

# Virtual Testing and Correlation for a Motorcycle Design

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## ABSTRACT

Two-poster rig plays a very important role in accelerated durability evaluation in a motorcycle industry, similar to what a four-poster rig does in a car industry. The rig simulates the exact road conditions in the vertical direction through tire coupling by applying feedback control on displacement. On account of its ability to simulate to the exact customer usage conditions, it reproduces the failures realistically as it happens on the field. However, as complete vehicle is required for testing on the rig, the testing happens mostly in the advanced stages of product development. Any failures beyond the concept stage have a huge impact on the development time and cost and the same should be avoided. Therefore, in this paper, a virtual testing methodology is proposed, based on which potential failures on the vehicles can be captured at the concept design stage itself.

An ADAMS model of a motorcycle was created. In the model, frame, footrest, swing arm etc, were modeled as flexible bodies. The rubber elements in the vehicle like rear suspension eyelet rubber, swing arm rubber etc. were measured and modeled as well. Road load data acquisition was done on a rough road and the same was simulated on a two-poster rig. To validate the model, the motorcycle was tested in the lab using the simulated road load on two-poster rig. Satisfactory virtual to physical validation results were achieved. After model validation, the motorcycle model was integrated with a tire coupled virtual test rig to form a virtual testing system.

Different iterations were conducted using the virtual testing system. Front and rear wheel hub acceleration and shock displacement signals were used as control signals for tire

coupled virtual testing. A Comparison was done on physical and virtual acceleration, potentiometer & strain signals. The results indicate that there is a fairly good match for acceleration signals between the tire coupled virtual test system and the two-poster rig.

To better understand the limitations of a two-poster system, the same motorcycle model was integrated with a hub-coupled system to form a hub-coupled virtual test system. Front and rear wheel hub vertical accelerations, fork bending moment, swing arm pivot joint longitudinal force, front and rear shock displacements were used for hub coupled virtual testing. On comparison with the road, a definite improvement was seen in the results. In general, it was observed that virtual testing with a hub-coupled system has better acceleration and strain correlation results than a tire-coupled system.

Also, a comparison study was conducted to find out the difference between virtual testing using tire coupled and hub coupled motorcycle virtual testing systems. The results showed that tire- coupled system could only reproduce vertical signals accurately, which is what a two-poster rig does. The hub-coupled system can reproduce vertical and longitudinal signals accurately, a combination of which is what is seen on the road. As a result, damage associated with longitudinal loads for components such as front fork can be reproduced more accurately by using a hub-coupled testing system.

## INTRODUCTION

Many vehicle/motorcycle manufacturers and component suppliers are moving towards a laboratory test as the sign off durability test. Some are also thinking that to replicate this final laboratory test in the analytical world would be a

valuable tool. Before this can be possible, a sufficiently accurate model of the specimen and the test rig must be developed. This requires conducting both physical tests and virtual tests. Where results are not sufficiently matched, an explanation for the difference must be determined and either the physical or virtual system adjusted.

Virtual testing provides an opportunity for the development of such a characterization. Due to the repeatability of the virtual testing process, analysis will be able to discern small changes to the vehicle/motorcycle model.

The main advantages of virtual testing include:

- Virtual testing can evaluate the design early in development when the prototype is not available
- Virtual testing can help when setting up the physical test to better utilize the testing equipment
- Virtual testing can be conducted faster and cheaper than physical testing
- Boundary and load conditions can be obtained easier and faster by virtual test
- Virtual testing results can be validated with data from the physical test it modeled.

Virtual testing requires people who understand both physical testing and virtual simulation in order to get good results. These people have to know both specimen and test rig. Model solving usually takes longer than real time. RPC iterations usually take long time. Therefore, it is important to automate the solving process such as using RPC Pro tools and processes to conduct analysis automatically.

