Using MSC.ADAMS to develop MIRA's Virtual Test Environment

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MIRA has a long and established history of vehicle test and development, especially within the fields of vehicle ride, handling, NVH and durability. With the move towards zero prototype engineering, fewer vehicles are available for development and greater emphasis is placed on conducting more accurate analysis upfront at the concept and design stages. MIRA has embraced this shift, by integrating its vehicle development activities into the simulation environment. In adopting this approach, the same methods and techniques for assessing vehicle performance can now be conducted in the virtual world. ADAMS has taken centre stage in this process and MIRA now has the capability to perform virtual rig tests and undertake ride, handling and durability analysis on the MIRA Virtual Proving Ground. This paper outlines how ADAMS is employed to develop vehicles using the virtual tools created.

In order to maintain confidence in the process, MIRA undertook an extensive correlation exercise on a single case study vehicle. This ensured that the models used were valid and that the virtual test environment was representative. In order to improve model accuracy, MIRA received assistance from MTS and MDI to evaluate and assess the performance of the MTS Empirical Dynamics Modelling software. The results of this study are also presented.

Introduction

It is well cited throughout the industry that the onus is on reducing product development times and costs. Over the years, MIRA has witnessed a reduction in the number of prototype vehicles used for development, and instead, a growth in CAE activities. This shift is progressively moving forward in the development programme, with many analyses being conducted upfront at concept and early design stages. The pressure is rising for simulation to lead the product development process, and to deliver results on full vehicle attributes earlier.

In addition to the increased demand, several other factors make simulating full vehicle behaviour even more challenging.

With each new generation of vehicles, customer expectations rise. In response to this demand, vehicle complexity increases, in terms of both the number of components fitted and in their individual sophistication. Hydramounts, active bushes and adaptive dampers are good examples of components introduced to improve vehicle refinement and ride. These in turn demand a higher level of electronic technology, which in turn may support full vehicle control strategies such as ESC or EBD. It is therefore essential to understand the way these components behave in order to simulate their responses.

With increased reliance on simulated data, increased accuracy in the data produced is essential. The ability to simply predict trends is no longer acceptable. Within the durability process, road load data generated through simulation is passed into fatigue solvers to predict component life. Errors of just a few percent calculated in component load will return a much greater error in predicting component life. The need to accurately predict component response is therefore even stronger.

Finally, development through simulation needs to satisfy the criteria of every other process. It must either deliver real savings and reductions in time and cost, or facilitate improved product development in terms of quality and innovation. So it is of great benefit if the models created can assess a range of vehicle attributes, such that the effect of a design change can be assessed in terms of vehicle ride, handling and durability.

The process developed at MIRA

To satisfy the requirements listed above, MIRA drew upon its experience in full vehicle development. All existing processes and skills currently used were reviewed and it was identified how these could be applied in a similar fashion to the virtual world. From the outset, it was obvious that it was necessary to wholly integrate the rig and proving ground tests into the simulation activity, so that the same techniques and methods could be used in the product development programme. The obvious environment in which to do this was ADAMS, being ideally suited for full vehicle simulation and rig test, and with a good track record of use within the company.

As shown in Figure 1, tests in the real world progress at an increasing level from simple component tests to full vehicle instrumented tests. In the process, MIRA's wide range of facilities including damper rigs, Kinematics and Compliance (K&C) Rig and extensive Proving Ground provide essential information. In this way, individual components, complete systems or whole vehicles can be interrogated. To offer the same process in the virtual world, virtual equivalents of the K&C Rig, test machines and the MIRA Virtual Proving Ground were created.

As part of an internal research programme, entitled Integrated Corner Technology, MIRA undertook an extensive model correlation programme to ensure that the process was formed correctly. This comprised three sections, component characterisation studies, correlation to the static rig tests and correlation to vehicle ride and handling tests. Each of these was directly supported by a series of real vehicle and component tests on a case study vehicle, the Fiat Punto.

