# Steering Module Test Simulator (SMTS)

Continuous Innovation
Global Test Solutions

AUTOMOTIVE · AEROSPACE · INDUSTRIAL

MB Dynamics
TECHNOLOGY, TEST PROCESSES & ENGINEERING SERVICES

BEST-IN-CLASS QUIET™ SQUEAK & RATTLE TEST · MODAL EXCITATION · CALIBRATION · MILLENIUM™ DYNAMIC TEST CONTROLLERS · STEERING SIMULATORS · AND MORE …

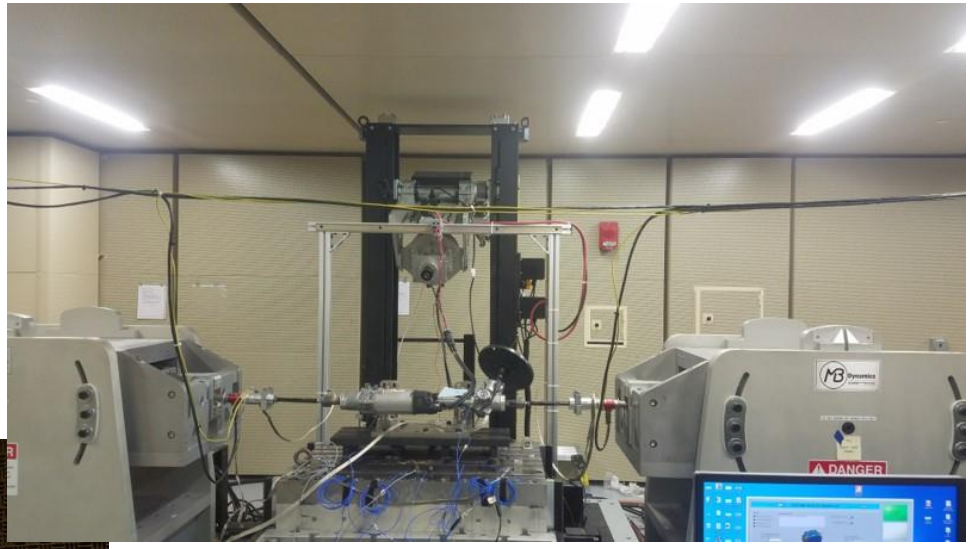
SMTS is a non-hydraulic lab test system that simulates DRIVER functions and ROAD & VEHICLE inputs acting on a STEERING SYSTEM to experimentally develop, evaluate and validate NVH metrics and to experimentally verify EPS functions in order to achieve performance goals over the customer-equivalent useful life of a steering system.

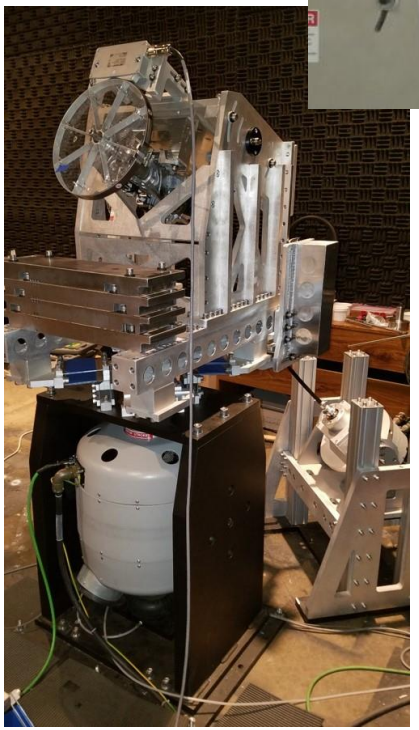
# Applications, Solutions & Test Procedures

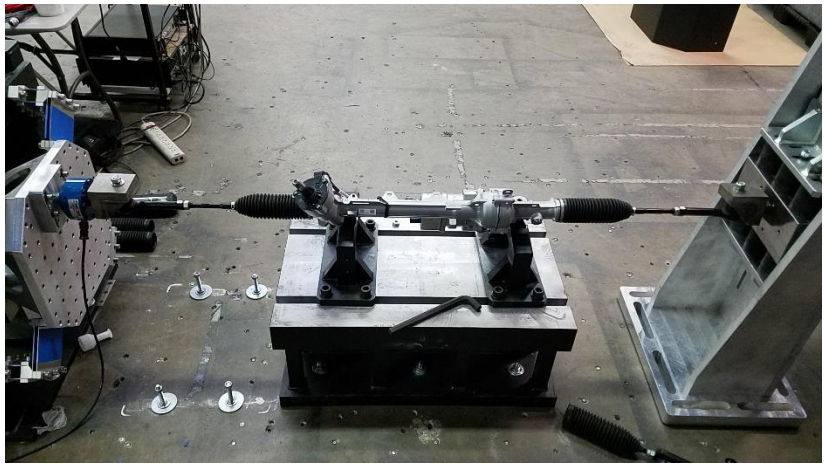
- **Rack Rattle:** rattles, impacts, knocking or clunking noises heard & felt during straight-ahead driving on rough surfaces, during turns on loose or rough surfaces, and impulsive loads from sharp road inputs caused by backlash in rack and pinion, EPS motor assist gear mesh and belts, or elsewhere in column.
- **Zipper Noise:** Structure borne noise heard when the steering wheel is rotated left or right. The noise is typically an order of the motor / mechanical system.
- **Reversal clunks:** Direction Reversal – objectionable noise heard when changing the direction of travel of the steering gear; includes any noise from lash in the system and any noise as a result of the changes in the electric motor direction.
- **Growl Noise:** Low frequency noise while slowly turning steering wheel, <30RPM
- **Howl Noise:** EPS noise – any objectionable noise from the EPS control module or the electric motor during steering wheel on-center or normal driving conditions.
- **End of Travel Noise:** Any objectionable noise heard when steering gear reaches end of travel – includes EPS unit noise and any mechanical noises in the gear.
- **I-Shaft Noise:** Objectionable I-shaft noises from stick-slip, shaft rotation, lower bearing, isolator, hysteresis and lash noises, rattle performance before & after durability tests

# Users of MB Equipment for Steering System Annoying Noise & NVH Engineering

- GM North America
- MANDO: Korea, China, India & USA
- Nexteer: USA, China, Mexico
- Hyundai MOBIS
- Ford Europe
- Ford North America
- Hitachi
- Bosch North America
- TKP
- NSK
- Delphi Korea
- Changan Auto
- PATAC
- SAIC
- BYD
- Merit Automotive
- QH Talbros

