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Vehicle Chassis Dynamometer



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## Objective

1. Understand the purpose of a vehicle chassis dynamometer
2. Understand what kind of tests can be performed with the dynamometer

### 4x4 Vehicle Chassis Dynamometer Overview

#### Description

A dynamometer is used for measuring vehicle speed, torque and power. Additionally, controlled loading can be applied to a test vehicle such as a constant force speed, or simulated values [1]. The dynamometer pictured in Figure 1, a 4x4 Vehicle Chassis Dynamometer with Individual Wheel Control, is capable of directly measuring the roll shaft rpm/speed and torque/force applied to the dynamometer's roll shaft(s) [1]. Other values (acceleration, power, etc.) can be derived from these two original measurements.



Figure : 4x4 Vehicle Chassis Dynamometer with Individual Wheel Control

This dynamometer is a 4x4 Vehicle Chassis Dynamometer, providing individual control of one, two, three, or all the four double-rolls by controlling the four power absorbers. Hence, each of the four wheels of the vehicle placed on the Dynamometer can be individually controlled.

The speed capability is up to 44.7 m/sec (100 mph). Four-wheel power absorbers can develop 130.5 kW (175 hp) per wheel for continuous operation and 261 kW (350 hp) intermittently. The wheelbase is adjustable from 2.26m to 3.23m (89 to 135 inch) with extension to 4.45m (175 inch).

A chassis dynamometer and the vehicle that is being tested on it effectively form a geared power transfer system. While force is obviously not an engine-crankshaft relative term, and power values do not scale (ignoring transmission losses) from shaft to shaft in a geared system, torque values do scale from shaft to shaft in a geared system. So, in order for a chassis dynamometer to report engine crankshaft relative torque values, the control software must know [1]:

1) Dynamometer roll shaft torque.

2) Dynamometer roll shaft RPM.

3) Engine crankshaft RPM.

Using these 3 values, the control software can calculate the engine crankshaft torque that the engine must be producing, using the formula below:

EngineTorque = ((DynoShaftTorque \* DynoShaftRPM) / EngineRPM) (1.1)

When engine RPM is not available, there is no way to report an engine crankshaft relative torque value.

#### 1.2 Equipment Capabilities

* Unique, one of a kind 4x4 Vehicle Chassis Dynamometer with individual wheel torque electronic controls of one, two, three or all four-drive wheels.
* Four individual wheel power absorbers with 175 HP per wheel capability for continuous operation and up to 350 HP – intermittent.
* 89 – 135 inches adjustable wheelbase with an extension capability unto 175 inches.

The Chassis Dynamometer is for testing wheeled vehicles under electronically controlled conditions for each of the wheels to accommodate different driveline systems.

Dynamometer General Specification:

|  |  |
| --- | --- |
| Dynamometer Type | Eddy Current |
| Cooling Type | Self air-cooled |
| Peak speed | 100 mph |
| Power adsorption | 175 hp/wheel – continuous; up to 350 hp/wheel – intermittent |
| Wheelbase | 89 inches to 175 inches |
| Axle Weight Capacity | 6,000 lbs/axle |
| Outer Track | 100 inches |
| Inner Track | 30 inches |
| Torque Measurement | Load Cell. Four Sensors |
| Torque Transfer | Power Chain Belt |
| Speed Measurement | Hall-effect Pick-up (60-ppr). Four Sensors |
| Controller Type (Mode 1) | Computer based, embedded |
| Controller Type (Mode 2) | DAQ based with RS232 communications to PC |
| Installation | Flush Floor |
| Envelope Dimensions | 240 inches x 200 inches |
| Power (dynamometer) | 240 VAC, three phase |
| Power (instrumentation) | 115 VAC, single phase |

Control Mode 1:

This control mode shall allow the operator to test a vehicle under normal loading conditions, whereby load to the vehicle is distributed across the vehicle driveline system. The Chassis Dynamometer shall be mechanically connected prior to commencement of any test exercise of this type.

Control Mode 2:

This control mode shall allow the operator to test a vehicle under abnormal operating conditions, whereby load to the vehicle driveline system is controlled separately at each wheel.

#### 1.3 Test Vehicle Parameters

Figure 2 shows a vehicle set up for testing on the dynamometer. The test vehicle, a 2000 Ford Mustang GT, has a rear-wheel drive with 5-speed manual transmission and tires of size P225/55R16. Tab. 1 provides some of the main parameters of the vehicle’s weight, geometry, engine, transmission, and tires.



