



Specification for 261 Powertrain Mounts

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This document provides the standard technical requirements for the powertrain mounting systems. References to the program-specific technical specification are included in this document where program-specific requirements are expected to exist. All components of the subsystem must meet the requirements of this specification regardless of the phase of the program including production, unless a deviation is agreed to by GM Engineering.

Note: The program-specific technical specification may include additional program-specific requirements that are not referenced in this document and may supercede any requirements included in this document. In the case of any conflicts between this document and the program-specific technical specification, the program-specific technical specification takes precedence.

Definition for some of the technical terms used in this document may be found in ASTM D4092. This specification supercedes requirements in the referenced documents where there is conflict.

See Program Subsystem Technical Specification (SSTS).

1.2 Applicability. The powertrain mounting subsystem locates the powertrain in the vehicle, isolates powertrain vibrations, and controls powertrain motion under external load events, while meeting the program objectives of durability for the life of the vehicle. The powertrain mounting subsystem is to perform these functions as well as meet specific vehicle program/platform requirements as defined in this document.

1.3 Remarks. This specification is complemented with a SSTS which is program-specific. References to that document are made throughout this specification where program-specific information may be required.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ASTM D471

ASTM D4092

ASTM E505

SAE J1085

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2.2 GM Standards/Specifications.

GMW2	GMW3224	GMW14682	GMW15026
GMW5	GMW3359	GMW14734	GMW15147
GMW8	GMW3362	GMW14735	GMW15148
GMW10	GMW14149	GMW14738	GMW15272
GMW11	GMW14181	GMW14762	GMW15615
GMW3028	GMW14228	GMW14868	GMW15862
GMW3032	GMW14229	GMW14872	GMW15946
GMW3035	GMW14473	GMW14888 (ID)	GMW16285
GMW3059	GMW14504	GMW15011	GMW16331
GMW3172	GMW14676	GMW15025	GMW17026
GMW3191			

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2.3 Additional References.

- CG4340 - Hydraulic Powertrain Mount Internal Noise Force Measurement
- Component Technical Specification (CTS)
- Global Chassis Council Notice of Action (NOA) Number GCC 467A
([https://gmweb.gm.com/sites/NOA/Pages/Global-Notices-of-Action-\(-NOA-\).aspx](https://gmweb.gm.com/sites/NOA/Pages/Global-Notices-of-Action-(-NOA-).aspx)) (ID)
- Global Product Development Staff Notice of Action (NOA) Number GPD 509
([https://gmweb.gm.com/sites/NOA/Pages/Global-Notices-of-Action-\(-NOA-\).aspx](https://gmweb.gm.com/sites/NOA/Pages/Global-Notices-of-Action-(-NOA-).aspx)) (ID)
- GM Best Practices Auros Active Knowledge System Technical Memory Website
(<https://gmweb.gm.com/sites/E2ks/Pages/Home.aspx>) (ID)
 - GAFSTNG-11
 - PTMOUNT-9, PTMOUNT-14, PTMOUNT-25 (see program SSTS)
- GM Computer Aided Engineering (CAE) Guideline:
 - 20-00-001 - Joint Design Criteria
 - 20-06-001 - Powertrain Motion and Mounting System Analysis (ID)
 - 20-06-002 - Dynamic PT Mount Loads Prediction for Extreme Torque Events (ID)
 - 20-06-003 - General Finite Element (FE) Modeling Guidelines for Powertrain Mount Structural Components
 - 20-06-004 - General FE Analysis Guidelines for Powertrain Mount Structural Components
- GM Global Fastener Catalog
(<https://gmweb.gm.com/sites/fastening1/Global%20Fastener%20Catalog/Forms/AllItems.aspx>) (ID)
- GM Packaging Sign-Off Form
- MTS Systems Corporation, Eden Prairie, Minnesota (www.mts.com)
- Statement of Requirements (SOR)
- Subsystem Technical Specification (SSTS)
- US Patent number: US 9,158,868 B2
- Validation Cross Reference Index (VCRI)
- Vehicle Technical Specification (VTS) (ID)

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3 Requirements

3.1 System/Subsystem/Component/Part Definition. See program SSTS for powertrain mounting system configuration description.

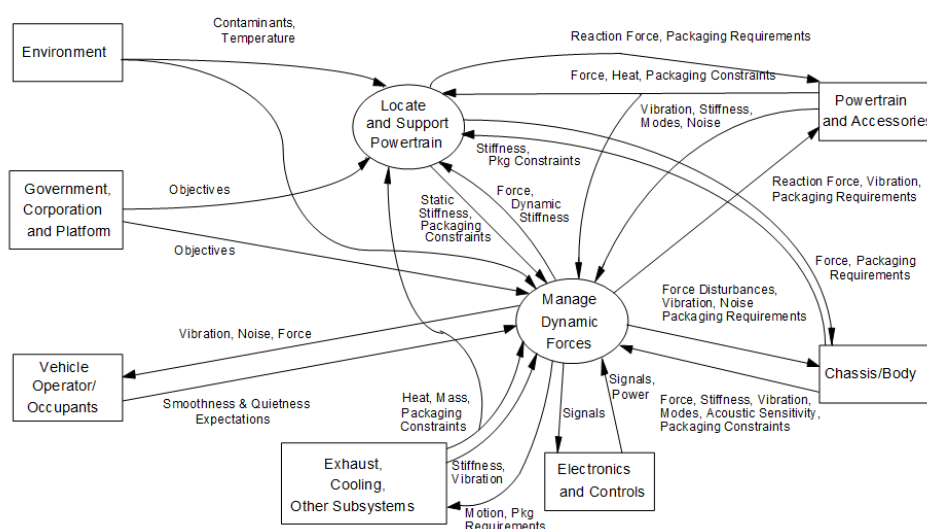
3.1.1 Appearance. Not applicable.

