Drive Quality Testing and Fuel Economy Estimation for a 2WD Vehicle on a Chassis Dynamometer

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Introduction

REPS is a software suite developed by Revolutionary Engineering for test cell data acquisition and control. REPS has been designed to be flexible and customizable for a multitude of test cell applications. RE has successfully implemented REPS for axle testing, engine dynamometers, emissions testing, valve-train dynamics testing and chassis dynamometers. The application discussed in this document involved using REPS in a 2WD chassis dynamometer to perform drive quality testing and miles per gallon estimation of a FWD or RWD vehicle.

The Challenge

The challenge was to provide a robust and cost effective data acquisition and control system for a 2WD chassis dynamometer to test a FWD or RWD vehicle. The system had to be setup with multiple control modes such as velocity control, force control and Road Load Simulation (RLS) mode. The robotic driver was setup to interface with the dynamometer system to drive through different EPA mandated drive cycles and several consumer product testing agency cycles. The system had to keep track of the fuel consumed during these drive cycles and estimate the miles per gallon for city and highway.

The Solution

Revolutionary Engineering used the REPS software package for data acquisition and control of the 2WD chassis dynamometer, which allowed for quick controls development and seamless deployment. The individual control modes were setup and the robotic driver was connected to REPS without any custom programming. The rapid controls development and deterministic processing features of REPS proved invaluable, resulting in an objective, repeatable and error-proof dynamometer system.

System Description

Our customer is a global leader in the manufacturing of automobiles. Drive quality testing and fuel economy estimation is a critical part of their testing for engineering and product marketing. The older control system did not allow them to interface with the robotic driver, supported a very few control modes and lacked any kind of test automation. As a result, a lot of this testing was performed manually on the testing tracks. A lot of these tests yielded inconsistent results because of the change in weather patterns, human fatigue etc. The customer wanted to automate this process in a
chassis dynamometer which would meet the following requirements:

- Develop control modes for
  - Throttle/Velocity, Throttle/Force
  - Velocity/Force, Force/Velocity
  - Throttle/Road Load Simulation, Robotic drive cycle/Road load simulation
- Simulate a specific axle ratio instead of physically swapping the axle for testing.
- Automated unmanned testing and test schedule development tool.
- Interface to the robotic driver system.
- Automated report generation and saving.

The mandatory requirements of the customer were

1. Flexibility – The system had to have the capability to develop any number of control modes and automated test schedules.
2. Reliability – Test results had to meet strict requirements for reliability and repeatability.

The instrumentation hardware used in this dynamometer is an industry standard, off the shelf, FPGA based data acquisition and control hardware. Revolutionary Engineering retrofitted its latest data acquisition and control system on the already existing DC drives. The two DC Drives controlling the individual chassis dynamometer rolls were configured in constant current mode. REPS PID channels were setup to control the speed, force or RLS by changing the current command to the drive.

### Vehicle Mechanical Losses

One of the most frequent applications for this dynamometer was to estimate the amount of friction contributed by the individual components of the vehicle power train. This is the first of many steps in drive quality testing. The customer setup REPS to run an automated test schedule to estimate the amount of force expended by the dynamometer to spin the vehicle in Neutral with engine idling.

The force expended was logged at different speeds from 5mph to 75mph. We programmed REPS to generate a custom report that gives out the coefficients of 2nd order Force-Speed curve as shown below.

![Force-Speed Curve](image)

To estimate the frictional force contributed by the individual components of the power train, the technician would remove that specific component and re-run the spin loss test again. The difference between the new coefficients and the previous coefficients will give the frictional force of that specific component that was removed. Apart from finding the frictional force of the individual power train components, these coefficients are used to arrive at an
optimal Target Road load simulation (RLS) coefficients (F0, F1, F2).

Drive Quality Testing and Fuel Economy Estimation

Typically, a car that is being driven on the road would experience resistance from wind, rolling resistance and gravity when climbing up or down a hill. The resistance that is being experienced by a vehicle on the road can be modeled into an equation that the dynamometer can simulate.

\[
\text{RLS Force} = F0 + F1 \times \text{Velocity} + F2 \times \text{Velocity}^2
\]

- \(F0\) ⇒ Target Road Load Coefficient (N)
- \(F1\) ⇒ Target Road Load Coefficient (N/kph)
- \(F2\) ⇒ Target Road Load Coefficient (N/kph²)

The robotic driver system was setup along with this dynamometer system and an interface mechanism was put in place so that the dynamometer and the robotic driver can act in tandem during the standard drive cycle. For instance, to preserve the brake life of the vehicle, the dynamometer was setup to switch from RLS control mode to speed control mode to slow down the vehicle and still follow the drive cycle trace. Upon completion of braking, the dynamometer was setup to switch back to RLS control.

The customer was able to setup the following drive traces for fuel economy testing.

Standard EPA drive cycles
- FTP 72
- FTP 75
- FTP 505
- Highway Fuel economy

Consumer reports testing
- City driving cycle
- Highway cycle
- Trip cycle to simulate rural and urban driving

MVEG and Euro Testing
- MVEG A Automatic Transmission
- MVEG B Manual Transmission

Apart from the standard drive cycles, the dynamometer was setup for estimation of fuel economy of steady state speed such as 60kph, 90kph and 120kph.

An in-line fuel flow meter was used for measurement of fuel consumption. The fuel consumed was calculated by REPS by measuring the fuel meter pulse accumulation. The flow rate was calculated by differentiating the fuel accumulation w.r.t time. Using this value, REPS was able to provide a live update of the estimated miles per gallon.

Gradeability Testing

The gradeability test is a measurement of the maximum grade the vehicle can manage in a specific gear. It tests the dynamic disturbances associated with the vehicle power train system while driving up a dynamometer simulated gradient. The REPS based dynamometer system was setup for
• Simulating infinite number of grades between 0 and 100 %
• Direct measurement of gradeability for a specific speed

The gradeability test is usually run in 90kph, 105kph and 120kph. The vehicle target speed was controlled by the robotic driver and allowed to settle at the constant speed prior to applying the grade. Starting from 0%, the simulated gradient is slowly ramped up at a rate of 0.01% per second until a transmission downshift occurs. REPS monitors the engine RPM and any significant change in the RPM will be detected as transmission downshift. The grade at which the downshift occurs is recorded as the gradeability at that speed. This drive quality test is to measure performance of the vehicle to its technical specification for gradeability.

Summary

Our customer wanted a cost effective dynamometer system to meet their testing requirements. The REPS based system allowed us to provide a value added solution and helped us develop and deploy our application on time, earning us another happy customer.

Some of the benefits of REPS based dynamometer are listed in the table below:

<table>
<thead>
<tr>
<th>Metric</th>
<th>Old Control System</th>
<th>REPS Based System</th>
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<tbody>
<tr>
<td>Test Time</td>
<td>Manual (~ 6 Hrs)</td>
<td>3 Hours</td>
</tr>
</tbody>
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Utilization | Operator controlled manual test | Unmanned test with capability to run 24 x 7
Reliability | Inconsistent because of changing driver /temperature patterns | Highly repeatable test results
Ease of Use | Required extensive training for each step | Intuitive user interfaces informs operator about next step

About Revolutionary Engineering

Revolutionary Engineering, Inc. (RE) was established in 2001 to provide companies with a dynamometer system integration resource and testing facility that responds to their needs. Our services and products are designed to provide the customer with cost effective solutions tailored to their requirements.

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