

Using Road Simulation Technology for Durability Verification of Plastic ATV Fenders

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ABSTRACT

To validate the durability of ATV fenders in the lab, it is necessary to apply a testing method that utilizes inertial reactions with large displacements and high accelerations that are present in actual vehicle usage. A relatively simple test rig was devised utilizing an ATV frame, hydraulic actuators, and beam structures. The test rig can reproduce many high amplitude events common to ATVs such as jumps, whoops, and log crossings. By combining this test rig with road simulator technology, a simulation test method was developed. A correlation study to actual riding durability testing demonstrated the test method's ability to reasonably recreate testing conditions and validate ATV fender durability. With this method, efficient and timely part validation was achieved. This simulation method was successfully applied during development and continues to be utilized in additional research and development projects.

1. Introduction

In recent development of new models and revamping of existing models, the plastic fenders on ATVs have typically been parts of major focus. To maintain a styling advantage in the market, new part configuration and construction has been desired. Also with ever increasing economic pressures, finding methods that allow reduced part cost or part count is a focus. These two factors, along with others, lead to designs such as the 2008 TRX400X ATV. This model utilizes a multi-layer fender structure that includes a base fender and an over fender. With this structure, it was possible to get a revolutionary new look while reducing part cost and increasing part toughness.

With this new part configuration, the methods used to evaluate the strength and durability of the fenders in the past may not have been suitable. Methods such as actual vehicle riding durability can take a long time to verify the parts, while methods such as impact testing may not accurately indicate weak areas of the construction. Fatigue testing methods of a point applied load with constant amplitude or a point applied displacement with constant amplitude were also determined not able to accurately indicate the weak points of the structure. Even inertial reacted testing with constant amplitude or frequency was considered to be deficient in accurately

reproducing the actual situation. It was determined that the best method to efficiently test the new construction would be to use an inertia reacted Remote Parameter Control TM test method, more commonly termed road simulation.

This paper describes the techniques used in the creation of a method for applying road simulation technology to verify the durability of plastic ATV fenders.

2. Considerations in designing road simulation test rig

When it was determined that durability testing would need to be conducted on the new fender structure, many test methods were considered. One of the first methods considered, primarily due to simplicity, was to measure deflection at the tip of the fenders during actual vehicle operating conditions, then to conduct a displacement controlled constant amplitude test by applying the load/displacement near the tips of the fenders. The amplitude of displacement would be determined by common strain damage correlation procedures. This test method was deemed inappropriate as the deflection shape of the fender would most likely be different than actual operating conditions. The deflection shape is largely influenced by the inertial input loads due to large accelerations as well as the frequencies at which these inputs occur. The

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geometry of the fender is generally quite complex and has several bolted connections in addition to contact points with the frame body. In addition to strain damage, proper deflection shape is necessary to accurately reproduce wear on contacting surfaces as well as possible slip loads at bolted connections. The fenders are relatively long, wide, and thin, with a significant portion of the mass cantilevered from the frame. During high speed jumps with large accelerations, a distributed load applied to the surface would be more appropriate, yet difficult to reproduce in the lab.

In order to recreate the proper deflection shape, inertial reaction would need to be used. Briefly considered was a method where a single hydraulic actuator would be attached near the center of the ATV frame-body and control the displacement amplitude at either a constant frequency or through a frequency sweep. This method was not chosen because it was thought that it would also not be able to sufficiently reproduce all the deflection shapes that occur in the highly dynamic usage conditions. It was then determined that a method using two vertical inputs to reproduce vertical and pitch motions should be sufficient for a first try at recreating the actual usage. Using existing equipment and fixtures, the first generation test rig was constructed and operational in a very short time. The test rig consisted of 2 hydraulic actuators with 250 mm (10 inches) of stroke capability, an aluminum link with roller bearings on each end attached to a bracket that was bolted to the rear of the frame, a collar welded to the front of the frame with roller bearing, and the ATV frame body with fenders attached. Fig. 1 shows the 1st generation test rig.