3.1.2 Content.

3.1.2.1 Physical Content. See program SSTS for mounting system components descriptions.

3.1.2.2 Functional Content. The powertrain mounting subsystem functional space is illustrated in Figure 1.

- Locate and support the powertrain in its static design position (3.2.1.4).
- Isolate the chassis/body from powertrain disturbances (3.2.1.1).
- Control powertrain shake to satisfy ride isolation requirements (3.2.1.1).
- Control powertrain motion to satisfy the packaging interface requirements (3.2.1.2.1).
- Control powertrain torque loads and forces and road induced loads (3.2.1.3).
- Control powertrain retention under crash loads as required (3.2.1.2.4).



Note: Pkg = Package.

Figure 1: Powertrain Mounting System Functional Content

3.1.3 Ambient Environment. The ambient environment conditions that the powertrain mounting subsystem may encounter during its life, and the countermeasures, are defined in 3.1.3.1 through 3.1.3.5.1.

3.1.3.1 Temperature. See program SSTS for design and validation temperatures for the mounts in the system.

3.1.3.1.1 Age Resistance (Heat Aging). All elastomers used in the components of the system shall demonstrate age resistance according to GMW15025 and GMW15026.

3.1.3.1.2 Cold Resistance. All elastomers used in the components of the system shall demonstrate cold resistance according to GMW15025 and GMW15026.

3.1.3.2 Contaminants. Refer to ASTM D471 for the comparative ability of rubber and rubber-like compounds to withstand the effect of industry standard liquids.

3.1.3.2.1 Material. The powertrain mounting subsystem components shall withstand exposure to the following contaminants without incurring loss of function:

- Water (with and without salt, at freezing and hot temperatures).
- Ozone.

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- Dirt/Mud.
- Engine Coolant.
- Windshield Fluid.

3.1.3.2.2 Packaging. The powertrain mounting subsystem components shall be packaged to assure minimal exposure to the following contaminants:

- Brake Fluids.
- Transmission Fluid.
- Air Conditioning Lubricant.
- Degreaser.
- Motor Oil.
- Axle Lubricant.
- Diesel Fuel.
- Diesel Exhaust Fluid (DEF).
- Power Steering Fluid.
- Bearing Grease.
- Gasoline (Including methanol and gas-alcohol blends).

3.1.3.2.3 Design Features. All mounts shall have design features that prevent fluids or debris from accumulating inside the mount. The features might have open design attributes where it is not possible for fluids or debris to accumulate, or shields to prevent fluids or debris from entering the mount in the first place. Mount position relative to the source of the contaminant shall be taken into consideration when deciding on these design features. All GM Best Practices (i.e., PTMOUNT-14) relevant to debris management are to be considered. The supplier shall work with the GM Design Responsible Engineer to comprehend this requirement.

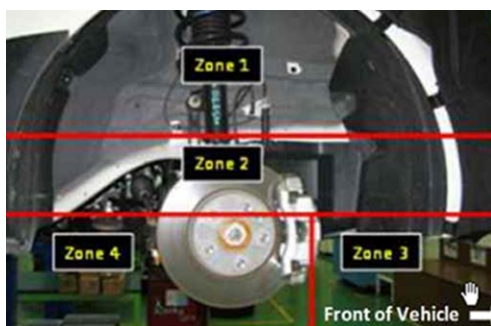
See program SSTS for specific shielding requirements.

3.1.3.2.4 Glycol Mixture. Water content in hydraulic mount glycol fluid shall be certified to be less than 1% by weight. In addition, residues from the manufacturing process of enclosing components (e.g., mold lubricants and metal stamping oils) shall not be present in the glycol mixture. See also GMW15025.

3.1.3.3 Ozone Exposure. All elastomeric components of the system shall demonstrate Ozone resistance according to GMW15025 and GMW15026.

3.1.3.4 Resistance to Hydraulic Fluid. Hydraulic mount elastomers that are in contact with hydraulic fluid shall meet the requirements of GMW15025.

3.1.3.5 Corrosion Resistance. When installed in the vehicle, all components and assemblies must remain structurally functional at 15 years/240 000 km (150 000 mi) and shall meet underhood and underbody vehicle corrosion performance and validation requirements as defined in GMW15272. See Figure 2.



Note: Where referenced in GMW15272:

- Zone 1: Test to GMW14872, UH, High PS, 4 sp, Method 1/2, Exposure E.
 Zone 2: Test to GMW14872, UH, All, 4 sp, Method 1/2, Exposure E.
 Zones 3 and 4: Test to GMW14872, UB, All, 4 sp, Method 1/2, Exposure E.

Figure 2: Front Compartment Splash Zones

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GMW17026 (15 year option) shall be used to validate mating dissimilar metal components with a standard Electrode Potential (E°) of $< -2.0 E^\circ$ (volts) (e.g., Magnesium or similar).