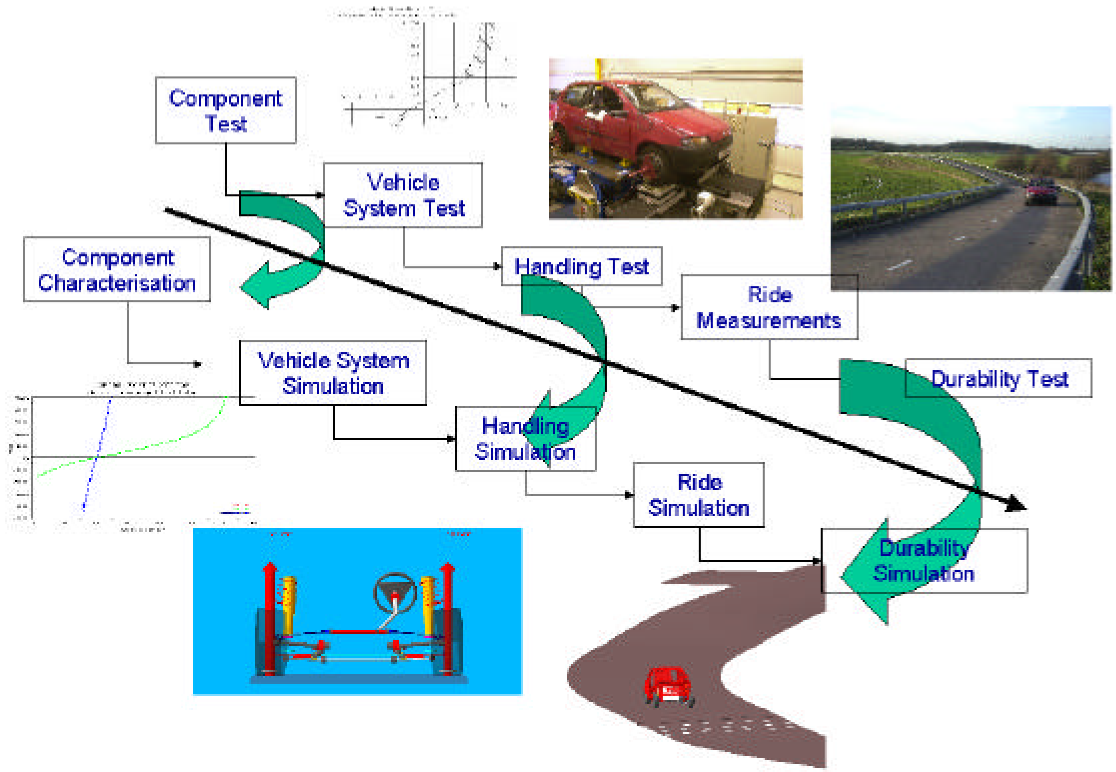


Figure 1

Component Characterisation Study

The crux of the process lies with the ability to accurately predict component response. The level of sophistication at the component level ultimately determines the quality of results at every subsequent step.

Traditionally, modelling components that exhibit non-linearity in terms of amplitude and frequency has been a complex affair. Unfortunately, these components are typically the most common elements on a vehicle; tyres, bushes and dampers are good examples.

Recent developments in black box modelling techniques have suggested that characterisation through neural networks is possible. To investigate further, MIRA undertook a case study in modelling dampers using the Empirical Dynamic Modelling (EDM) toolkit from MTS.

Dampers are predominantly characterised by their amplitude non-linearity in terms of force and velocity. This is usually done by subjecting the component to a stepped sine sweep signal of constant displacement. The damping force at each velocity is captured and plotted on the force-velocity graph similar to that seen in Figure 2. This force-velocity relationship is directly entered into the ADAMS environment as a spline function.