In general, virtual testing include following steps:

1. Collect data on a vehicle/motorcycle.
2. Perform virtual test using RPC Pro to reproduce the road data.
3. Obtain load time history of components using Multi-Body Dynamics tool.
4. Conduct fatigue analysis and evaluate the design.
5. Conduct correlation with laboratory test to improve the model.

It is impossible to model every detail of physical system. Therefore, physical testing must be conducted to validate the design and to understand predictability of virtual testing. Overuse virtual testing result could lead design to wrong directions. Virtual testing cannot replace physical testing.

Virtual testing is still in its early stage. People still have difficulties to get good physical to virtual correlation results.

Therefore, it is important to understand predictability of the virtual testing results and use the tool properly.

## VIRTUAL MODEL GENERATION

Correct modeling of front and rear motorcycle shocks is critical to obtain good analysis result. Each shock provides a spring force, friction force and a damping force. Characterization tests were conducted to characterize these forces, which were described in terms of splines.

One of the most difficult tasks in virtual testing is to model elastomer isolators such as bushings and rubber mounts accurately. Elastomer isolators usually have non-linear load deflection relationship. The relationship is also frequency dependent. With small deflect, however, the isolators can be simplified as linear and frequency independent. If the isolators are in linear load-deflection relationship range, ADAMS bushing elements can be used to model the isolators. If the isolators are in non-linear load-deflection region and frequency dependency can be ignored, ADAMS G-force elements can be used. If frequency dependency cannot be ignored, complicated modeling technique, such as EDM technique should be used.

For the motorcycle studied, most of the isolators are made of hard rubber. The deflection of these isolators is relatively small and the isolator is quite linear. Therefore, these isolators are modeled by linear bushing elements.

In tired coupled and hub coupled lab tests, usually, a dummy rider is used to simulate the real rider and some static weights are placed on passenger seat to simulate the passenger. Since virtual testing is to simulate the lab testing, in the ADAMS model, the dummy was modeled according to information provided by the dummy rider manufacturer. The dummy rider includes head, lower arm, upper arm, lower leg, thigh, head and torso as separate parts. Between the rider and seat, there is spring damper simulating the seat isolation. On the passenger seat of the motorcycle model, parts with proper weight were added to simulate the static weight in the lab. Spring dampers were added to simulate the seat isolation.

Rider and passenger simulation in the lab testing is a difficult issue. It could provide big impact to lab testing results. Special active restrain system should be designed to simulate the realistic response of rider and passenger. Virtual testing could be an effective tool to evaluate different rider and passenger simulation methods and help to select the active rider and passenger simulation designs.

The virtual 2-Post test rig simply contains two virtual actuators. A vertical motion generator is applied to the slider joint to provide motion to the virtual actuator. The interface between the virtual actuator and the wheel is modeled by an force function that has the stiffness of the tire.

The virtual hub coupled test rig model is modified from MTS standard hub coupled test rig model. To simplify the problem, all parts in the test rig model are rigid bodies except bushing components. In motorcycle testing, there is not much lateral input to the motorcycle. Therefore, lateral actuators, lateral struts, and lateral bell cranks were not modeled. The motorcycle and rider were restrained laterally by ADAMS In-Plane elements. Adding the lateral actuators would only cause un-necessary complication to the virtual system.

In longitudinal direction, there are two actuators. If both actuators have displacement control, there will be a lot of cross coupling effect between the front and rear longitudinal actuators. RPC iteration may have difficulty to converge. To avoid this problem, the front longitudinal actuator was modeled as displacement control and rear longitudinal actuator was modeled as force control.

In vertical direction, the hub coupled test rig has two displacement control actuators that can provide vertical excitation through struts and bell cranks.

In this work, motorcycle frame, power train, swing arm, handle bar, side guard, front fork, front and rear tires, top and bottom portion of the shocks are considered to be separate parts. The frame, swing arm, handle bar, and side guard are modeled as flexible bodies. MNF files were generated using ANSYS.