3. Preliminary simulations

With the test rig design selected, data from actual vehicle operation needed to be collected. Initially, the best metric (acceleration vs. strain) and locations for the parameter to be reproduced was not certain. With the unknown of which parameters would be the desired signals for reproduction and which would be used for reference, many parameters were recorded simultaneously. Acceleration data was acquired at 2 points on the ATV frame body and 2 points near the tips of the fenders (1 front, 1 rear). Strain measurements were taken at 6 points on the fenders as well. Once the data was collected, the instrumented fenders along with the frame mounted accelerometers were transferred to the test rig.

When the test rig was ready to run, a white noise displacement signal was input into the hydraulic actuator system and the response of each of the above mentioned parameters was measured. All being performed within road simulation software, the frequency response function (FRF) and coherence were determined. It was quickly discovered that the coherence, or how much of the output signal is related to the input signal, of the accelerometers attached to the tips of the fenders and the strain gages were very low, and thus using these as controlling parameters would have caused difficulties in creating good reproductions. Being far removed from the displacement input points; these locations have responses that are heavily dependant on many other factors aside from vertical displacement. With the frame mounted accelerometers attached in close proximity of the displacement input points, coherence was good, and thus

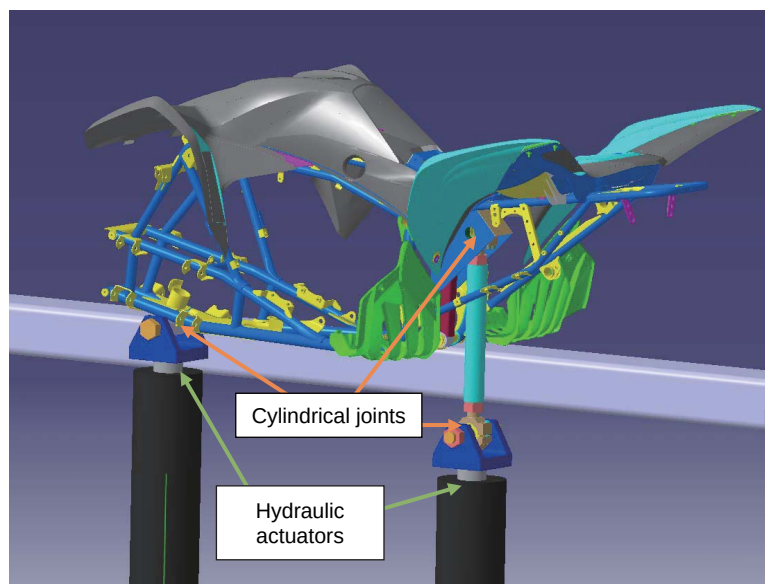


Fig. 1 Computer model of 1st generation test rig

they were chosen as the controlling parameter.

With the measured FRF, the inverse FRF was calculated within the simulation software and the iterative process of reproducing began. During this stage, it was discovered that the available stroke of the hydraulic actuators were not going to be sufficient for reproducing acceleration of several key events a sport ATV experiences such as a triangle jump or running a whoops section. In addition to the lack of stroke capability, it was observed that during other events such as staggered log crossings, the lack of body roll was significantly reducing the calculated strain damage. With these two short falls, it was determined that a more elaborate test rig would need to be developed.

4. 2nd generation test rig and simulations

In determining the design of the next generation test rig, there were 2 primary requirements: (1) there must be adequate displacement to reproduce jump events and (2) body roll motion should be simulated in addition to vertical and pitch motions. Primarily due to the shape and orientation of the fenders, it was determined that forward, lateral, and yaw motions would cause limited additional motion and damage to the parts. To determine the amount of vertical displacement needed, a linear drive estimate was performed using unitary gain in a single iteration on the 1st generation test rig. The displacement that the simulation software indicated plus some additional buffer was calculated to be approximately 500 mm (20 inches). With the rig requirements and much consideration to full DOF (Degree Of Freedom) constraint, the 2nd generation test rig was designed.