Figure : Test Vehicle on Dynamometer

Table 1: Vehicle Specifications [2, 3]

|  |  |
| --- | --- |
| Vehicle Type | 2000 Ford Mustang GT |
|  | |
| **Geometry and Mass:** | |
| Base Curb Weight | 3241 lbs. |
| Height | 53.3 in. |
| Length | 183.2 in. |
| Width | 73.1 in. |
| Wheelbase | 101.3 in. |
|  | |
| **Engine:** | |
| Engine Size | 4.6 L |
| Horsepower | 260 hp @ 5250 rpm |
| Cylinders | V8 |
| Torque | 302 ft-lbs @ 4000 rpm |
|  | |
| **Wheels and Tires:** | |
| Tire Size | P225/55R16 |
| Wheel Size | 16 in. x 7.5 in. |
|  | |
| **Transmission and Drivetrain:** | |
| Drivetrain | Rear Wheel Drive |
| Clutch Size | 52.25 in. |
| Transmission | 5-speed manual w/OD |
| First Gear Ratio | 3.37:1 |
| Second Gear Ratio | 1.99:1 |
| Third Gear Ratio | 1.33:1 |
| Fourth Gear Ratio | 1.00:1 |
| Fifth Gear Ratio | 0.67:1 |
| Reverse Ratio | 3.22:1 |
| Final Drive Axle Ratio | 3.27:1 |

**1.4 Dynamometer Applications**

##### Vehicle Performance – Traction:

Develop optimum vehicle traction performance and vehicle energy efficiency by experimental research for power distribution to the tire/ground contact patches for each of the (4) wheels.

Results in developing optimum driveline system hardware to accomplish top vehicle performance: open and limited slip differentials, locking differentials, viscous drive, traction control, and other mechanical and mechatronic driveline systems. Also, wheel power balance may be experimentally studied to better tire design.

##### Vehicle Performance – Turnability/Ride Stability

Without going to a proving ground gives a unique opportunity to experimentally evaluate vehicle turnability and ride stability on the basis of the lateral forces of each of the (4) wheels, lateral acceleration and yaw resistant and assistant moments. Results in developing ride stability systems and driveline systems to control vehicle over- and understeering.

##### Vehicle Performance – Acceleration/Braking

Vehicle timing tests with various types of acceleration/braking and distance runs. Results in performance evaluation of vehicles with different driveline system arrangements.

##### Durability

Vehicle driveline durability testing for improving design and life of the hardware. Testing includes all powertrain components and can apply manually controlled loads and simulate proving ground test cycle loading.

##### Diagnostic Testing

Experimental studies with total vehicle systems to diagnose system, subsystem, and component level hardware problems and verify corrective actions for effectiveness.

##### NVH (Noise, Vibration, and Harshness) Development

Experimental studies for all noise and vibration concerns on vehicle driveline systems with structure borne noise.

##### Safety

Experimental studies of active safety system elements to better design (angular and linear velocity sensors, longitudinal and lateral acceleration sensors, modulators, etc.).

##### Fuel Economy Improvement

Improve vehicle energy efficiency and fuel economy by developing driveline systems based on optimum power flow distributions to each of the (4) drive wheels.

##### Emissions

Routines to perform various type emissions tests for vehicles with gas and diesel engines, and with various powertrain layouts.

##### Next Generation Concept Vehicle Development

Develop novel driveline arrangements with alternative next generation energy sources for fuel cell, electrically, hybrid-electrically, and hydraulically powered vehicles with 4x4 full and part time, and 4x2 wheel-drive formulae. Results in optimum logic algorithms and electronic hardware to individually control power distributions to each of all the drive wheels to provide top vehicle performance in various operational conditions.

### Dynamometer Safety Considerations

1. These Safety Instructions are to be reviewed by Students, Technicians, Faculty Members and any other persons before they operate the Dynamometer or observe any Dynamometer testing.

2. Any dynamometer should be considered a dangerous tool to operate! The following list of safety precautions is not exhaustive, but represents a minimum level of safety precautions to be considered.

3. Keep away from the Dynamometer testing area while a test is in progress. Only the Vehicle Driver and Dynamometer/Vehicle Control Units Operator(s) should be in the vicinity of the Dynamometer/Vehicle when a test is being performed.