See program SSTS for program-specific corrosion requirements.

Note: Independent of the design of the part, the mechanism of galvanic corrosion has to be considered and must be prevented by specific design and/or material choice.

If any metal loss (loose/flaking corrosion product or noticeable pitting of the substrate after media blasting the corroded area) is observed, additional analysis will be required, and must be conducted with the assistance of GM Corrosion and/or Materials Engineering.

The part shall remain structurally functional under required operating conditions after being subjected to the required corrosion testing. Functional requirements are defined in 3.2.1.2.4 and 3.2.1.3.2.

3.1.3.5.1 Corrosion Resistance of Switchable Mount Electrical Components. The solenoid and other electrical components shall meet all performance test requirements during and after exposure to a corrosive environment, tested to GMW3172 C, G, F, B, E, IP6K8 and IP6K9K.

3.1.4 Interfaces. The powertrain mounting subsystem physically and functionally interfaces with several entities that will affect or constrain its functionality and design. Paragraphs 3.1.4.1 through 3.1.4.4.2 describe such interfaces and how they could affect the design or function of the mounting system.

3.1.4.1 External-to-Vehicle to Subsystem. The external-to-vehicle items that could affect and must be considered in the design of the powertrain mounting subsystem are:

- a. Vehicle shipping (truck and rail).
- b. Vehicle lift (packaging).
- c. Wash rack clearances (packaging).
- d. Towing (packaging, clearance to ground and tow truck).
- e. Ground clearance (parking, etc.)
- f. Curb line (packaging relative to cradle/frame longitudinal members).
- g. Road condition, (smooth road shake, rough road shake, potholes, irregularities, etc.)
- h. Off-road driving, as applicable.

3.1.4.2 Subsystem to Powertrain. Proper placement and layout of bosses on the powertrain structure for mount bracket attachments are critical to adequate performance of the mounts and their brackets. Refer to relevant GM Best Practices in GM Technical Memory for design guidelines. The supplier shall work with the GM Design Responsible Engineer to comprehend this requirement.

3.1.4.3 Subsystem to Body or Chassis Structure. Attachment points, layout, and scheme shall take into consideration structure stiffness (mobility), manufacturing requirements, service requirements, and structure load carrying capacity.

3.1.4.4 Subsystem to Others. The powertrain mounting subsystem brackets may be used to anchor plumbing fixtures, electrical wiring, shifter cables, heat shields, or the like, as necessary. These attachment schemes are typically not defined until later in the program development timing but prior to soft tooling design freeze date. The supplier will design features in the mounts brackets to accommodate such attachments as needed. Such design requirements are considered within the scope of the bracket design and integral to the Statement of Requirements (SOR) of which this document is part of.

3.1.4.4.1 Interfaces to Electrical Switchable Mount. The solenoid assembly packaging shall be designed to allow proper wire harness routing and clearances from the vehicle harness to the solenoid assembly.

The solenoid connector shall be downward facing and not higher than 15 degrees below the vehicle horizontal axis. The connector design shall comply with GMW3191 and receive approval from Electrical Connector Bill of Material (BOM) Family Owner (BFO).

3.1.4.4.2 Interfaces to Vacuum Switchable Mount. The vacuum switchable mount has vacuum male connector/connectors that are connected to the vacuum subsystem female connector/connectors respective. The connector design shall meet the error proofing and serviceability requirement (3.2.4.3.1 and 3.2.7.2).

3.1.5 Usage Definition. Not applicable.

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3.2 Product Characteristics. Sections 3.2.1 through 3.2.7 define the subsystem and component performance requirements, physical characteristics, reliability requirements, serviceability requirements, and manufacturing requirements.

3.2.1 Performance Requirements.

Note: The Vehicle Technical Specification (VTS) supercedes this specification and shall be the ultimate and controlling requirement for the program.

3.2.1.1 Isolate Vibrations. System and component level noise and vibration isolation requirements for the mounting systems considered are defined in 3.2.1.1.1 through 3.2.1.1.3. Static, low frequency, and high frequency requirements cover both low amplitude (e.g., idle and smooth road) and high amplitude (e.g., rough road) conditions.

3.2.1.1.1 Powertrain (PT) Rigid Body Modal (RBM) Requirements.

3.2.1.1.1.1 Low Load Idle Condition PT RBM Requirements. The PT RBM frequency and mode decoupling requirements are provided in the program SSTs for all powertrains for low amplitude conditions. System to ground requirements are used to develop the fundamental system and component attributes using subsystem analysis tools and possibly subsystem test rigs, and the in-vehicle requirements are used to guide vehicle level tuning (using hardware or vehicle level models). Modeling guidelines for PT RBM analysis are provided in Appendix G (Table G1, Table G2, Figure G1, and Figure G2).

In-vehicle PT RBM measurements shall be done according to GMW14762.

3.2.1.1.1.2 Idle at Incline PT RBM Requirements. When vehicles are parked at an incline, and the parking brake is not applied, wheel torque that holds the vehicle in place is reacted by the powertrain mounts. This condition can occur when the vehicle is in a nose-up or nose-down parking condition. Transverse Front Wheel Drive (TFWD) vehicles are especially sensitive to this condition. Under this circumstance, vehicles with internal combustion engines with a parking grade torque applied, the PT pitch mode (TFWD) frequency shall be offset from the corresponding engine main order firing frequency as specified in the program SSTs. This is a due-care requirement (not VTS driven) and should be assessed for all TFWD applications.