As shown in Fig. 2, the method chosen to obtain the required displacement was to use simple lever arrangements with 3 hydraulic actuators. The center pivot of the levers were made such that the fulcrum points could be changed, thus allowing for additional displacement if needed. The ATV frame-body was still used as the base for attaching the fenders as in the 1st generation test rig. The front suspension components were also used with the exception that the dampers were replaced with rigid links. In order to attach the actuator/lever assemblies to the front spindles, simple links with spherical joints at each end were used. The rear of the frame was connected to the third actuator/lever assembly via a single spherical joint. This left the entire structure with a single uncontrolled DOF, so a double arm arrangement was designed to laterally support the front of the vehicle with a spherical joint. The design allowed for the roll axis of the vehicle to be placed easily based on the location of two spherical joints. The roll axis was initially chosen to be the same as the suspension roll axis. This arrangement caused a majority of the mass to be above the roll axis and was quite violent to the test rig structure. The roll axis was then moved closer to frame-body center of mass. This resulted in a much smoother operating rig and had minimal effect to damage correlation of the test parts. An additional revision that was made at a later time was to add 2 additional links. One was between the rear of the body and the actuator/lever assembly. The other was a very long arm between the rear of the body and a reaction fixture. This revision reduced the lateral and fore/aft forces transmitted to the actuator/lever assembly, improving stiffness and test rig component life. Motion capability of final test rig was over 500 mm (20 inches)

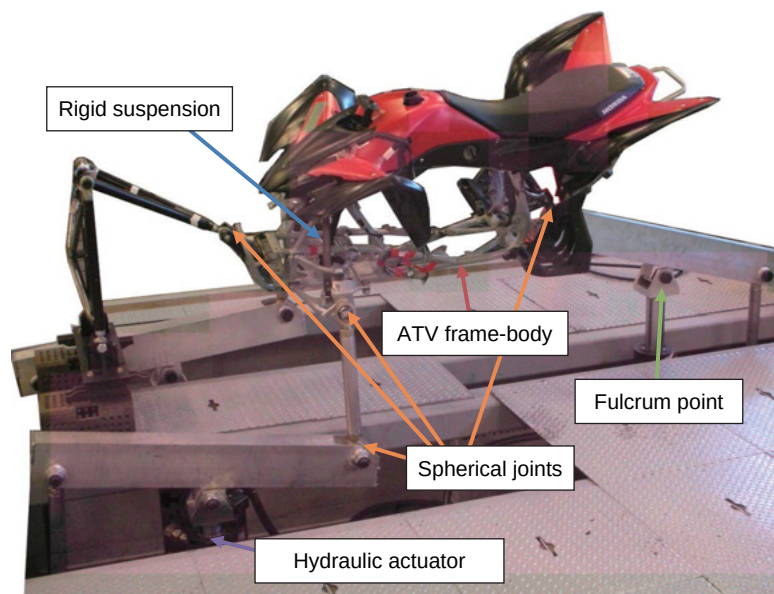


Fig. 2 2nd generation test rig

of vertical motion and more than 20 degrees of both pitch and roll motion.

With the 2nd generation test rig having 3 actuators, there were 3 control channels for the simulation software, requiring 3 response signals for simulation. From findings during the 1st generation preliminary simulations, it was determined that frame body accelerations would be the best control signals. Positions on the frame body were chosen so that each of the 3 accelerometers would be primarily sensitive to only 1 input. Preventing significant cross couplings in the control/response systems aids in quicker and less difficult simulations. Due to the frame body structure of the TRX400X not being very wide in the front, a light-weight rigid beam with the accelerometers secured to it was attached to the front of the vehicle. This allowed for placement of an accelerometer near each of the front actuator/lever assembly connection points. A coherence check confirmed the beam mounted accelerometers to be adequate control signals for simulations with the 2nd generation test rig. A quick try of controlling with the fender tip mounted accelerometers was also checked, but as with the 1st generation test rig, coherence was low. As stated before, maintaining close proximity between input points and response measurement points aids in achieving good coherence.

5. Additional considerations during simulations

One of the parameters to be considered during simulation is the range of frequencies that will be reproduced. With ATVs, the more severe events that one wants to reproduce are jumps, which require large amounts of stroke to reproduce the actual events exactly. When looking in more detail at a jump, it can be broken up into 4 separate events. The first section is the launch. This is when the vehicle changes directions to include some significant portion of vertical velocity. This typically occurs quickly and can be somewhat damaging.