4. When a test is being performed, Students, Visitors or any other people are not allowed to stay in the class area that is behind the wall with the plastic glass. The Dynamometer/Vehicle Control Units Operator specifies a safe place for the observers.

5. Be aware that the signs “Do not enter! Test is being performed” have been placed on all doors outside of the Vehicle Dynamics Laboratory. Remove the signs after experiments are over.

6. During actual testing only the operator(s) should have the possibility to access to the Dynamometer/Vehicle Control Units. Any computers with access to the Dynamometer/Vehicle Control Units software are prohibited to students and visitors.

7. Vehicles must always be securely restrained before testing on the Dynamometer. The vehicle must be restrained not only against forwards/backwards movement, but also against side - to side movement.

8. “Spotters” must be placed around the test vehicle before any and all Dynamometer testing.

9. All spotters must be in their places in front and behind the vehicle during testing.

10. Do not wear loose fitting clothing around the Dynamometer Ties, sleeves, scarves, chain, etc. Can become wrapped around the rolls, shafts, etc. and cause serious or fatal injuries.

11. Do not leave tools, ropes, chains, parts or any other objects loose around the Dynamometer. These objects may be thrown, crushed, twisted, etc. if they vibrate into contact with the Dynamometer or the Vehicle under test.

12. Do not apply sudden Vehicle throttle or brake changes to the Vehicle while it is on the Dynamometer because this may cause the Vehicle under test to suddenly change position on the Dynamometer causing loss of control of the vehicle.

13. The Dynamometer contains very heavy components operating at high speeds with high forces. Do not touch or come into contact with any part of the Dynamometer when it is in operation, particularly the rolls, shafts and belts.

14. The Dynamometer can throw foreign objects at very high velocity. Always wear eye protection when working around Dynamometer.

15. The Dynamometer contains power-absorbing units (PAUs or Motors) that may become very hot. Do not touch any part of PAUs or Motors to avoid potentially severe burns.

16. The Dynamometer/Vehicle Control Units and Control Boxes on the wall contain dangerous voltages. Only qualified personnel should ever work on Control boxes, PAUs, or any other electrical component of the Dynamometer. Furthermore, some Control Boxes contain multiple power sources, anyone working on a Control Box must be qualified to do so and must be certain that all power sources have been disconnected and locked-out prior to working on the equipment.

17. High pressure air is used in various elements of the Dynamometer. Before experiments are initiated, make sure that the air pressure is on and working.

18. The lift/roll-lock devices of the Dynamometer can lift the Vehicle! Do not allow any part of your body to fall into the lift/roll-lock area of the Dynamometer to avoid potentially fatal crushing wounds.

19. The Vehicle exhaust gasses as well as exhaust calibration gasses are poisonous and can be fatal. Make sure that adequate laboratory ventilation is provided before operating the Vehicle on the Dynamometer or the exhaust gas analyzer. During test operation the pit fan must be operating for moving air out of the Dynamometer pit.

20. To the Vehicle Driver: IN AN EMERGENCY, TURN THE IGNITION OFF.

21. To the Dynamometer/Vehicle Control Units Operator: IN AN EMERGENCY, HIT THE EMERGENCY STOP BUTTON LOCATED ON THE TEST BOX ON THE WALL.

22. Before you start an experiment, locate the emergency pull stations in the event of fire and the first aid station.

23. Following the equipment manufacturer's specifications. Do not violate Federal Regulations.

24. Prior to testing, make sure that the vehicle was examined and it is ready for the experiments.

### Dynamometer Test Examples

#### 3.1 Horsepower Curve Test

The Horsepower Curve Test (Fig. 3) allows the operator to perform a sweep-type power measurement test on the vehicle. This test routine supports both a fixed-sweep-time mode and a vehicle-simulation-loading mode. The vehicle simulation-loading mode will most accurately reflect the actual power that the vehicle will deliver in use, while a fixed-sweep-time mode test can be used for comparing against test-stand dynamometer values. In this test, the vehicle is driven at just below a specified starting speed, and then accelerated at full power until reaching a specified stopping speed. This test supports:

1. A fixed-time mode: this mode can be used for comparing against test-stand dynamometer values.
2. A vehicle-simulation-loading mode: this mode will most accurately reflect the actual power that the vehicle will deliver in use.



Figure : Power Curve Test

## Intended Test Procedure

The general testing procedure is outlined below.