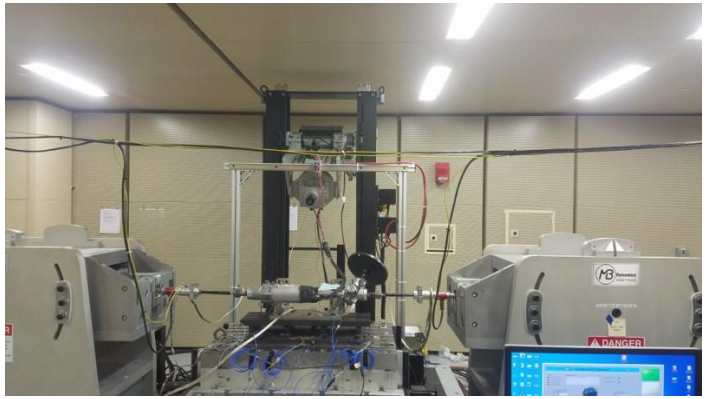


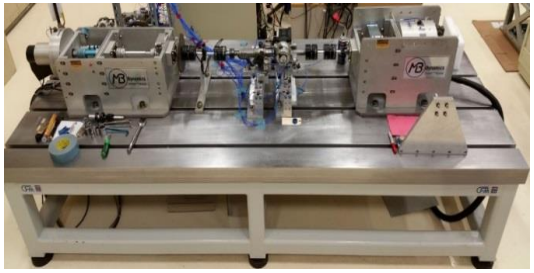


# Applications, Solutions & Test Procedures

- Unified acoustic test bench: quiet, non-hydraulic NVH lab testing of manual, HPS and rack EPS gears, columns, and intermediate shafts for rattle, clatter, zipper and running noises, reversal clunk and steering performance characterization during driving maneuvers; apply time history road loads and synthesized waveforms; structure-borne & airborne noise measurements; characterize for EV & AV apps



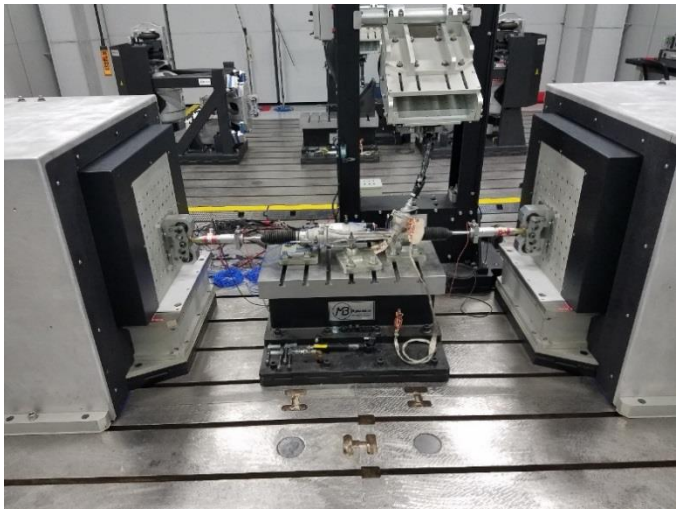

- Column EPS acoustic test bench: all above noise & performance tests; simultaneous steering input shaft position and rack load torque; supports HIL real-time simulation



- Driver Simulator for quiet, in-car, repeatable, zipper and other driving maneuvers measuring noises at 0 km/hr plus position, rate, torque; performs in-lab reproduction of same motions

# Applications, Solutions & Test Procedures

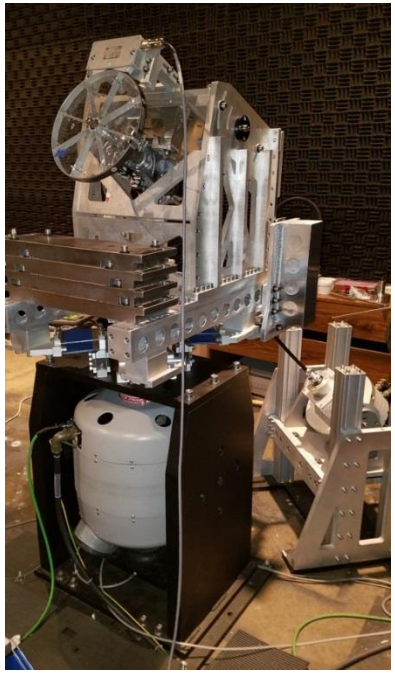
- Perform quiet steering gear rattle and clatter tests under simulated road load conditions; single and dual tie rod excitation; jounce, rebound, fore, & aft tie rod angles; closed-loop control of static compression and tensile loads plus dynamic loads; structure-borne (accelerometer) & airborne (microphone) measurements; MIMO control



- Running noise, zipper noise and gear wear conditioning; Driver Simulator applying steering motions (90 RPM); Rack Load Simulators applying forces to tie rods; ±12kN quasi-static force, DC - 2Hz; 200mm pk-pk @ tie rod end

# Applications, Solutions & Test Procedures

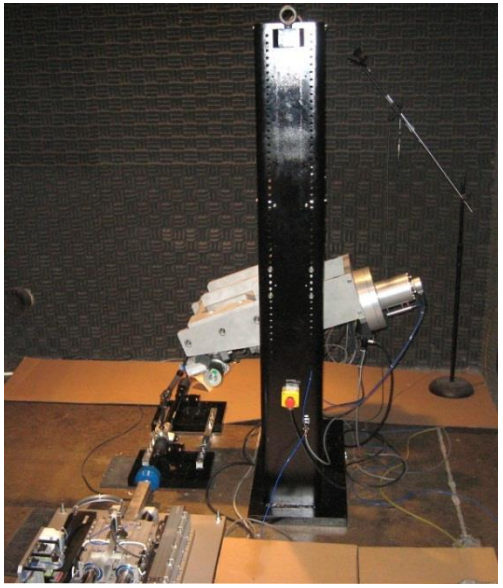
- Quiet column and I-Shaft vibration squeak and rattle; X/Y/Z durability loads; torsional loads of 45Nm; quiet shaft rotation for noise measurements of column/I-shaft/lower bearing; X/Y/Z translational road load S&R vibration combined with shaft and column rotation; I-shaft stick-slip, lash, hysteresis; control rotations at steering wheel or gear end of I-shaft or column; tight velocity control to overcome U-joint velocity fluctuations



- General Motors has licensed MB Dynamics to sell and support GM's steering know-how, processes and software related to testing and evaluating rack rattle, zipper, reversal clunk, and I-shaft annoying noises in vehicle steering systems plus steering performance evaluations. Licensed know-how includes structure-borne noise data reduction and analysis executable software; test procedures; user documentation; and engineering services to set up and run tests and use the software and technology.

# Steering Module Test Simulator for NVH

- SMTS PC-based, Multi-Test Head, Closed - Loop Acquisition & Control
- Driver Simulator
- Rack Load Simulator – single, both tie rods
  - *Electrodynamic*
  - *Linear Motor*
  - *Pneumatic*
- Torque, Force, Angle, Acceleration, and Displacement Sensors & Acquisition
- Separate, Moveable, Height-Adjustable, Gear Fixture and Column Stand
- Tilt Positioner for In-line Force Application at Different Tie Rod Angles
- Lab & In-Vehicle: Sound & Acceleration Acquisition