3.2.1.1.1.3 Launch Judder PT RBM Requirement. This is a due-care requirement (not VTS driven) for all three (3) and four (4) cylinder powertrains. Obtaining an accurate drive axle torque under the specified conditions might not be possible; therefore, the analysis/assessment can be viewed as a worst case condition warranting further investigation if deemed problematic. The powertrain resonant pitch frequency for TFWD systems under maximum forward torque load at 1000 rpm (engine) for four (4) cylinder engines, or 1200 rpm (engine) for three (3) cylinder engines, as applicable, shall be < 30 Hz for the three (3) cylinder powertrains or < 34 Hz for four (4) cylinder powertrains.

This requirement pertains to being able to launch the vehicle under maximum available powertrain torque without the engine primary firing order excitations (1.5 order for three (3) cylinders, or 2nd order for four (4) cylinders) coinciding with the powertrain natural resonance frequency under the drive load.

Theoretical maximum drive axle torque values for the respective powertrains at specified engine speed (rpm) maybe be used for the calculations (see program SSTs). These values may be limited by engine torque management, wheel slip, and/or clutch slip for manual transmissions, and therefore should be obtained from the Energy and Drive Quality (EDQ) team.

Mount nominal dynamic rates at load, should be used for all PT to ground rigid body analyses.

3.2.1.1.2 Mount Rate Characteristics. The listed requirements govern mount static and dynamic stiffness characteristics generally determined by mount design and rubber compound.

GMW14682 should be used to determine force-deflection characteristics of elastomeric components under uniaxial stress.

GMW14738 and GMW15615 should be used to produce the dynamic stiffness and damping curves from hardware testing. Also, refer to SAE J1085 for additional information.

GMW15615 Appendix test conditions are to be followed and provided for all development tuning set mounts and mounts to be used in supplier or GM testing. Any deviation from this process must be approved by the GM Validation and Design Release Engineer.

3.2.1.1.2.1 Static Load-Deflection (LD). Defining the LD curves for all the mounts for all powertrain combinations will require careful balancing of the requirements in this specification. Deviation from these

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requirements will require explicit approval by GM Engineering after careful consideration of the effect on loads management, Noise and Vibration (N&V) isolation, or powertrain motion control.

3.2.1.1.2.1.1 Measurement Requirements. Static LD curve data is to be provided for initial mount designs and updated after any design changes that may affect the LD curve.

Unless otherwise specified by the GM Design Release Engineer, complete static LD results in raw tabular (MTS Systems or equivalent) format shall be provided to GM for all mounts in the system. The load range for the test shall comprehend the **extreme** loads (see 3.2.1.3.1) for each mount in all directions.

This data is to be provided as measured without extrapolation, if physical measurement is not possible to these limits, the GM Design Release Engineer is to be notified and must agree to any deviations. Test setup and fixture designs are to be provided to GM.

3.2.1.1.2.1.2 Deflection under Static Preload. The unrestrained Main Rubber Element (MRE) of the load bearing mounts of the system shall have a maximum deflection under the static weight of the powertrain as specified in the program SSTs. If required for packaging reasons, the MRE may be pre-compressed to achieve a lower deformation amount under static preload in the mount assembly. Vertical deformation of load bearing mounts unconstrained MRE shall be limited to 7 mm. Mount deformation variation from nominal value under static preload shall not be more than ± 0.5 mm for TFWD load bearing mounts and ± 0.75 mm for Longitudinal Rear Wheel Drive (LRWD) mounts (e.g., due to MRE common usage for complexity reduction).

3.2.1.1.2.1.3 Lateral Cornering Acceleration. The general requirement is that the load on the mount in all three (3) directions in the local mount coordinate system under a 0.3G lateral acceleration applied at the Center of Gravity (CG) of the powertrain will be in the linear or progressive transitional zone of the mount LD curve, and never in the hard stop zone. The acceleration requirement for performance vehicles is 0.5G.

See program SSTs for possible program-specific requirement.

3.2.1.1.2.1.4 On-Center Static Stiffness. The on-center static stiffness of all mounts in all directions shall be determined by the requirements of the powertrain rigid body modal requirements at 0.1 mm peak-to-peak (p-p) as per 3.2.1.1.1.1. Dynamic to static hardening ratios appropriate for the mount design and rubber compound shall be used for the calculations. The supplier shall confirm used values by actual test measurements on similar mounts/compounds.

3.2.1.1.2.1.5 Idle Isolation. Idle assessments, including powertrain rigid body modes (3.2.1.1.1.1), shall be made under the static equilibrium position of the powertrain.

For automatic transmissions, the free (no snubber engagement) travel in the mounts shall be determined such that idle torque load shall fall in the linear range of the mount LD curve. Under certain conditions, a balanced total system solution (e.g., loads management) may require tighter snubbing in the mounts than is required in free travel under idle torque. In this case, some of the mounts might be into the snubber under idle torque load and therefore a detailed N&V assessment of idle shake performance will be required. For powertrains with manual, double clutch, or hybrid transmissions, which have no driveline torque load at idle, the mounts for these powertrains may have more limited free travel. This is desired to allow for progressive stiffness buildup for extreme dynamic loads management and also for mitigating powertrain transient events (see 3.2.1.1.2.1.6). Manufacturing variation in the components, system, and vehicle general assembly process shall be taken into consideration when deciding the free travel for the mounts (typically done by GM).