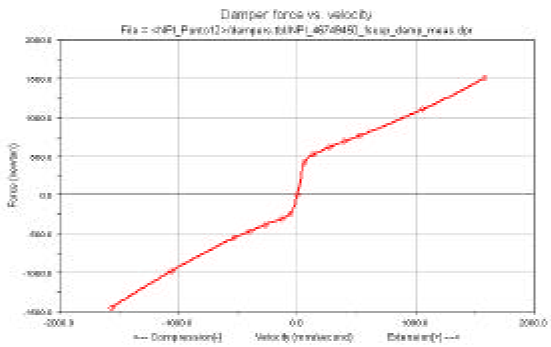


Figure 2

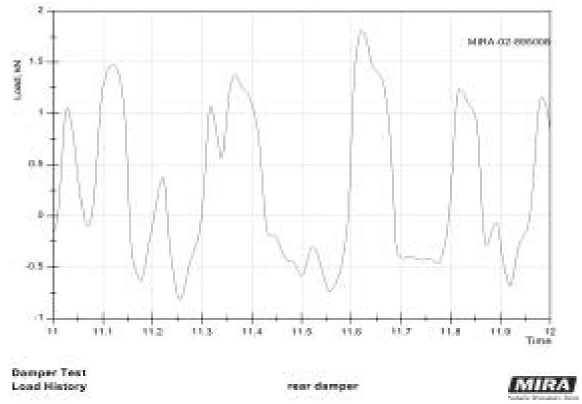


Figure 3

In practice, dampers are very rarely subjected to pure sinusoidal road inputs and are subjected to more random inputs. If the damper is driven by a white noise signal, of which a 1 second period is shown in Figure 3, the force-velocity profile gains width, Figure 4. This is the hysteresis of the damper and is not captured by the traditional method of representation.

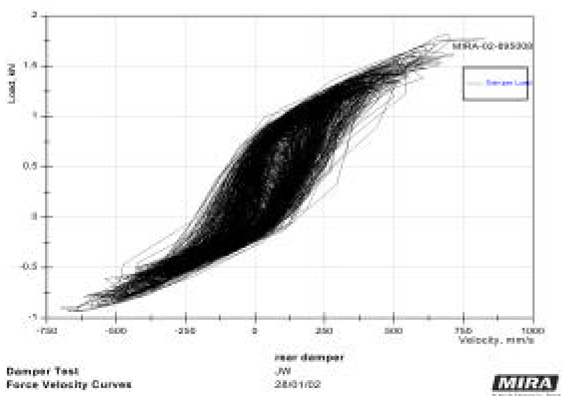


Figure 4

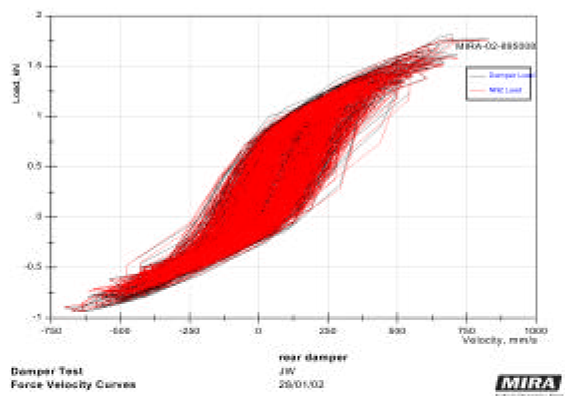
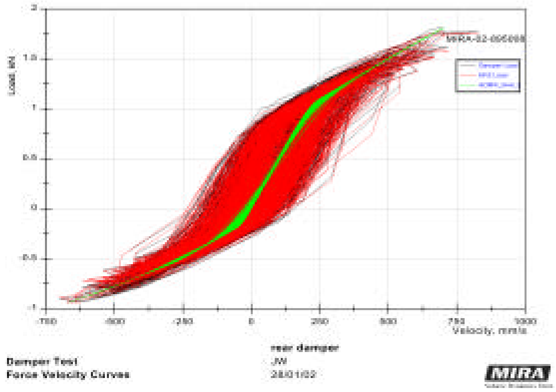


Figure 5

The EDM approach utilises a random displacement signal to drive the damper and records the force at each displacement. The neural networks are trained on this signal according to a prescribed length of time or until a level of accuracy is attained. Of the many models available, the most comprehensive is the Neural2. This uses both velocity and displacement as inputs and delivers force as the output.

To evaluate the performance of the Neural2 model, it was used to predict the response of the damper to the white noise signal shown in Figure 3. The response, shown as the red line in Figure 5, compares well with the measured response in black. When the response of the ADAMS damper spline to the same signal is compared, shown in green in Figure 6, the EDM result is seen to capture both the hysteresis and non-linearity.