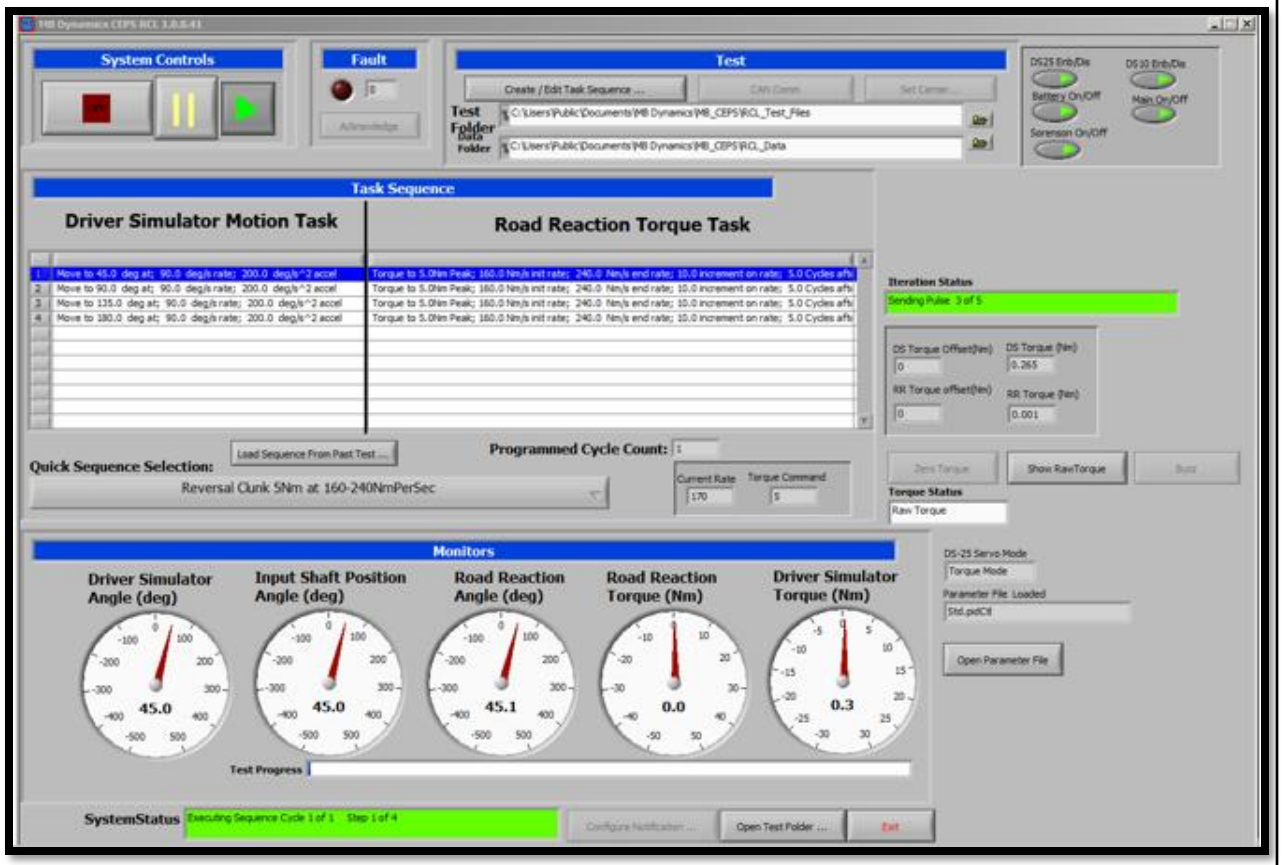


- NOTE:  Quiet, no hydraulics, all electric & air

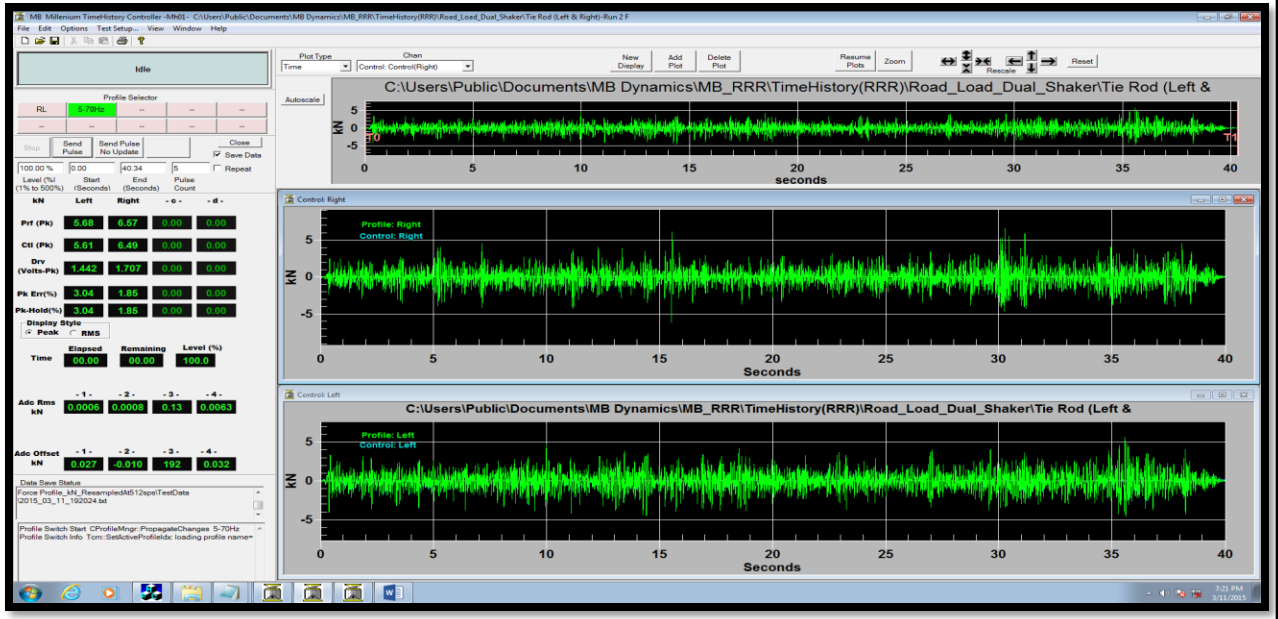
# Summary of SMTS Options & Specifications

| | Tie Rod Excitation | | |
|---|---|---|---|
| **Specification** | **Electrodynamic + Dual Air Spring** | **Linear Motor** | **Pneumatic** |
| Force, Static (compression or tension) | ±12kN | ±10kN | ±12kN |
| Force, Transient or road load | ±10kN pk dynamic | ±15kN pk dynamic | Quasi-static |
| Force, Continuous | ±4.5kN pk sine | ±10kN pk sine | ±12kN pk sine |
| Displacement | 20mm pk-to-pk | 200mm pk-to-pk | 200mm pk-to-pk |
| Response for road load data, Hz | DC – 100Hz | DC – 50Hz | DC – 2Hz |
| Force control | X | X | X |
| Displacement or position control | X | X | X |
| Acceleration control | X | X | X |
| Time History & arbitrary waveform control | X | X | X |
| Sine sweep, dwell, & sine-on-sine control | X | X | X |
| Triangle & trapezoid control | X | X | X |
| PSD Random control | X | X | X |
| Relative cost | $$ | $$$ | $ |