See program SSTs for free travel specifications for the mounts.

3.2.1.1.2.1.6 Stiffness Graduality.

Note: Specifications in this section are protected under US Patent US 9,158,868 B2. Patent is pending in China, Germany, and Brazil.

To help manage extreme dynamic loads in the mounts due to road or powertrain induced excitations, and also to help mitigate powertrain transient vibrations; the rate of change of mount static stiffness under load (graduality) shall be managed and controlled. The objective is to minimize dynamic extreme loads in the mounts by a mounting system that efficiently absorbs input energy, and also to provide for a continuously changing powertrain natural resonance frequency. Stiffness graduality is specified in Figure 3 and Table 1.

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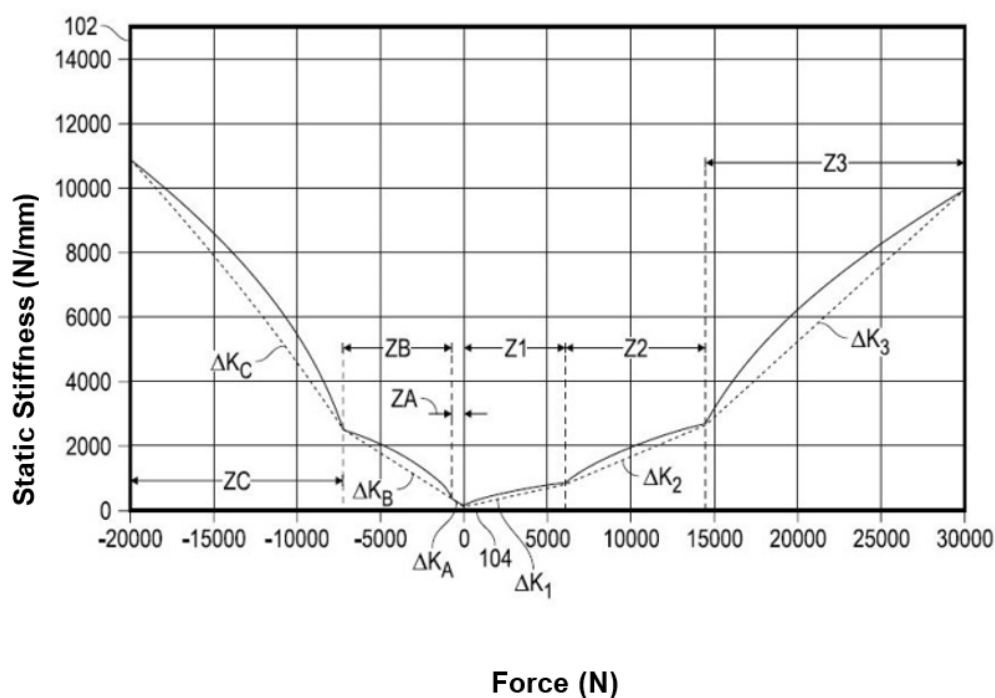


Figure 3: Illustration of Stiffness Graduality

Table 1: Graduality Specification

Main Bushing of Torque Reacting Mount		
Load Management Zones	Force (N)	Average Graduality ((N/mm)/N)
ZC – Reverse Extreme Loads	Maximum Predetermined High Cycle Load	ΔK_C (as low as possible without exceeding a predetermined total displacement in the mount)
ZB – Reverse Moderate Loads	Maximum Predetermined High Cycle Load to Maximum Pleasability Load	ΔK_B (larger than ZA rate and smaller than ZC rate as needed for a smooth transition between end of ZA range and beginning of ZC range)
ZA – Reverse Drive Isolation Zone	Maximum Pleasability Load (e.g., idle load at incline)	ΔK_A (as large as possible without exceeding one or more predetermined vehicle isolation requirements as determined by any other suitable method)
Z1 – Forward Drive Isolation Zone	0 to Maximum Pleasability Load (e.g., 1 st gear Wide Open Throttle (WOT))	ΔK_1 (as large as possible without exceeding one or more predetermined vehicle isolation requirements as determined by any other suitable method)
Z2 – Moderate Loads	Maximum Pleasability Load to Maximum Predetermined High Cycle Load	ΔK_2 (larger than Z1 rate and smaller than Z3 rate as needed for managing moderate transient and durability loads)
Z3 – Extreme Loads	Maximum Predetermined High Cycle Load to Maximum Extreme Load	ΔK_3 (as low as possible without exceeding a predetermined total displacement in the mount)

Note: Δ = Change.

The force inflection points referenced in Table 1 are specific to the type of mounting system and recommended values are specified in the Program SSTs.

Additional or less inflection points in the mount design might be required to meet the average graduality requirement for the given load zone.

