2021-2022 DAQ Validation Plan

GT Off-Road Racing | Data Acquisition
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1.0 Overview

1.1 Introduction

The purpose of this document is to provide a plan for the data acquisition team's goals for GTOR's Spring validation. It outlines the validation plans for each design subsystem on the team, along with any miscellaneous validation plans that aren't specific to any one sub-team.

Every test that is planned for the Spring will be listed out in this document, and if there is any test or measurement requirement that needs to be run that is not listed in this document, it needs to be communicated to the DAQ sub-team as soon as possible. The list should be finalized by the beginning of the Fall semester.

The format for this document is as follows, a test or measurement requirement will be described and accompanying the test/measurement will be the physical requirements for the test i.e., what type of sensors are needed, what mechanical components are needed, and if any specialized software is needed (such as a specific minimum or maximum sampling rate that is desired). If any of the physical requirements require work outside of the DAQ sub-team, those will be listed out as well, otherwise it should be assumed that DAQ will do the work necessary to meet the listed requirements.

2.0 Chassis Validation

2.1 Chassis Stiffness Test

The chassis stiffness test measures the force vs. displacement of one corner of the chassis with the other three corners of the chassis fixed.

The chassis stiffness test requires a mechanical means of fixing the chassis in place and applying a load on one of the corners of the chassis. This is typically done using an adjustable steel rig that is clamped to a table. The rig is bolted on where a hub for each wheel on the car would typically be bolted. A screw jack with a drill is then used to apply a force to the corner that is free with a load cell in between the chassis and the screw jack to measure the force. This test requires two measurements, the force, and the displacement of the free corner of the chassis. The displacement is usually measured manually with a dial indicator. Since this is a static test, the sampling rate does not need to be fast, and the force measured by the load cell should be viewable in real-time.

Most of this test will be performed by the chassis team, however the load cell will be provided by DAQ along with software/instructions and any assistance in using the load cell.

2.2 Vibration Test

The vibration test will measure vibrations in the chassis that are induced by the engine.

The vibration test requires an IMU and a way of mounting the IMU securely onto the chassis. For measuring vibrations, the IMU sampling frequency must be greater than the Nyquist frequency of the engine. Since the engine will never go faster than 4000 RPM, this means that the minimum sampling frequency is $2 * \frac{4000RPM}{60s/min} = 133Hz$. However, the fastest sampling frequency that can be obtained should be used.

The only thing that the chassis team is required to do is to make sure that there are mounts for the IMU in whatever locations they want to measure vibrations. DAQ has CAD for the IMU enclosure that can be used for this.

2.3 Strain Gauge Analysis of Chassis Members

This test is simple, the chassis team would like to measure the strain on different members in their chassis.

The requirement for this test is some sort of strain gauge that can be affixed to any of the chassis members, along with some sort of signal conditioning circuit for the strain gauges.

2.4 CFD Analysis

While the plans for CFD analysis of the chassis aren't fully fleshed out yet, it is still included here. There are no specific requirements for this analysis yet since the actual method of running this test hasn't been determined, but DAQ should be able to assist with any sensing requirements if a scale model test for this is desired.

3.0 Suspension Validation

3.1 Linear Measurement of Shock Position

To measure the linear position of the shocks on the car, LDS sensors will be used next to each of the shocks.

Measuring the shock position requires LDS sensors (in the past we've used 225mm stroke LDS sensors for the rear shocks and 200mm stroke LDS sensors for the front shocks). It also requires a way to mount the LDS sensors parallel to the shocks.

The suspension team will need to design a way to mount the LDS sensors to the car. It should be noted that 3D printed mounts have been used in the past and they have usually broken easily, so some sort of steel bracket would likely be a better option for these mounts.

3.2 Inertial Measurement of Car

The inertial measurement of the car will use the same IMU as the chassis vibration test and will measure the acceleration of the car in 3 axes along with the rotational velocity of the car in 3 axes.