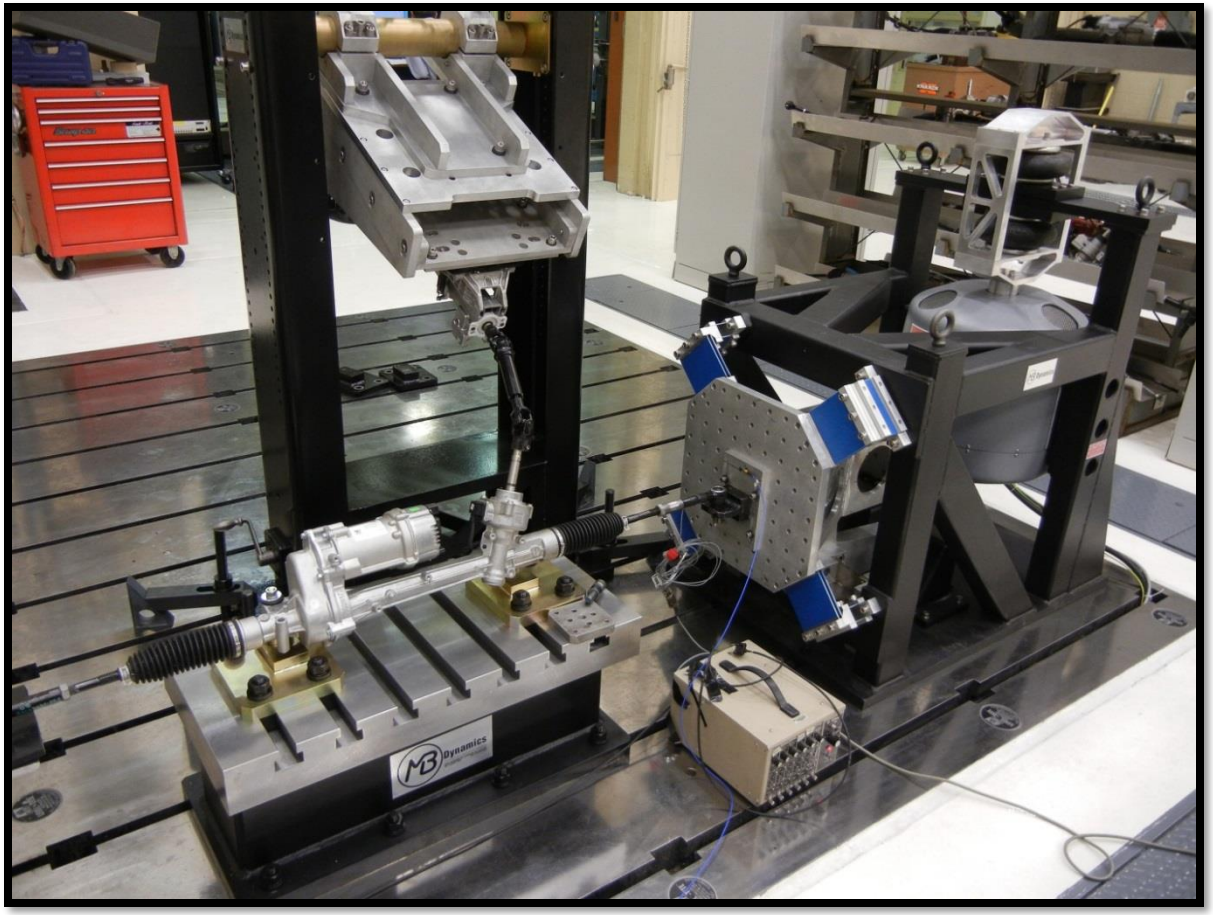
# Applications, Solutions & Test Procedures

| *Application* | *Solution Offered* | *Test Procedure Supported* |
|---|---|---|
| • Running Noise incl. Zipper<br>• Rack & Column Rattle<br>• Reversal Clunk<br>• Displace-ment vs. Torque<br>• Smooth Road Shake<br>• Road-excited S&R<br>• In-vehicle Zipper |  <br>**Run-Time GUI** | Software Control Over All Applications That Follow |

# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedure Supported*** |
|---|---|---|
| • Running Noise incl. Zipper<br>• Rack & Column Rattle<br>• Reversal Clunk<br>• Displace-ment vs. Torque<br>• Smooth Road Shake<br>• Road-excited S&R<br>• In-vehicle Zipper |  <br>**Run-Time GUI** | Software Control Over All Applications That Follow |

# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedure Supported*** |
|---|---|---|
| Rack Rattle and Clatter |  | GMW16216 “Steering Gear Rattle Evaluation” |

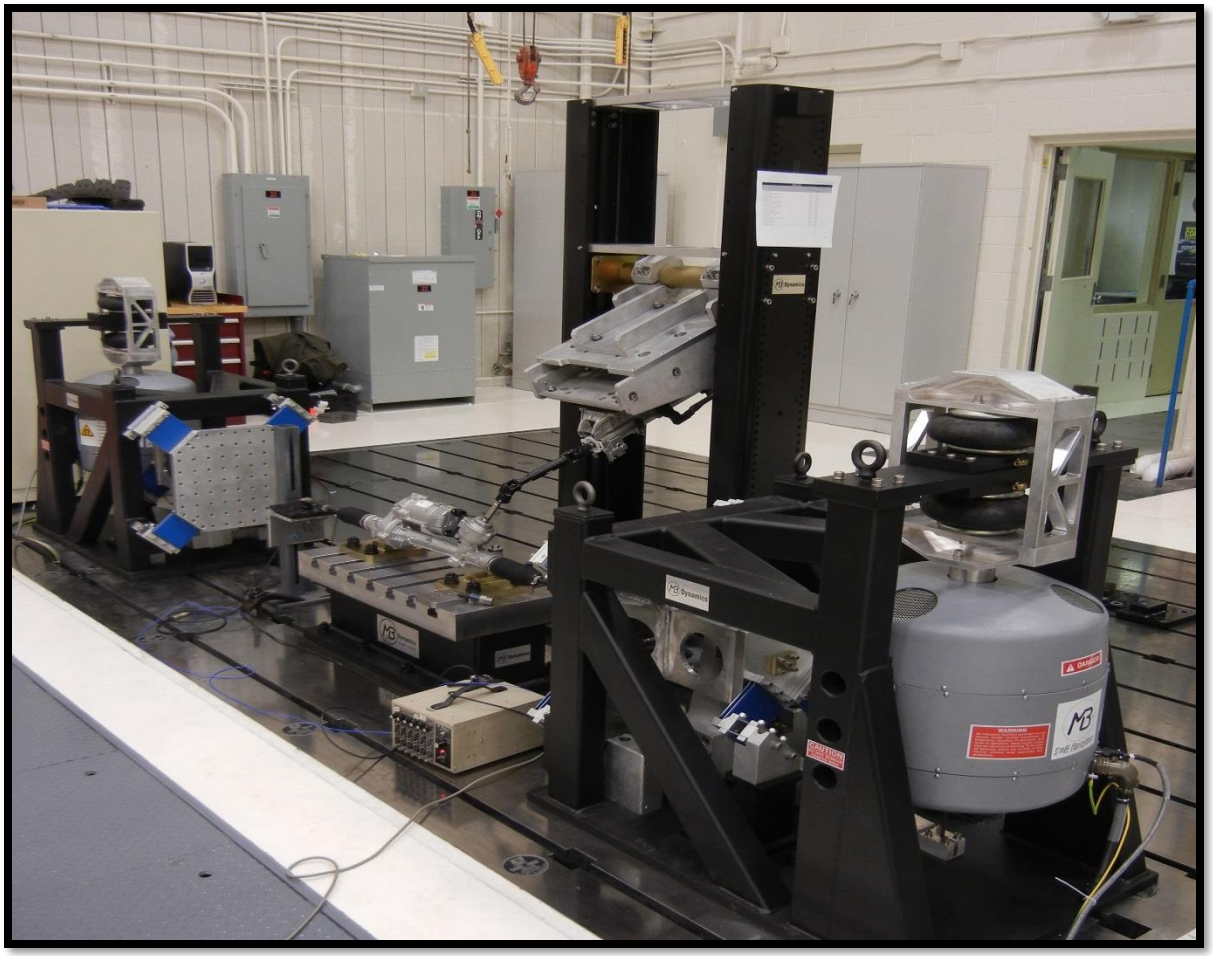
# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedure Supported*** |
|---|---|---|
| Rack Rattle and Clatter |  | Ford Core Engineering requirements |