3.2.1.1.2.1.7 Balanced Powertrain Rotation. All mounts in the system shall have LD progression whereby the powertrain rotation around its natural torque roll axis shall have minimum translational displacement in the

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fore/aft direction for pendular TFWD systems, vertical and fore/aft direction for Neutral Torque Axis (NTA) systems, and lateral direction for LRWD systems. This requirement shall apply at all load points up to and including extreme dynamic torque load events. The objective is to mitigate high dynamic loads on the mounts due to drive axle oscillations and also to reduce powertrain dynamic response under powertrain transient load events (e.g., start/stop; tip-in/out; garage shift, etc.) This requirement also helps keep the powertrain natural modes decoupled under engine load.

This requirement is especially critical for TFWD torque axis mounting systems, and in particular pendular systems. The following methods shall be used to balance pendular systems. The dynamic frequency sweep analysis (CAE procedure 20-06-002) may be used to determine the final optimal stiffness of the mounts for loads management. Some powertrains will have inertia characteristics where the CG location will result in balanced Load-Deflection Curves (LDC) that are too tight to be able to provide sufficient isolation. Under this circumstance, the LDC may be adjusted to provide more balance for all requirements.

3.2.1.1.2.1.7.1 Assumptions. As shown in Figures 4, 5, and 6 there are certain assumptions made in the simplified balance method including the location of the mounts relative to the powertrain torque roll axis and the axis about which rotation is balanced. Errors from these assumptions shall be accounted for by using system analysis tools to verify loads management and adequate isolation through the mounts. Final mount LD curve determination should be based on dynamic analysis for managing mount loads.

3.2.1.1.2.1.8 Other Considerations.

- a. The mount shall be demonstrated in the free unloaded position and in the installed, loaded position.
- b. Variation due to installation variation, mount build variation, and rubber compound variation shall be studied and assessed.
- c. Load bearing mounts creep (refer to 3.2.1.4) should be accounted for when determining the free travel length of the mount. All pleasability loads zoning shall consider the mount in the post-creep position.
- d. Mount LD curves as specified in this specification do not include elastic or permanent deformation in the metal components of the mounts or attachment brackets.
- e. Load-deflection curves from component measurements will likely include elastic/plastic deformation in the mount structure, and fixture compliance which should be considered when comparing actual mount measurements with specified or target LDCs for the mount.

See Program SSTS for specific mount LDC requirements.

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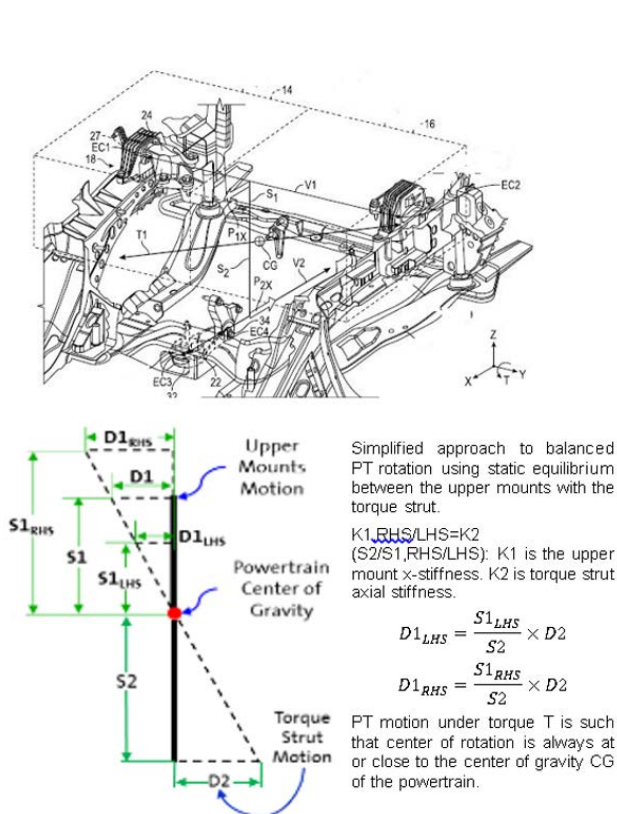


Figure 4: Pendular Mounting System

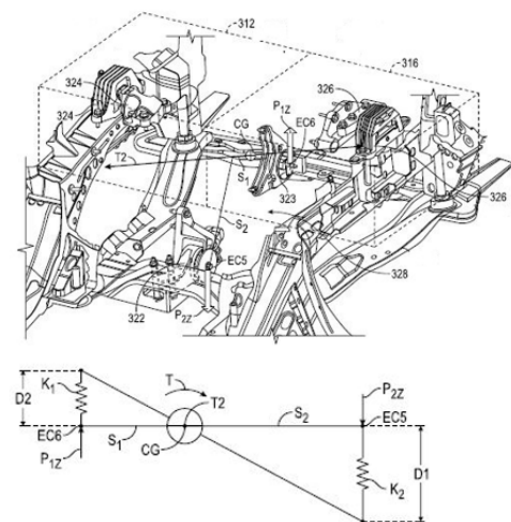


Figure 5: NTA Mounting System

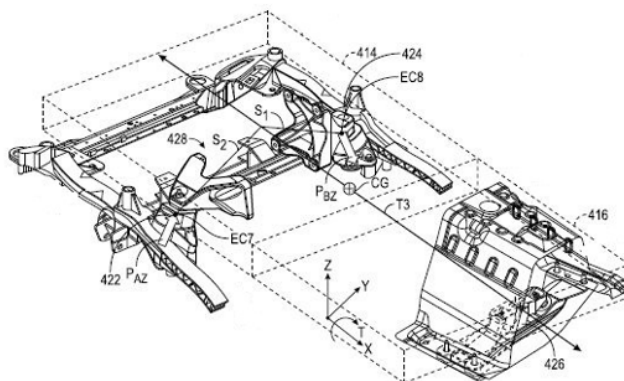


Figure 6: LRWD Mounting System

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3.2.1.1.2.2 Mount Dynamic Stiffness and Damping Specifications. Dynamic stiffness and damping characteristics are specified for all mounts in the subsystem.