This is shown by the red zone in Fig. 3. The second portion is the upward motion portion shown as green in Fig. 3. This event is not very damaging, but can cover a vertical motion of 2 m (6 feet) or more. The 3rd portion, shown as blue, is the fall. This also is not very damaging, and covers basically the same displacement as the upward motion. The last portion is the impact and suspension oscillations that follow. This is the orange section in Fig. 3. This high acceleration is very damaging for inertial loaded parts. So in considering the jump, damaging events for the fenders occur quickly, or at a relatively high frequency, while the majority of the vertical motion occurring at a relatively low frequency is not very damaging.

An easy way to remove this large, undamaging motion is to apply a high pass filter to the acceleration data. The question then becomes how high of frequency content can be filtered out before integrity of the test begins to diminish. This can be answered a couple different ways. The field data can be filtered and compared to unfiltered data through a damage or pseudo-damage calculation. Another way is drive the test rig with a sinusoidal displacement, starting with a very slow frequency and gradually increasing the frequency while either recording frame to fender tip displacement, strain on the fender, or simply visually observing the frame to fender motion.

The upper frequency limit of the band for simulation is often determined by the design and capability of the test rig. In order to achieve high accelerations, the rig was designed to be light. However, with lightness often comes lower stiffness. This results in lower natural frequencies of the system. Ideally, the rig is designed with detailed CAE analysis to optimize this weight/stiffness balance. Once the test rig is built, it is fairly easy to determine this upper limit. During the FRF measurement process, the coherence will become low once this limit is reached at higher frequencies. This lower coherence means that it will be difficult for the simulation software to accurately reproduce the desired response at higher frequencies. To determine if it should be attempted

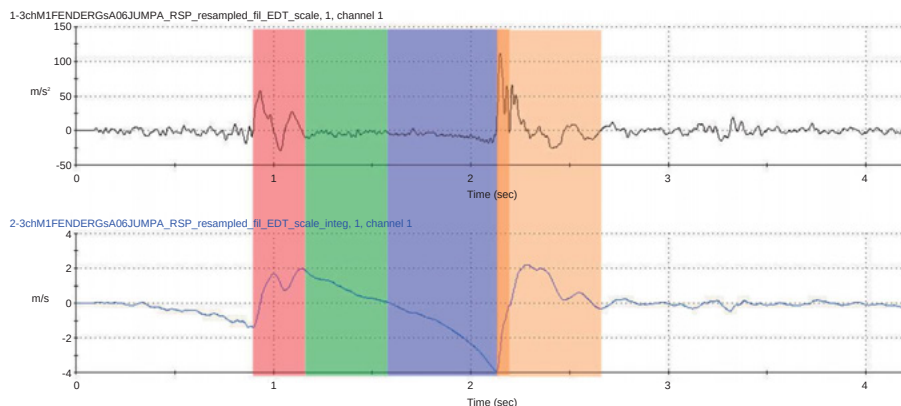


Fig. 3 Acceleration versus time (top) and velocity versus time (bottom) of frame near front left corner of ATV

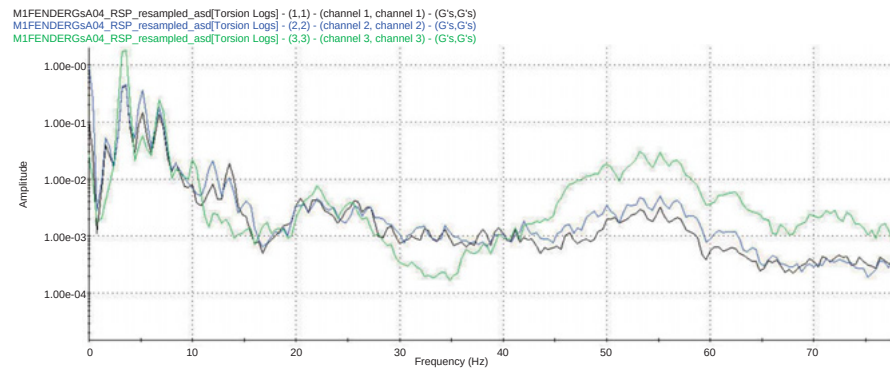


Fig. 4 Spectrum analysis of field data acceleration measurements at 3 different locations