It is generally best if the IMU is placed as close to the center of gravity of the car as possible (although this is usually impossible because it is usually where the driver is sitting). A good place for it would be above the driver on one of the chassis members. It is also generally best if it is mounted so that one of the axes is parallel to the gravity vector and if another axis is parallel to the forward direction of the car. This makes post processing IMU data easier since the axes will already align with the coordinate system used to design the car.

The IMU mount for this measurement will need to be welded onto the car by the chassis team.

3.3 Shock Dyno

The shock dyno measures the spring rate and damping coefficients of our shocks. It does so by oscillating the shock in and out at different frequencies and measuring both the force and position of the shock.

The shock dyno requires a mechanical rig with a motor for oscillating the shock back and forth, along with a load cell for measuring the output force of the shock, and an LDS sensor for measuring the position of the shock.

The shock dyno has been designed and is in a semi-working condition. The circuitry needs redesigned and so does the software. There are some safety concerns with the mechanical workings of the shock dyno that the suspension team will need to address before we are able to use the shock dyno. There are also some improvements that might need to be made to improve the longevity of the shock dyno (and to prevent it from potentially imploding), which either will require some analysis of the design to determine problem areas, or a meeting with Billy will need to be set up because he might have some recommendations for improvement as well.

3.4 Rack Validation

To validate the design of our custom rack this year it will be desirable to know the steering wheel position.

To know the steering wheel position, it will either require a potentiometer or hall effect sensor.

The design of the mount for this sensor will be the responsibility of the suspension team.

3.5 Strain Gauge Analysis of Uprights

The strain gauge analysis of the uprights will be similar to the strain gauge analysis of chassis members.

3.6 Strain Gauge Analysis of Steering Wheel

The strain gauge analysis of the steering wheel will be similar to the strain gauge analysis of chassis members.

3.7 ARB Torsional Stiffness Test

The ARB torsional stiffness test will measure the torsional stiffness of the anti-rollbar. This will be done by applying a torque to the ARB and measuring the angular deflection.

This test will need a load cell and some rig to fix one end of the ARB and a way to measure the angular deflection.

Similar to other tests, DAQ will provide the load cell and supporting software.

4.0 Driver Controls Validation

4.1 Brake Line Pressure Measurement

For the brake line pressure measurement, two pressure sensors will be used, one for the front brake circuit, and one for the rear brake circuit. They will measure the brake pressure in PSI.

The brake line pressures will need a T-style fitting (or cross-style fitting, because usually analog pressure gauges are used as well) to screw into. The sensors will need to be rated to not corrode with brake fluid and to also be able to withstand the pressures that build in the brake lines.

The driver controls team will need to make sure a proper fitting is selected for the sensor to screw into (ask DAQ to know what sensor is being used).

4.2 Throttle/Brake Pedal Position

The throttle and brake pedal position can be measured with potentiometers mounted on their axes of rotation.

Some sort of mount will need to be designed (most likely 3D printed) so that the potentiometers can be mounted next to the throttle and brake pedals and it will need to fix the back of the potentiometer being used but allow the shaft of the potentiometer to rotate with the pedal along its axis of rotation.

The driver controls team will need to design the mounts for these potentiometers (ask DAQ for CAD or drawings of the potentiometers being used).

4.3 Braking Force Transfer Test

The braking force transfer test will measure the efficiency of braking force being transferred from the rear of the car to the front of the car through the differential. This will be done by applying a known torque to the driveshaft in the rear of the car and measuring the output torque at one of the outputs of the diff (the other output can be locked).

The test will require a rig for locking one output shaft of the diff and for measuring torques on the different shafts. This will probably be done by having a lever affixed to each shaft and using load cells to measure the torques on the shafts.

The load cells and software for this test will be provided by DAQ, but everything else that is needed to run this test will need to be done by the driver controls sub-team.

4.4 Driveshaft Slip Test

The driveshaft slip test will use the rig that is used to measure torsional stiffness, but instead of fixing the other end of the shaft, a brake caliper and rotor will keep the driveshaft from freely rotating. A predetermined pressure will be applied to the brake caliper and rotor and an increasing torque will be applied until the driveshaft slips. This will be repeated for different brake line pressures.