3.2.1.1.2.2.1 Measurement Conditions. Damping shall be specified as nominal loss angle peak in degrees at a given stroke and frequency range with a stated tolerance. The following formula should be used to calculate damping amplitude (C) as a function of complex dynamic stiffness K^* , phase loss angle Φ , and frequency f :

$$C = K^* \sin(\Phi) / 2\pi f$$

Mount dynamic requirements are specified as nominal values with a stated tolerance according to the conditions in Table 2, as appropriate; and the supplier shall demonstrate the performance of the mounts according to these same conditions.

GMW14682, GMW14738, and/or GMW15615 should be used to characterize mounts for dynamic stiffness and damping.

Table 2: Mount Performance Conditions

Load Condition		Frequency Range (Hz)	Stroke Amplitude (mm)
Low Load (Idle and Smooth Roads) Condition	Gas	1 to 50	± 0.05
	Diesel	1 to 50	± 0.10
High Load (Rough Road) Condition		1 to 50	± 0.50
Low Load Condition		10 to 300	± 0.10
Low Load Condition		10 to 600 ^{Note 1}	± 0.05

Note 1: Some applications may require mount characterization beyond 800 Hz at ± 0.05 mm stroke amplitude. For these special conditions, the supplier shall provide a plan to achieve this requirement. See program SSTS for any special mount condition requirements.

Unless otherwise specified by the Performance Integration Engineer or Design Responsible Engineer, low frequency vertical (local mount coordinates) dynamic rate and damping properties shall be measured, with static preload applied, for every prototype mount supplied to GM for development testing and integration builds. (Reference GMW15615.) Prototype mounts must be identified with a specific serial number that is permanently and clearly scribed on the mount. Static and dynamic characterization results shall be provided in electronic format (Microsoft Excel preferred) in both graphical and tabular form and must reference this unique serial number.

Unless otherwise specified by the Performance Integration Engineer or Design Responsible Engineer, complete dynamic measurement results in raw (MTS Systems or equivalent) format shall be provided for all hydraulic mounts as in Table 3.

Table 3: Low Frequency Hydraulic Mount Dynamic Rate and Damping Characterization Requirements

Hydraulic Mount Characteristic	Frequency Range (Hz)	Frequency Increment (Hz)	Stroke Amplitude (mm)
Damping and Stiffness	1 to 50	1.0	± 0.05, ± 0.10, ± 0.15, ± 0.20, ± 0.25, ± 0.5, ± 1.0, and ± 1.5

Unless otherwise specified by the Performance Integration Engineer or Design Responsible Engineer, complete dynamic measurement results in raw (MTS Systems or equivalent) format shall be provided for all elastomeric mounts as in Table 4.

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Table 4: Low Frequency Elastomeric Mount Dynamic Rate and Damping Characterization Requirements

Elastomeric Mount Characteristic	Frequency Range (Hz)	Frequency Increment (Hz)	Stroke Amplitude (mm)
Damping and Stiffness	15	Not applicable	± 0.05, ± 0.5

In addition, high frequency dynamic stiffness measurements may be requested on select hydraulic and elastomeric powertrain mounts. Dynamic stiffness curves and raw (MTS Systems or equivalent) data shall be provided with static preload applied in electronic format (Microsoft Excel preferred) as in Table 5.

Table 5: High Frequency Powertrain Mount Dynamic Rate Characterization Requirements

Hydraulic Mount Characteristic		Frequency Range (Hz)	Frequency Increment (Hz)	Stroke Amplitude (mm)
Stiffness	Diesel	10 to 300	10.0	± 0.1
	Gas	10 to 600	10.0	± 0.05

Damping measurements shall be in both **degree of phase loss angle** and **Newton-seconds/millimeter**. Dynamic stiffness units of measurement shall be in **Newtons/millimeter**. Stroke amplitude may be referenced in p-p form as dictated by the Design Engineer or Performance Integration Engineer. See program SSTS for mounts dynamic stiffness and damping requirements.

3.2.1.1.2.2.2 Rubber Hardening (Payne Effect). Rubber/elastomer hardening (without hydraulic effect) by virtue of the choice of the rubber compound or rubber geometry shall have a Dynamic Hardening Ratio (DHR) as low as possible; but should be limited according to the program SSTS.