1. Edit Curve Ranges: sets the power and torque averaging ranges and the absolute range for data collection during testing. Recommended settings for the by-MPH values are 1.0 MPH ranges with 0.5 tolerances, and for the by-RPM values are 250 RPM ranges with 125 RPM tolerances. The lowest and highest band center values should be set to the minimum and maximum values expected to be encountered during testing.
2. Start Speed: this field should be set to the lowest speed at which the vehicle is to be tested. If the vehicle is being tested in a single gear, this is the lowest speed at which the vehicle will run cleanly in the selected gear.
3. Stop Speed: set to the highest speed at which the vehicle is to be tested. This should be the highest speed at which the vehicle can be operated in the highest gear that will be used during testing. The test will end when the speed reaches this speed.
4. Stop after Test: Check this box to stop the dynamometer after the power sweep is complete to save wear on the vehicle’s brakes.
5. Additional settings depending on the test mode selected:

Control Sweep Rate: Running time

Sets the running time of the sweep test. Using the longest running time that the vehicle can comfortably tolerate will enable additional data collection during the sweep.

Vehicle Simulation: Vehicle Wt, Pwr @ 50 and Simulated Inertia:

The values will default to the values entered for the vehicle currently selected for testing. It is recommended that the Simulated Inertia option always be left on.

1. Set the Save Results and Save Trace check boxes. If the Save Trace check box was checked, charts will be generated for the data from all input channels. Trace data cannot be saved unless the Save Results is also checked.
2. Click the Start Test button to begin the test. The screen will indicate to the driver when the test is complete.
3. The test automatically terminates once the dynamometer is stopped. The Stop Test button may be used to cancel a test which you do not wish to complete.
4. After the test, saved test results will be available for viewing or printing.

## Results Obtained

If the Save Results check box is checked, a record of the test results will be saved to the application’s database. Information saved to the test record includes the following:

* The date and time the test was performed on the currently selected vehicle.
* Maximum torque and power values with the speed (MPH/KPH) at which they were measured.
* Maximum torque and power values with the engine speed (RPM) at which they were measured.
* A series of data points representing the torque and power measured during testing, ordered by ground speed (MPH/KPH).
* A series of data points representing the torque and power measured during testing, ordered by engine speed (RPM).
* Strip-chart style trace data for all input channels if the Save Trace option was selected.

## Special considerations for this test:

* Torque values recorded as a function of vehicle speed (MPH/KPH) are in terms of dynamometer roll shaft torque, not engine crankshaft torque.
* Torque values recorded as a function of engine speed (RPM) are in terms of engine crankshaft torque.
* The by-speed and by-RPM values may not exactly agree because the measured power and torque values are averaged into MPH/KPH and RPM ranges. Size of the averaging ranges may be significantly different depending on the user-specified settings.
* Because of the averaging of the power and torque values, the power curve test specific curves may not show torque and power crossing at exactly 5252 RPM.
* A longer sweep time should generate higher power and torque readings, since a lower acceleration rate means that less power is absorbed by the vehicle’s drive-train.

#### 3.2 Programmed Force Test

In the Programmed Force Test (Fig. 4), the user applies a time-based force loading profile to the test vehicle. The profile is a series of points that describe a load to be applied and the time duration for which to apply it. This test can be used for durability or performance testing, or to simulate real-world loading profiles.



Figure : Programmed Force Test [1]

## Intended Test Procedure

The general testing procedure is outlined below.

1. Select Test Profile: choose the directory and file location of the test profile to follow. Refer to the **Programmed Force Editor** section at the end of this document for how to create a new profile.
2. **Number of Loops:** enter the number of times to repeat the selected test profile.
3. Set the Save Results and Save Trace check boxes.
4. The driver should start driving the vehicle at the desired testing speed.
5. When the vehicle at the testing speed, click the Start Test button.
6. The load on the vehicle will be controlled by the selected test profile. The vehicle should continue to be driven until the test completes.
7. The test ends when the final data point of the profile is completed for the last loop of the test profile.
8. Any saved test results may be viewed and/or a test report printed.

**Programmed Force Editor**

This form (Fig. 5) allows the user to edit or create time-based force loading profiles to be used for this test.



Figure : Force Editor Form

Each point in these profiles specifies a target loading value, and the number of seconds for which the specified loading should be maintained.