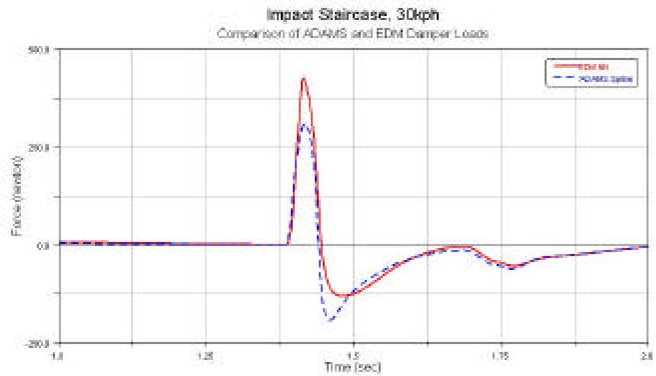


Figure 6 **Figure 7**

The EDM neural network damper was also tested within ADAMS/Car, with the vehicle striking a sharp edged impact strip. The results in Figure 7 show the predicted damper loads for the EDM damper, blue, and the traditional damper spline, red. It can be seen that the EDM damper exhibits reduced damping and returns higher loads than the ADAMS damper. This is accomplished with little overhead on solve time.

The main limitation with EDM is that a certain degree of foresight is required when training the neural network. If the NN receives under training (in terms of training duration) or is not trained over the complete operating range it will experience during simulation, errors are recorded. As a result, the damper returns erroneous loads and the simulation requires resubmitting with a different damper model.

Static Tests

In order to understand the role of a component within a system it is essential to perform a series of repeatable tests on the system. This method is currently practised on real vehicles at MIRA using the Suspension Parameter Measurement Machine, the Kinematics & Compliance Rig. ADAMS/Car has included in it the Suspension Test Rig that conducts half car tests on the front and rear assemblies independently.

MIRA undertook a study to compare these two test rigs to ensure that the results of one could be compared to the other. Only when tests have been conducted using the same inputs and the same outputs recorded can the data be processed and presented for correlation. This required ensuring that a common coordinate system was employed, that measures were all referenced to the same datum and that data could be exported in a way that allowed for ease of comparison.

This exercise proved useful in two respects, it improved the ease of correlation, by increased understanding of the origins of the data, and it assisted the model construction, enabling more accurate results to be obtained.

MIRA Virtual Proving Ground

It has always been possible to conduct vehicle handling studies in ADAMS and compare them to real test data, but this has been limited to tests conducted on flat surfaces. However for ride and durability analyses, a full 3 dimensional proving ground is required. Therefore the single greatest challenge was to recreate within ADAMS the full MIRA Virtual Proving Ground. Data on the real Proving Ground was available from two sources, existing drawings and measurements.

MIRA maintains a record of the original design specifications of many of the surfaces present on the Proving Ground. These are used for maintenance and for development of additional features. The drawing for the impact strip on the Ride and Handling Circuit at the bottom of the hill is shown in Figure 8. A process was devised whereby the Proving Ground drawings were translated into ADAMS road data files for use during simulation. These were created such that the features could remain discrete, or as continuous inputs as found on the circuits. In this way, the vehicle can be tested over individual impacts such as a pothole or over entire duty cycles. A section of the Ride and Handling Circuit, including the short wave corrugations and crowned road intersection, is shown in Figure 9.

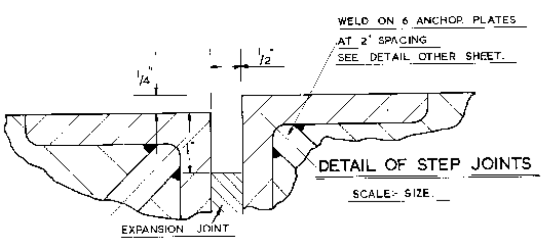


Figure 8

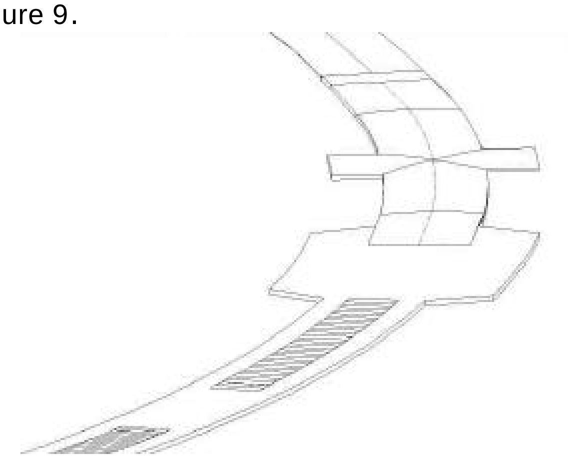


Figure 9

The other means for generating the Proving Ground surface was from direct measurement. Surfaces like the Belgium Pavé, Figure 10, have been measured and stored, such that the data can be compiled into a road data file. This is supported by laser profiling, to provide additional definition when required. An example of this can be seen in Figure 11 for the profile of one of the impact strips. Using this technique, it has been possible to map public roads as well as Proving Ground surfaces.