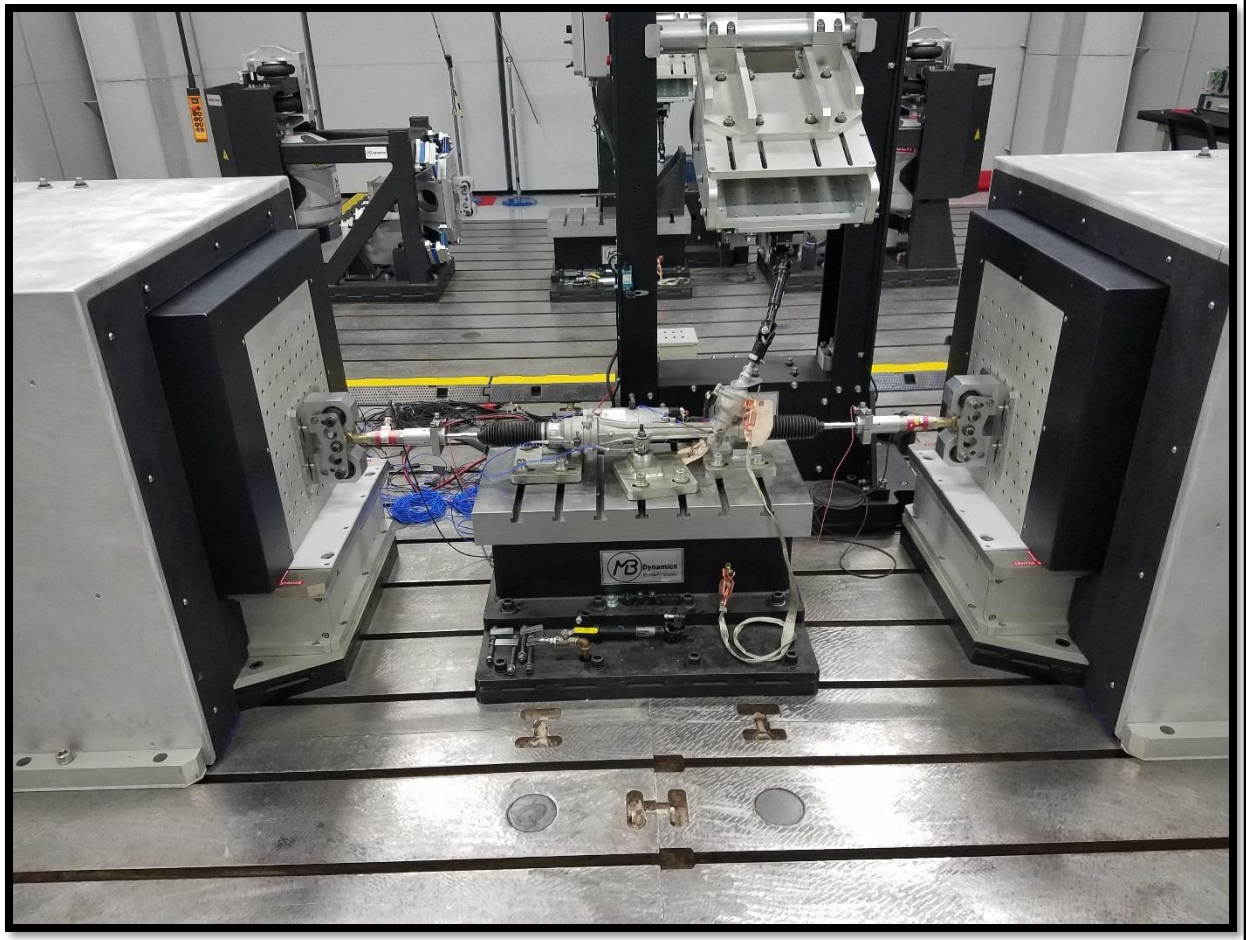
# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedure Supported*** |
|---|---|---|
| Rack Rattle |  | HMC ES56310-00, Steering Rack Rattle Testing |

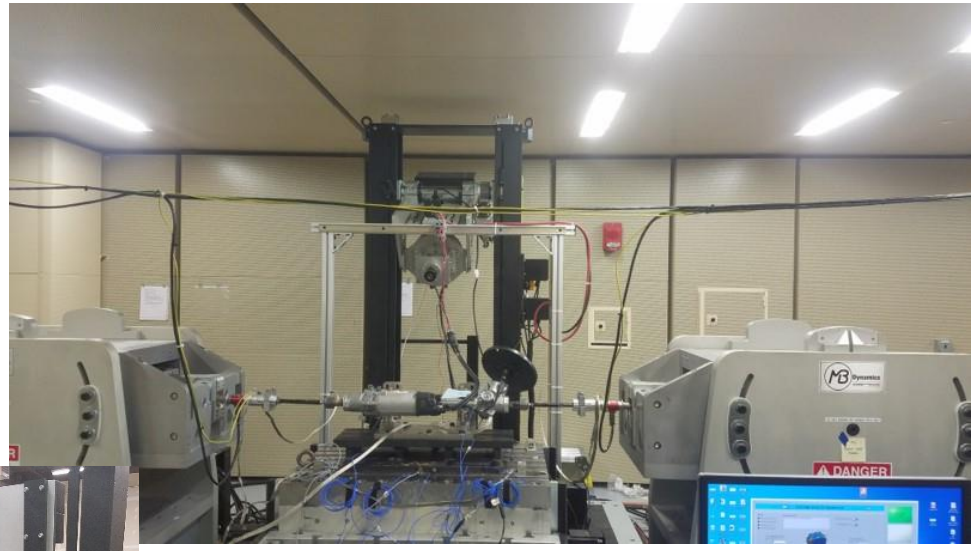
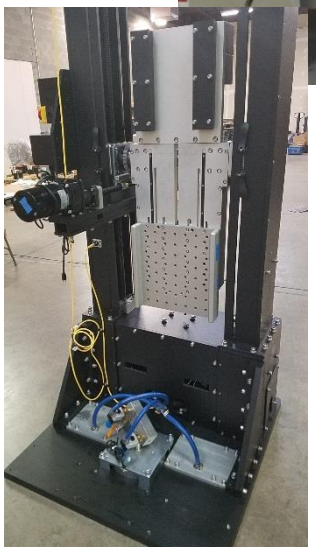
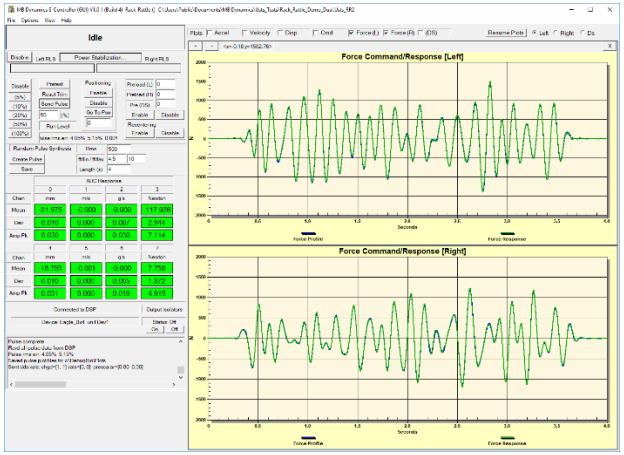
# Applications, Solutions & Test Procedures

| *Application* | *Solution Offered* | *Test Procedure Supported* |
|---|---|---|
| Rack Rattle and Clatter |  | GMW16216 "Steering Gear Rattle Evaluation" |

