates and interchangeable sub systems to match the design of the vehicle and progression of the development. Other libraries such as VeSyMA – Suspensions, VeSyMA – Engines, VeSyMA - Powertrain, Electrified Powertrains or Batteries provide high fidelity models and controllers of suspension systems, engines, transmissions, electric motors, or batteries, respectively.

Vehicle Simulation

The choice by the OEM to use Dymola was based on the capabilities of both the acausal language and the hierarchical modelling structure. Combined with the templates and models provided with libraries such as the VeSyMA Suite allowed them to work on distinct areas of investigation separately and chose models of complexity to match the availability of data throughout development. A combination of different system complexities was also used in the same model, mixing a simple suspension with a complex powertrain model or vice-versa. This provided targeted and efficient investigations by only simulating complex elements that affected the outcome of the investigation.



Simulation of a vehicle with multibody suspension and Pacejka tyre models on an alpine road.

When conducting any vehicle simulation, the effect of interdependent systems must be considered and accommodated, as in the real vehicle. In durability studies this is of even higher importance, while small changes to component behaviour may have small or negligible effects in short term tests, when performed hundreds of times in durability studies, it can have a resounding effect. Having simulations with active sub-system modelling produces a more accurate result. With sub-systems becoming more active and interdependent in modern vehicles, this is becoming more important than ever.

"Our solutions allow a range of vehicles to be put through the same test with the same driver and environment models, allowing one library of tests for all vehicles." says David Briant, Project Engineer

Driver and Environment Simulation

Each test consists of a series of actions, which could include defined motions or require driver feedback control. Tests such as coasting around a corner involves not touching the throttle (open loop) but steering to follow the corner (closed loop). The VeSyMA drivers include both elements where a series of tasks is given to the driver to follow, changing from "closed loop" control to "open loop" demand dependent on the vehicle status, position, or time. This produces repeatable test conditions that in this project replicate their pre-existing durability studies.

The surface and tyres are also one of the key elements to get correct to match the fidelity requirement of the vehicle. Using the Pacejka tyre model, an industry standard tyre model for most of the vehicle simulations to produce the forces to move the vehicle, coupled to the VeSyMA grid contact model, allows the tyres to interface with rough surfaces and obstacles such as kerbs and cobblestones. The road surface can range from ideal flat surfaces for early investigations to millimetre resolution scans of proving ground roads. Roads can be defined using the CRG standard or using the same techniques developed and used in Formula One, on the road models scanned and available through the virtual environment software of rFPro. Roads such as Millbrook Testing Ground or racetracks such as the Nurburgring, commonly used in durability testing by many OEMs, are available in rFPro. Additional surfaces owned or specific to an OEM test can also be scanned and used; this allows for utilisation of pre-existing data as validation for the simulations.

This technology conceived for Formula One also includes the ability to use the same vehicle models run real-time in Driver-In-The-Loop simulations. The coupling of rFPro for the environment, Dymola for the vehicle and driver interfacing with simulators is common throughout racing. In this type of simulation professional drivers can analyse the performance of the vehicles at very early stages. This method can produce very close to the same feedback from the drivers concerning handling and performance characteristics that you would gain in prototype-based testing.

Interaction with other Tools

Modelling every aspect of the vehicle is possible in Dymola but sometimes may not be the optimum path to creating a valid vehicle model. Using multiple tools to their strengths can produce results quicker and sometimes with more applicable results. The FMI standard allows many tools such as Dymola and Matlab to be interfaced. Keeping to a low number of imported models retains simulation efficiency, by reducing the amount of interfacing overheads low. This allows the component controllers, such as active suspension systems, that are usually developed for final production in Matlab to be used directly by the vehicle models in Dymola.

This also extends to tyre modelling, using FTire to model the tyre and surface. While running in parallel with Dymola, the hub forces are fed directly out from FTire to the vehicle suspension. FTire allows for even higher fidelity tyre simulation by modelling aspects such as tyre belt deflection, dynamic pressure waves and tread pattern interaction with the road surfaces. With Pacejka considered to have an accuracy limit of 25Hz, FTire is used to analyse frequencies exceeding this, both transferred to the powertrain and to the bushes of the suspension.

Automated Testing

The goal of projects like this is to produce an automated, validated process where the only input required is the vehicle model. Once a new vehicle model is created, it can be run through the library of durability tests and results extracted automatically. But the scalability and diversity of the tests can be increased with simulation-based studies as the time to conduct and variety of tests is of a lot less consequence. Tests that were too costly or time consuming to add to the durability study can be included by adding any number of additional tests to the library.

With simultaneous simulation used to run all the tests at once, it allows the entire durability study to be run in as much time it takes to run the longest single simulation to be completed. With this process automated to be run at regular intervals the OEM can much more readily assess the ability of the vehicle periodically.

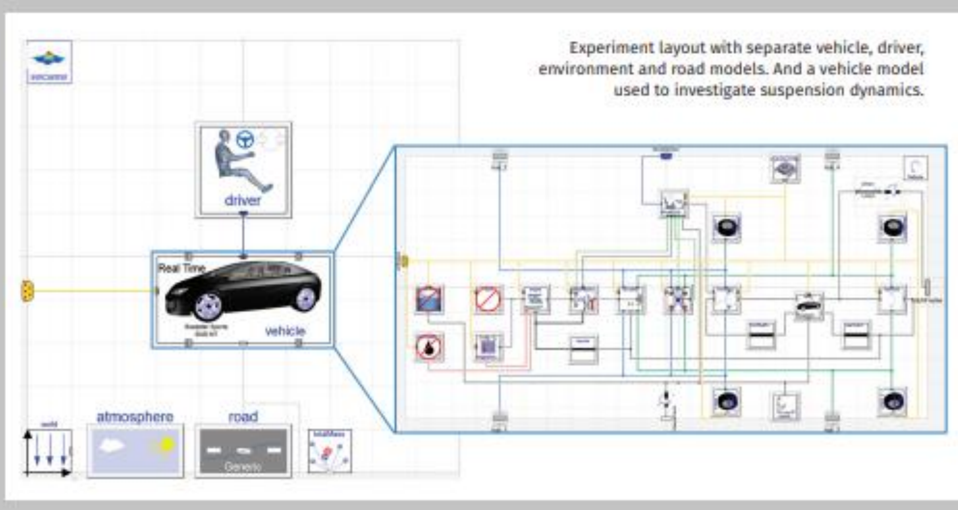
If chosen to extend this automation further, the cumulative results can be passed to secondary programs to perform analysis on specific aspects of the vehicle performance or degradation of components. An example of this would be using both peak chassis load curves with frequency of their occurrences within Finite Element Analysis tools to gain the chassis mount strength degradation over time. This can directly inform the engineers to the best component selection at a very early stage and if any unforeseen effects cause these loads to change, this can be flagged up for component re-evaluation.

Concluding

Reducing the number of prototype vehicles needed during vehicle development needs a large initial investment in both the production and validation of the simulations.

"Our solutions allow a range of vehicles to be put through the same test with the same driver and environment models, allowing one library of tests for all vehicles."

But once a simulation sequence has been fully developed, only new vehicles need to be created and run. But the benefits of using a simulation-based durability study gains more than just a reduction in the number of prototype vehicles. With a good implementation of a simulation tool chain OEMs can carry out and gain results from more evaluations a lot earlier in the development process, leaving a lot more time for refining and improving the vehicle. ■



Experiment layout with separate vehicle, driver, environment and road models. And a vehicle model used to investigate suspension dynamics.