In the lab 2-Poster testing, motorcycle is restrained in lateral and longitudinal directions by rubber straps attached to dummy rider and motorcycle frame. Motorcycle tires sit in grooves of the wheel pans. The side walls of the wheel pan grooves prevent lateral and longitudinal movement of the tires. In virtual testing, the rubber straps and the wheel pan grooves can also be modeled. However, modeling these elements can cause un-necessary model solving complication. To simplify the problem, in 2-Poster simulations, ADAMS In-Plane elements are used at dummy torso and rear wheel hub to eliminate lateral movement at these two places. A soft spring was added to the engine to prevent longitudinal drift of the motorcycle.

For hub coupled simulation, the test rig provides longitudinal restrain. Therefore, there is no need to add the artificial spring on the engine. The In-Plane elements were still used at the dummy body and rear wheel hub to provide lateral constraints.

Figure 1 and 2 show ADAMS models of the motorcycle - 2-Poster and the motorcycle - hub coupled virtual testing systems.

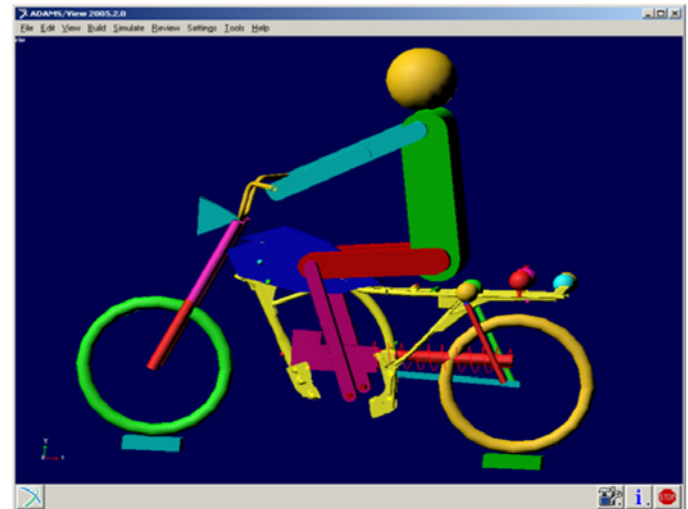


**Figure 1. ADAMS model of motorcycle on 2-Poster test rig**

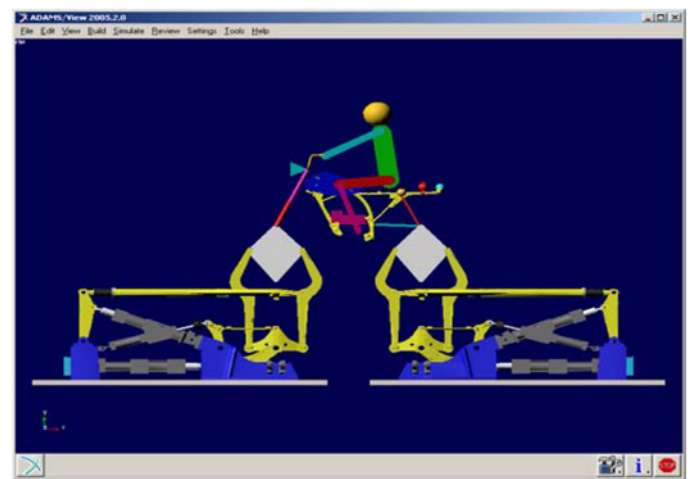


**Figure 2. ADAMS model of motorcycle on hub coupled test rig**

## VIRTUAL TESTING AND RPC PROCEDURE

The specimen was instrumented with various sensors before data acquisition. The sensors provide physical and virtual test control signals as well as correlation signals. Therefore, proper selection of sensor types and locations are very important. In this work, multiple accelerometers, displacement sensors and  $\frac{1}{4}$  bridge strain gages were chosen as control and correlation sensors

For the 2-Poster testing, vertical wheel hub acceleration and shock displacement signals were used as control channels to control both low and high frequency motorcycle response. For hub coupled simulation, it would be the best to have