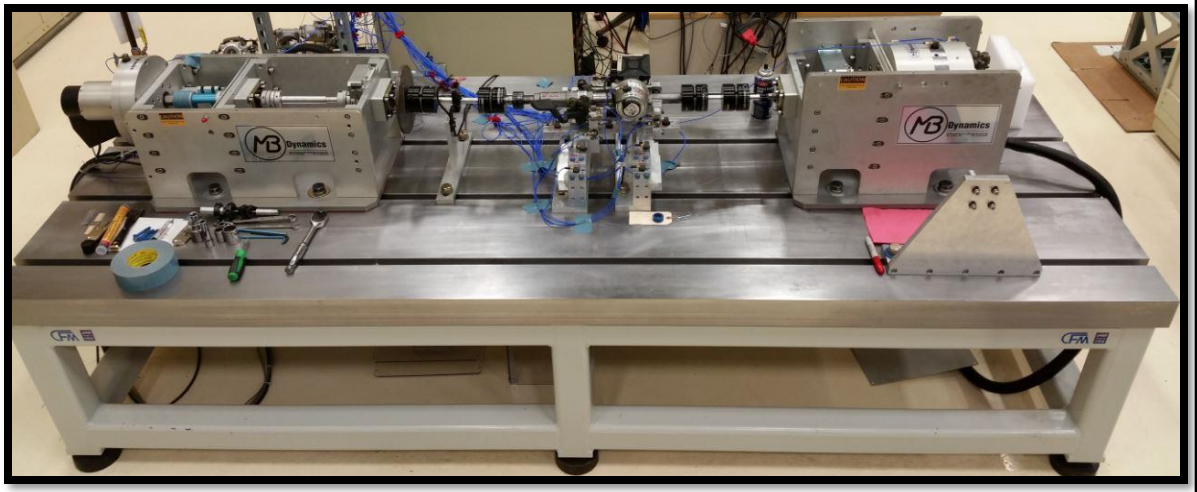
# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedure Supported*** |
|---|---|---|
| Running Noise and Zipper Noise and Gear Wear and Gear Conditioning |  | GMW 17112 “Electric Power Steering Gear Performance Test” |

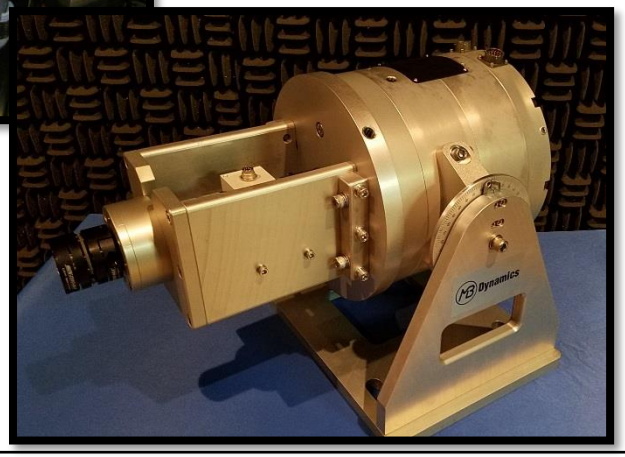
# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedures Supported*** |
|---|---|---|
| Unified Test Bench for Rack Rattle, Running Noise, Reversal Clunk, and Performance Characterization |    | All OEMs and Suppliers |

# Applications, Solutions & Test Procedures

| *Application* | *Solution Offered* | *Test Procedure Supported* |
|---|---|---|
| Column EPS Test Bench |  | All Test Procedures Developed and Used for Rack EPS Tests, plus<br>Steering Shaft Torsional Rate<br>Friction Torque<br>Backdrive Torque<br>Simultaneous steering shaft displacement and rack load torque<br>Column Rattle<br>Smooth Road Shake<br>Reversal Clunk |

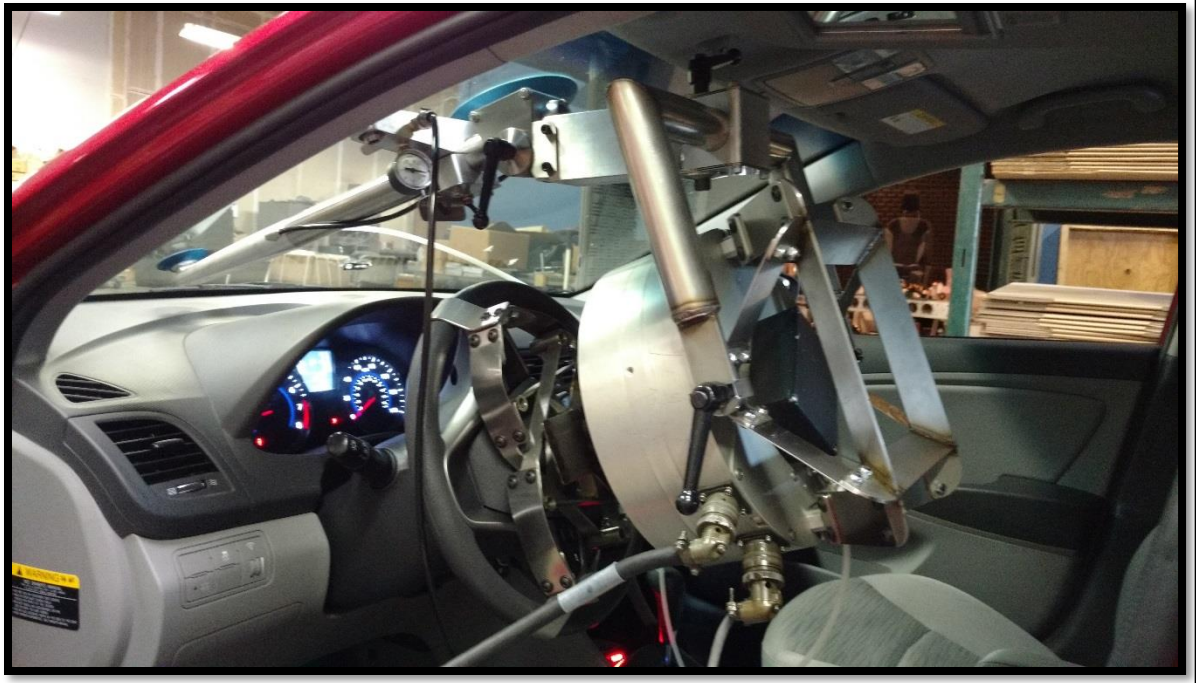
# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedure Supported*** |
|---|---|---|
| Quiet, No Cogging, Repeatable, Non-hydraulic Rotary Motion for Driving Columns and I-Shafts |   | All in-lab and in-vehicle steering motions from 30Nm – 150Nm pk or 10Nm – 75Nm continuous |