#### 3.3 Programmed Speed Test

A Programmed Speed Test (Fig. 6) allows the user to apply a time-based speed control to the vehicle. This test is very similar to the “Programmed Force Test”, except that the systems speed is controlled, rather than the applied loading force [1]. Refer to the section on the “Programmed Force Test” for additional information.



Figure : Programmed Speed Test [1]

**Programmed Speed Editor**

This form (Fig. 7) allows the user to edit/create time-based speed control profiles. This form is very similar to the “Programmed Force Test Editor”, except that the systems speed is controlled, rather than the applied loading force. Please see the section on the “Programmed Force Test Editor” for additional information. The “Throttle (%)” column has recently been added to support scripted loading scenarios using the integrated throttle controller. When any existing script file is loaded, the “Throttle (%)” values will show up as “0”,and will not affect the functioning of the script. If a value is entered, and the optional throttle controller is connected, the vehicle’s throttle will be controlled to the specified position (in %).) [1]



Figure : Speed Editor Form [1]

#### Speedometer Check Test

The Speedometer Check Test (Fig. 8) allows the user to check the accuracy of the vehicle’s speedometer. No load is applied to the vehicle during this test [1].



Figure : Speedometer Check Test [1]

## Intended Test Procedure

This test has no specific ending point, as the speedometer may be checked several times before ending the test.

The general testing procedure is outlined below.

1. The “Target Speed” field should be set to the speed at which the speedometer is to be checked.
2. The “Save Results” and “Save Trace” check boxes should be set appropriately.
3. The “Start Test” button is clicked.
4. The vehicle is driven, with no load. When the driver sees the speedometer indicating the target speed, the “Check Speed” button should be clicked. At this point, the actual speed (according to the dynamometer’s very accurate digital speed input) is displayed, along with the absolute error of the vehicle’s speedometer at the testing speed, and the percentage error that the absolute error represents.
5. The “Stop Test” button is clicked, and the test terminates.

#### 3.5 Standing Start Acceleration

A Standing Start Acceleration Test (Fig. 9) allows the user to simulate a 0-60 type standing start acceleration run with the vehicle [1].



Figure : Standing Start Acceleration Test [1]

## Intended Test Procedure

This test has a fixed termination time, when the vehicle has reached the specified top speed. The general testing procedure is outlined below.

1. The “Vehicle Weight” field will default to the weight entered for the vehicle currently selected for testing. The user may change this weight if desired.
2. The “Pwr @ 50 MPH” field will default to the value entered for the vehicle currently selected for testing. The user may change this value if desired.
3. The “Simulated Inertia” check box determines whether inertia simulation will be used or not. Mustang Dynamometer recommends that this option always be used.
4. The “Top Speed” value should be entered, typically 50, 60 or 100 MPH.
5. The “Save Results” and “Save Trace” check boxes should be set appropriately.
6. The “Start Test” button is clicked.
7. The vehicle is accelerated as quickly as possible to the specified top speed. Test timing begins as soon as the vehicle’s speed exceeds 0.1 MPH.
8. The test terminates when the vehicle reaches the specified top speed. The “Stop Test” button may be used to terminate a test you do not wish to finish.
9. Once the test is complete, the dynamometer’s PAU is used to stop the system, to avoid wear to the vehicle’s brakes.
10. Any saved test results may be viewed and/or a test report printed.

# References

[1] MD Mustang Dynamometer, MDSP 7000 Series Dynamometer Controller Software Manual, 2001. <www.mustangdyne.com>

[2] Edmunds, “2000 Ford Mustang - Features & Specs”, 2017. <https://www.edmunds.com/ford/mustang/2000/st-10582/features-specs/>

[3] The Car Connection, “2000 Ford Mustang 2-Door Coupe GT Specs”, 2017.

<http://www.thecarconnection.com/specifications/ford\_mustang\_2000\_2dr-cpe-gt>

## Assignment:

Experimental data is provided from the 2000 Ford Mustang GT tested on the dynamometer (shown in Fig. 2)

1. Using the experimental data provided, create plots of

* Torque vs. Time
* Power vs. Time

1. Locate the maximum values of torque and power achieved during the test.
2. What is the difference between control mode 1 and 2?
3. When using the programmed force editor, what data needs to be specified for each point?
4. What 3 pieces of information must be known in order to measure engine crankshaft relative torque values?
5. In an emergency, what actions should be performed by the vehicle driver and dynamometer control unit operator?