to reproduce higher frequencies, the damage effect of this higher frequency portion of the data needs to be investigated. This can be done as mentioned above by filtering the field data and then comparing the damage back to the unfiltered data. A quicker, but less accurate way, is to simply look at the spectrum analysis of the field data, such as an example shown in Fig. 4. As seen in Fig. 4, there is substantial spectrum content in the 50 to 60 Hz range that could cause significant damage, especially for the location indicated by the green line. Pursuing a simulation to include up to 60 Hz would lead to a more valid simulation for this example.

6. Qualifying results

Once the drive files were created, it was necessary to validate if the simulation was adequately reproducing wear

and damage. To quantify this, strain measurements were taken at the same locations as the initial field measurements. A damage analysis comparison was done to compare field versus lab results. The target for pseudo-damage values from lab testing was to be in the range of 0.5 to 2.0 times damage values from field data. As seen in Fig. 5, only 2 of 6 channels achieved this target. The remaining channels were in the range of 0.25 to 4.0 times. In the case of the initial test for the TRX400X, it was determined that the damage correlation was sufficient. An additional method to verify the simulation was to compare actual damage and wear to vehicle durability testing. This type of analysis was done, and confirmed the 0.25 to 4.0 times damage range to be acceptable. On later projects, limit testing has become more of a focus. In this case, the field acceleration data can be scaled to produce more severe events and accelerate damage accumulation with

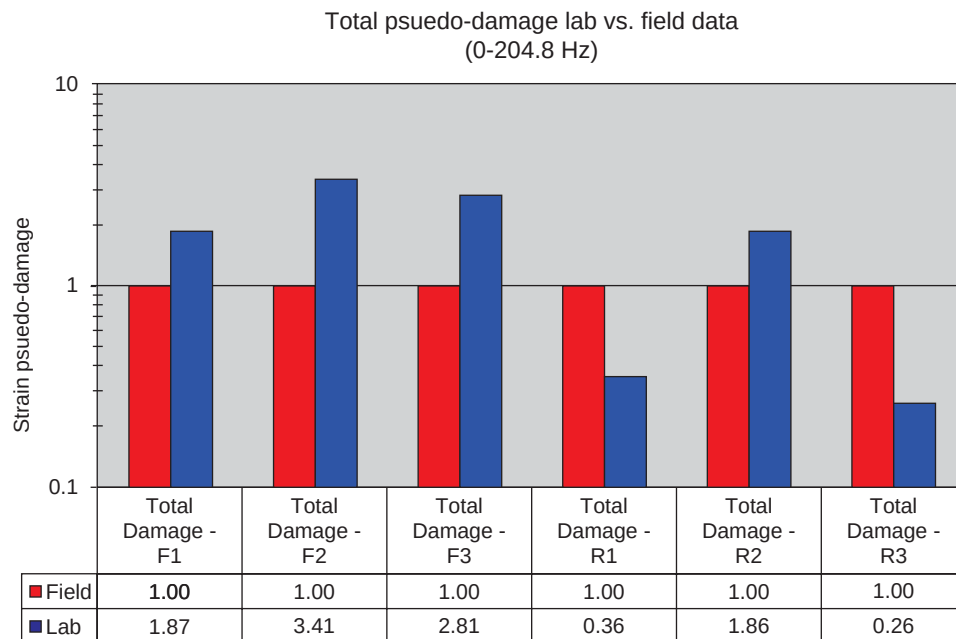


Fig. 5 Pseudo-damage of field and lab data at 6 different locations

relatively accurate results. Through experience with this and other projects, it has been demonstrated that the durability verification of plastic ATV fenders can be done with road simulation technology.

7. Conclusion

A unique test rig and method were developed to validate the durability of ATV fenders. This rig was able to reproduce high displacement events such as jumps as well as higher frequency vibrations. The result was the creation of an effective method for reproducing durability testing and quickly evaluating durability of the ATV fenders.

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