# DS10 Driver Simulator Acoustic Performance

| Test Condition | dB(A) | Sones N10 | Pk Amps |
|---|---|---|---|
| Ambient Noise, No Air, No AC, No Enable to motor | 20.8 | 0.34 | |
| Background Noise, Air @ 80PSI, AC ON, ENA ON | 22.5 | 0.50 | |
| Trapezoid, 30 RPM, ±500 deg, 900 dpss, 1 sec HOLD | 22.6 | 0.50 | 1.13 |
| Trapezoid, 60 RPM, ±500 deg, 900 dpss, 1 sec HOLD | 22.7 | 0.54 | 0.84 |
| Trapezoid, 75 RPM, ±500 deg, 900 dpss, 1 sec HOLD | 23.1 | 0.62 | 0.85 |
| Trapezoid, 90 RPM, ±500 deg, 900 dpss, 1 sec HOLD | 23.4 | 0.62 | 0.89 |
| Sine, 0.25 Hz, ±500 deg | 25.7 | 0.82 | 0.68 |
| Triangle, 1000 deg/sec, ±450 deg (0.556 Hz) | 32.6 | 2.38 | 12.10 |
| Position Time History, BW, ±510 deg, ±875 deg/sec | 24.1 | 0.94 | 3.38 |
| Pos. Time History, Sweep 2, ±510 deg, ±817 deg/sec | 25.0 | 1.02 | 3.09 |
| Pos. Time History, Sweep 3, ±510 deg, ±828 deg/sec | 24.8 | 1.02 | 3.34 |
| Reversal Clunk, , ±40 deg, 74 RPM, 2500 dpss | 26.1 | 0.86 | 3.44 |

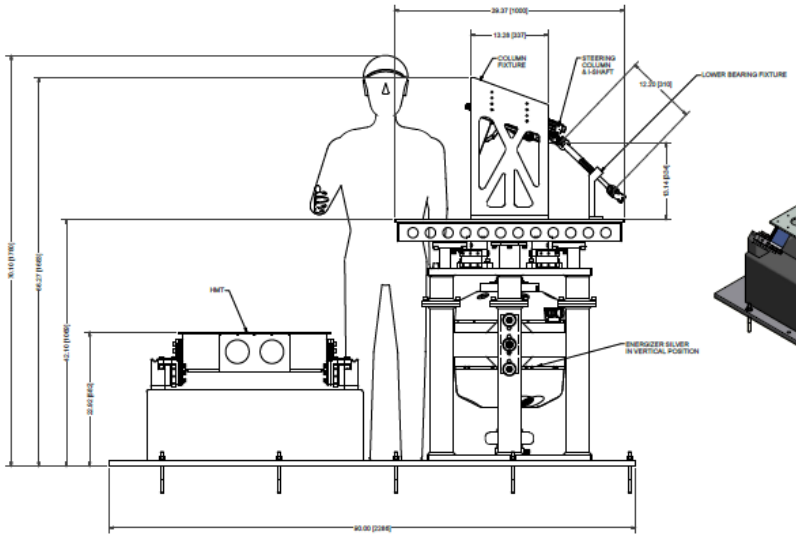
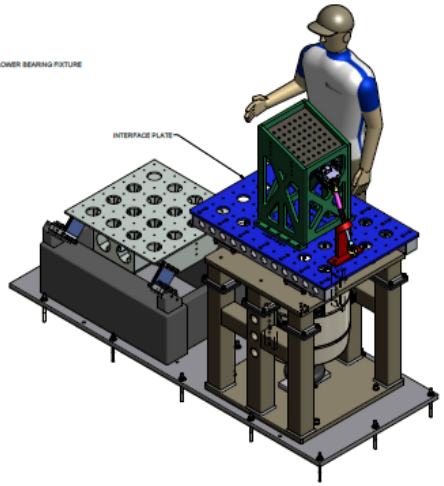
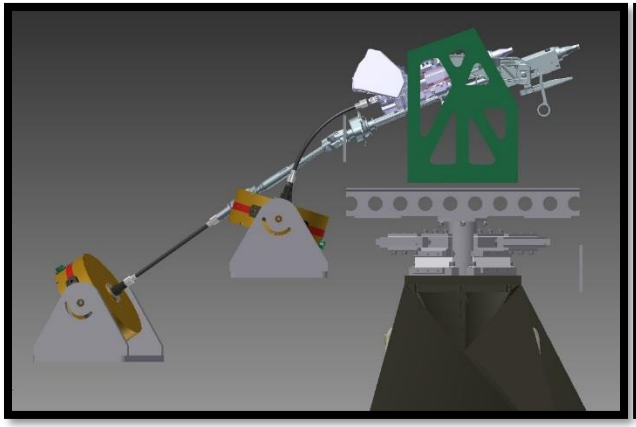
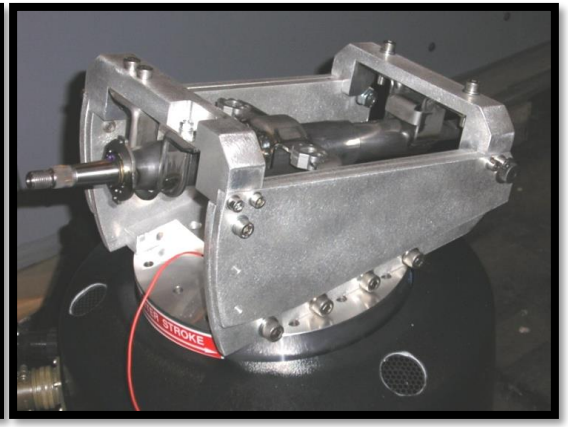
# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedure Supported*** |
|---|---|---|
| In-Vehicle Zipper Noise Measurement |  | GMW 14479 "Electric Power Steering Zipper Noise Evaluation Procedure for Steering Wheel Inputs in Vehicle" |