The driveshaft slip test will require some sort of mechanical rig for holding the driveshaft on one end and applying a torque on the other end. There will need to be a load cell for measuring the applied torque.

Similar to other tests, DAQ will provide the load cell and supporting software. If a digital means of measuring brake fluid pressure is desired, that could easily be added as well.

5.0 Drivetrain Validation

5.1 Engine RPM Measurement

The engine rpm measurement will measure the engine RPM in real time to be used for the driver dashboard, data collection, and any control systems on the car.

The engine RPM measurement will require two sensors. A high resolution mechanical quadrature encoder should be placed axially on the output shaft of the engine (or mechanically linked to the output shaft in some way). Assuming a 1:1 coupling to the output shaft, it will be able to measure the engine speed 300x more accurately than the second and backup engine RPM measurement, a tachometer to measure when the spark plug fires.

Some sort of mount for the mechanical engine speed sensor will need to be designed and manufactured by the drivetrain sub-team (DAQ has mechanical drawings for the actual sensor).

5.2 Transfer Case RPM Measurement

The transfer case RPM measurement will measure the rpm of one of the gears in the transfer case using a hall effect sensor. A scale factor will allow for the conversion from the gear speed to the overall car speed.

To measure the transfer case RPM, the hall effect sensor will need to be inserted so that it is 1-2mm away from the revolving teeth on the gear.

The drivetrain will need to design the transfer case so that the hall effect sensor can be threaded into it.

5.3 Car Timing Measurement (Light Gates)

Light gates will be used to measure the time between two points that the car travels. It uses a laser/receptor setup on one side, and a mirror on the other side to reflect the laser back.

5.4 Engine Dyno

The engine dyno measures the power output curve of the engine and the efficiency curve of the CVT.

The engine dyno consists of a rig for mounting the engine and also includes a way of measuring the engine RPM, output shaft RPM (for if a CVT is used), and the torque output of the engine. The engine output is fed into a hydraulic pump that, with a pressure increase, can applying varying loads to the engine.

5.5 Driveshaft Torsional Deflection Measurement

To measure the torsional deflection of the driveshaft, two angular position sensors will be placed on either end of the driveshaft while in use. Their angular positions will be zeroed before beginning, and their relative positions will be measured to determine the angular deflection of the driveshaft.

The measurement of torsional deflection will require two angular position sensors, placed on either end of the driveshaft, and a way of mounting these sensors.

The drivetrain sub-team will need to come up with a way of mounting these sensors (DAQ has CAD of the sensors being used).

5.6 Driveshaft Torsional Stiffness Test

The driveshaft torsional stiffness test will be very similar to the ARB torsional stiffness test.

5.7 CVT Spring Rate Test

The CVT spring rate test will simply measure the spring rate of the CVT spring.

This test will measure the force vs. displacement of the CVT spring using a load cell and a dial indicator.

The load cell and software for this test will be provided by DAQ.

5.8 Car Acceleration Curve Measurement

The car acceleration curve measurement will use an IMU to measure the acceleration of the car throughout time during an acceleration run.

This test will want the same IMU placement as the suspension team's inertial measurement validation.

5.9 CVT Belt Temperature Measurement

Measuring the CVT belt temperature will allow us to know the temperature of the belt while the car is running.

To measure the CVT belt temperature we will use an infrared sensor directed at the belt. This sensor will need to be mounted inside of the CVT case.

It will be the drivetrain sub-team's job to figure out a way to mount the IR sensor and make sure that there is a way for routing wires to the outside of the CVT case.

5.10 Driveshaft Strain Measurement

The driveshaft strain measurement will be similar to the strain gauge analysis of chassis members.

The only difference for this test is that there will need to be a slip ring for wire routing since the driveshaft is a rotating component.

The drivetrain sub-team will need to assist in making sure that there is a way to mount the slip ring.