3.2.1.1.2.2.3 General Dynamic Stiffness and Damping Requirements.

3.2.1.1.2.2.3.1 Low Frequency Events. Mounts in the system shall meet specific dynamic stiffness and damping performance requirements at the component level in the lower frequency range, usually 1 Hz to 50 Hz. The concerns may include all or part of the performance criteria:

- **Idle shake:** Engine firing order related shake isolation requirements. Rate dip in the mount for idle, if needed, should be clearly stated with the frequency range and amount of dip. Rate dip is particularly critical for switchable mounts.
- **Smooth road shake:** Mounts in the system might be required to provide high dynamic stiffness to reduce powertrain vibrational response resulting from excitation from tire/wheel imbalance at highway speeds. A minimum dynamic stiffness is traditionally specified at a displacement of ± 0.05 mm at first order tire excitation frequencies on the highway (typically in a range between 12 Hz to 20 Hz). This requirement is particularly pertinent to a switchable mount state in the smooth road shake state.
- **Rough road shake:** Usually specified as minimum damping in the mount at ± 1.0 mm stroke at frequencies close to vehicle front suspension ride frequency.
- **Auto-start:** Also called stop-start, might require specific tuning of the mounts including hydraulic damping levels at specific frequencies and mount stiffness ratios and stiffness levels.

3.2.1.1.2.2.3.2 High Frequency Engine Noise Isolation. Decoupled hydraulic mounts might be required for some powertrain combinations as specified in the program SSTS to have the capability to provide low dynamic stiffness (rate dip or broadband) in a specified structure-borne noise frequency range (typically above 100 Hz) to address specific structure-borne noise issues. This requirement will be identified at ± 0.05 mm stroke amplitude over a defined frequency range as a minimum percentage of dynamic stiffness reduction (when compared to the average dynamic stiffness) or may be referenced as a maximum dynamic stiffness in that specific frequency range.

See program SSTS for the dynamic stiffness requirements for specified powertrain combinations.

3.2.1.1.2.2.3.3 Active Fuel Management (AFM). Certain engines are enabled for cylinder deactivation. When in use, the N&V isolation requirements in the cylinder deactivation mode may be different than for the baseline operation of the engine. Generally speaking, mounts need to be in a softer state in the frequency band specific

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to the AFM engine speed operation range and also under vehicle dependent Equal Fuel Consumption (EFC) torque loading. The program SSTS defines the mounts stiffness requirements for AFM operation, if any.

See program SSTS for general mount stiffness and damping requirements.

3.2.1.1.2.3 Development Tuning Library. See program-specific SSTS for tuning library requirements.

3.2.1.1.3 Bracket Dynamic Stiffness Requirements. Powertrain mount bracket modal resonances shall not result in amplification in the overall level of powertrain noise nor shall result in audible degradation in powertrain sound quality in the passenger compartment. In-vehicle powertrain noise performance related to bracket Drive Point Dynamic Stiffness (DPDS) takes precedence over stated bracket minimum frequency requirements. See program SSTS for the DPDS requirements for specified powertrain combinations. If program-specific DPDS targets are not available, bracket minimum first mode frequency requirements are shown in Table 6.

Deviations to the stated requirements shall be reviewed and approved by GM Noise and Vibration and Design and Release engineers.

Table 6: Mounting Brackets and Housings Modal Frequency Requirements for Metal Components

Bracket	Number of Engine Cylinders	Engine Firing Order	Highest Significant Order	1 st Mode (Hz)	Condition	Notes
PT Side	3	1.5	4.5	> Maximum Engine rpm/60 × 3 × 1.55	In Vehicle	1. Except as noted in Program SSTS. 2. On 3 cylinder engines 4.5 order excitation is protected for by the 1.55 amplification factor. An amplification factor of 1.4 may be used to protect for 3 rd order excitation if 4.5 order is not of significant amplitude.
	4	2	4	> Maximum Engine rpm/60 × 4 × 1.4		
	6	3	3	> Maximum Engine rpm/60 × 3 × 1.4		
	8	4	4	> Maximum Engine rpm/60 × 4 × 1.4		
	Electric Motors	Not applicable	Not applicable	> 600		
Chassis Side	Not applicable	Not applicable	Not applicable	> 600	To Ground	Except as noted in program SSTS
Body Side	Not applicable	Not applicable	Not applicable	> 600	To Ground	Except as noted in program SSTS

Note: DPDS program-specific targets take precedence over the modal frequency requirements as given in Table 6. Non-metallic structural components are subject to different requirements. See program SSTS for any additional requirements.

See program SSTS for additional bracket modal frequency requirements.

Refer to 20-06-003 and 20-06-004 for CAE guidance.

Bracket resonance physical measurements should refer to test procedures GMW14181, GMW14228, and GMW14229.

3.2.1.2 Control Powertrain Dynamic Motion under Extreme Loads. The powertrain mounting subsystem shall control motion of the powertrain resulting from self-generated powertrain torque events or external-to-vehicle induced forces on the powertrain. Paragraphs 3.2.1.2.1 through 3.2.1.2.5 describe powertrain mounting system requirements for PT dynamic motion control.

3.2.1.2.1 Maximum Displacements and Rotations. Maximum powertrain displacements and rotations are limited by the underhood and chassis compartments package requirements and also by practical limits in allowed displacements in the mounts. Powertrain motion analysis is done with design loads specified in 3.2.1.3.1. Powertrain roll files are generated by GM and are used for packaging studies. Roll files shall be repeated when measured LD curves are available from the supplier based on physical measurements.

3.2.1.2.2 Powertrain Retention. The powertrain mounting subsystem shall retain the powertrain in the event of elastomeric loss of function for the conditions defined in validation test, GMW14888. This shall be accomplished by designing in hard stops into the mount brackets that will ensure the motion at the mount with severed main rubber element is limited.

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