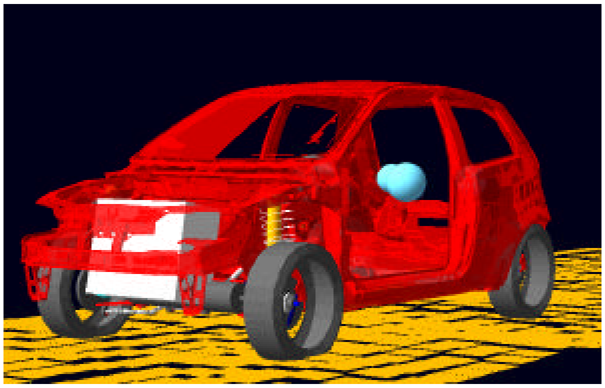


Figure 10

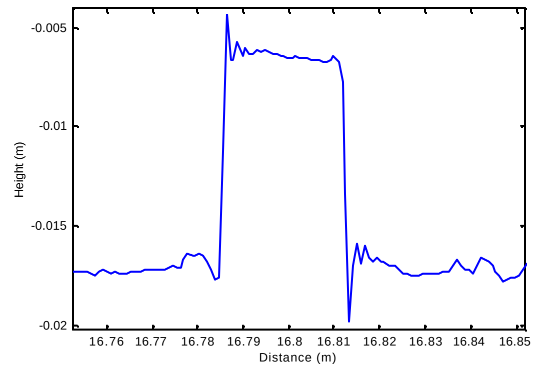


Figure 11

With the virtual environment created within ADAMS, the process of correlating real and simulated track test data was conducted.

Handling tests

With static ally validated front and rear vehicle models, the next stage was to simulate vehicle handling tests. These included steady state cornering tests as well as transient manoeuvres. Again, the suitability of the standard ADAMS/Car tests for direct comparison of the outputs to those generated during real vehicle test was assessed and modifications were made where necessary. Existing MIRA vehicle dynamics analysis tools were used to post process the simulated data in the same way actual vehicle test data is handled and the required handling attributes and measures for interpretation were calculated. In this way, simulated data was available for correlation with measured test data.

Ride and durability tests

The Impact Strip, shown in Figure 8, exists on the Ride and Handling Circuit to assess impact harshness of vehicles. The same feature was created as one of the suite of features available on the Virtual Proving Ground and was used to correlate simulated and measured time histories to wheel hub loads and accelerations.

In addition, full time histories were generated on the Ride and Handling Circuit and Pavé surface. This natural progression from a single discrete impact to multiple simultaneous impacts was used to assess the performance of the vehicle model and, in particular, the dampers and tyres. Again, the quality of the data was compared to the measured Road Load Data using a number of signal classifications.

As a deliverable to a second MIRA research programme, entitled Integrated Durability Engineering, load time histories for both the Ride and Handling and Pavé surfaces were used to predict the life of the twistbeam assembly during a simplified durability schedule.

Conclusion

MIRA has developed a unique process, by creating parallel virtual and real world environments. The virtual environment is capable of undertaking development of a single component through to full vehicle proving ground assessment. In doing this, MIRA has utilised the latest technology, in terms of virtual proving ground construction and component modelling.

The process builds on current vehicle development procedures and techniques used at MIRA, and commonises the real rig tests, ride and handling procedures and duty cycles with their virtual equivalents. The integration of test and simulation facilitates rapid correlation and increases model validity.

In terms of product development, by operating wholly within the ADAMS environment, one model is capable of assessing a wide range of vehicle attributes. Changes in component design can be assessed on a vehicle's ride, handling and durability. Consequently, the process is efficient and MIRA can offer more rapid concept development programmes. Finally, because stringent correlation and validation techniques are employed, the risk associated with virtual engineering is much reduced and product confidence is improved.

Acknowledgements

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References

[1] A Barber, *Accurate Models for Complex Vehicle Components using Empirical Methods,* SAE Paper 2000-01-1625.