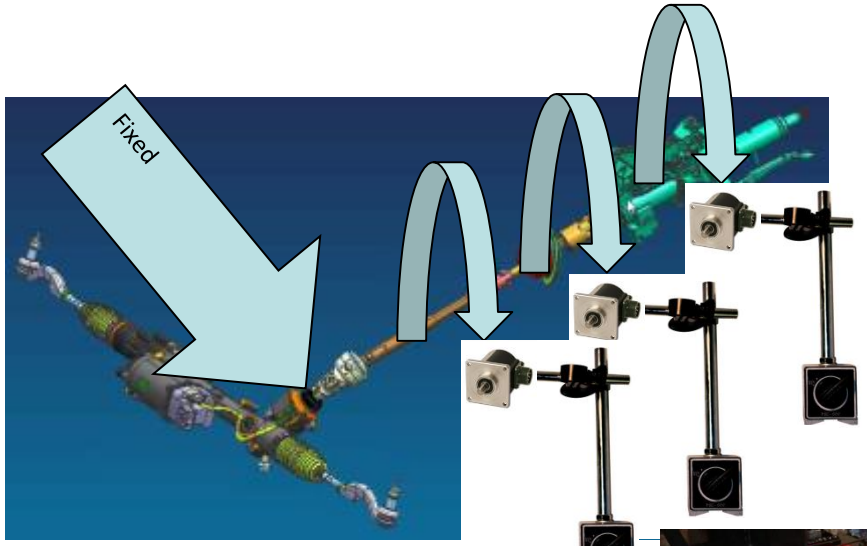
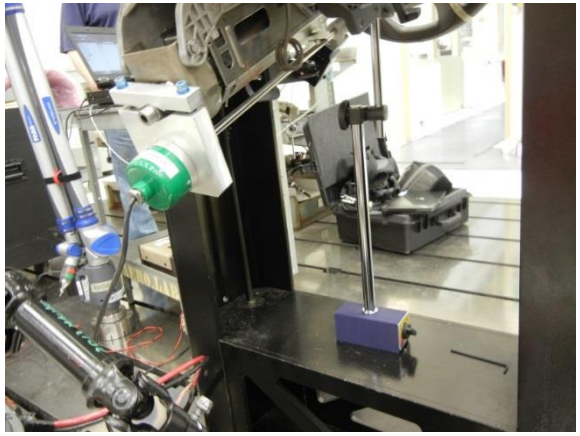
# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedure Supported*** |
|---|---|---|
| I-Shaft Turning Friction, Hysteresis, Lash, Stick Slip, Torsion Performance, Stick Slip Durability |  | GMW 17444 "Intermediate Shaft Rotating Friction Test Procedure"<br><br>GMW17422 "Intermediate Shaft Stiffness/Hysteresis/ Lash Test"<br><br>GMW17207 "I-Shaft Stick-Slip and Torsion Performance Test"<br><br>GMW15599 "Steering Column Intermediate Shaft Stick Slip Durability |

# Applications, Solutions & Test Procedures

| *Application* | *Solution Offered* | *Test Procedures Supported* |
|---|---|---|
| Column and I-Shaft Vibration Squeak & Rattle, Durability, Rotational Noise, Lower Bearing Squeak |     | Ford Core Tests:<br>III.B.1.5<br>III.B.1.3<br>III.C.1.6<br>III.C.1.8<br>III.C.1.13 |

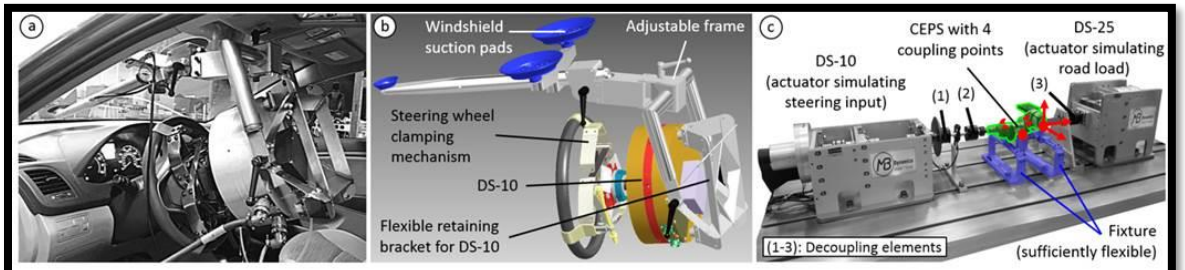
# Applications, Solutions & Test Procedures

| *Application* | *Solution Offered* | *Test Procedure Supported* |
|---|---|---|
| Upper Steering Column Position, Torsional Stiffness, Wrap-up & Hysteresis Measurement |    | As Required |

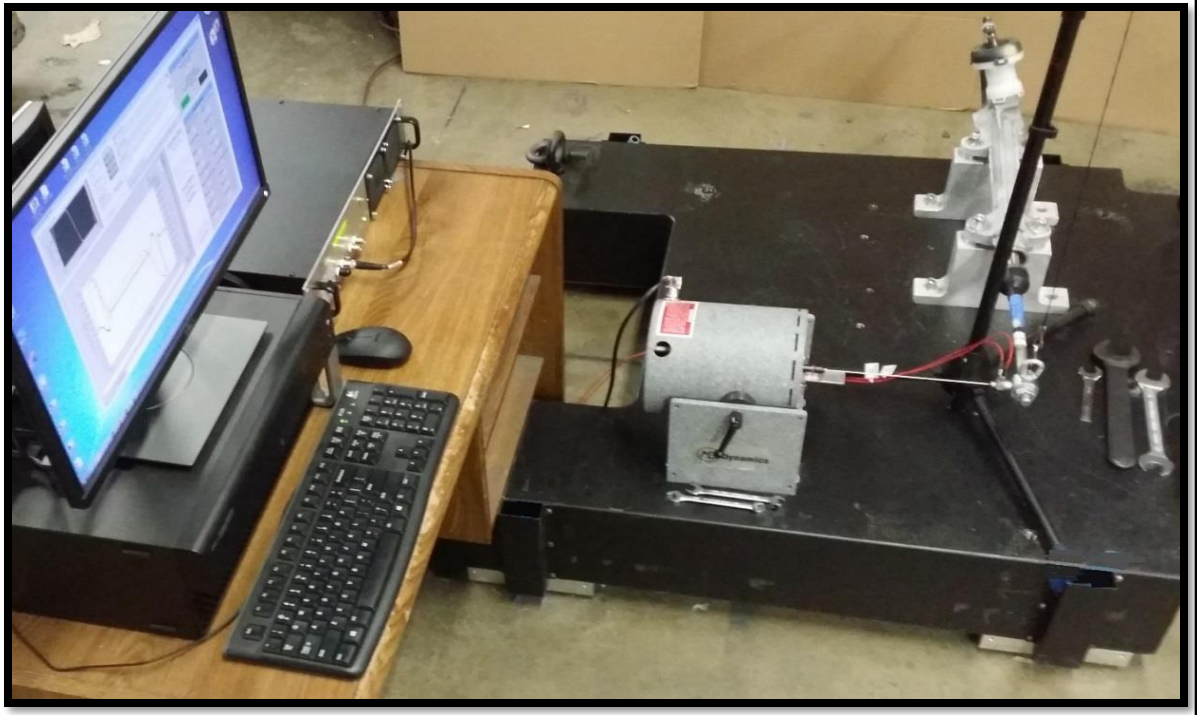
# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedure Supported*** |
|---|---|---|
| Smooth Road Shake |  | GM Proprietary |

# Applications, Solutions & Test Procedures

| *Application* | *Solution Offered* | *Test Procedure Supported* |
|---|---|---|
| Transfer Path Analysis and Virtual Acoustic Prototyping |  **Figure 2:** Operational measurements with low-noise Driver Simulators (DS) from MB Dynamics: (a) DS mounted in stationary vehicle via (b) windshield holding fixture to conduct in-vehicle steering noise evaluations; (c) Matched DS pair in horizontal arrangement to provide driver inputs and torsional road loads during CEPS lab tests. | Implementation of In-Situ Blocked Forces for In-Vehicle and In-Lab Implementation |

# Applications, Solutions & Test Procedures

| ***Application*** | ***Solution Offered*** | ***Test Procedures Supported*** |
|---|---|---|
| Characterize friction characteristics and stick-slip performance of inner tie rod ball joints under controlled conditions |  | Ford Inner Tie Rod Stick-Slip Test, ESAE5C-3280-AA |