HO CHI MINH CITY UNIVERSITY OF TECHNOLOGY FACULTY OF AUTOMOTIVE ENGINEERING

AUTOMOTIVE TECHNOLOGY PROJECT

TOPIC

TEST STANDARD AND PROCEDURE FOR SUSPENSION SYSTEM

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Class: CC01 – Group: 09

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I. INTRODUCTION

When cars operate on different types of roads, it will lead to shocks, vibrations, and vibrations of suspended and unsuspended masses. Vehicle vibration is a complex problem and has a negative impact on human health, the quality of goods and the stability of car movement. And the suspension system of the vehicle plays a critical role in ensuring the stability, comfort, and handling characteristics of a vehicle. The comfort of the vehicle is evaluated by many criteria such as: natural vibration frequency (Hz), vibration amplitude (m), vibration acceleration (m/s^2), and impact time (s)...

In order to improve the comfort of manufactured and assembled vehicles, the internation regulation and standard are issued, in which the allowable limit of vehicle's natural vibration frequency is clearly regulated. Therefore, this project will introduce the test standard and procedure for suspension system by determining natural vibration frequency and damping coefficienct of manufactured and assembled vehicles.

II. TEST STANDARD

Basically, the applied object of this project is 2-axle vehicles and standards for requirement of test are referenced from:

- MIL-STD-810H (Environmental Engineering Considerations And Laboratory Tests).
- JIS D 1601 (Japanese Industrial Standard, Vibration testing methods for automobile parts)
- QCVN09 – 2015/BGTVT (National technical regulation on safety and environmental protection for automobiles).
- Council Directive 96/53/EC (Council of the European Union 1996).
- ISO 8608 (Mechanical vibration Road surface profiles).
- 22TCN 336:2006 (Road vehicles - Vehicle suspension system - Methods for determining the natural vibration frequency and damping coefficient).

III. TEST CONDITION

3.1. Test model:

To ensure the model function correctly while measuring, we have to follow these conditions:

- The vehicle must be fully loaded according to vehicle's design.
- The suspension system must comply with vehicle's design.

- Tires must be new and the correct type for the vehicle's design.
- Tire pressure must comply with the manufacturer's regulations.

3.2. Test equipment:

Choose the specific exciters to be used based on:

- The size and mass of test items and fixtures;
- The frequency range required;
- The force, acceleration, velocity, and displacement required.

3.3. Test environment:

Vibration results in dynamic deflections of and within materiel. These dynamic deflections and associated velocities and accelerations may cause or contribute to structural fatigue and mechanical wear of structures, assemblies, and parts. In addition, dynamic deflections may result in impacting of elements and/or disruption of function. Some typical symptoms of vibration-induced problems follow. This list is not intended to be all-inclusive:

- Chafed wiring.
- Loose fasteners/components.
- Intermittent electrical contacts.
- Electrical shorts.
- Deformed seals.
- Failed components.
- Optical or mechanical misalignment.
- Cracked and/or broken structures.
- Migration of particles and failed components.
- Particles and failed components lodged in circuitry or mechanisms.
- Excessive electrical noise.
- Fretting corrosion in bearings

Because nearly all the accelerometer are affected by high and low temperature. Therefore, to ensure the accuracy while measuaring, it is necessary to consider these conditions:

- No rain
- Temperature: $10°C$ to $50°C$
- Relative humidity: 0% to 85%.

According to ISO 8608 random road profiles can be approximated by a PSD using the following formula:

$$\Phi(\Omega) = \Phi(\Omega_0)\left(\frac{\Omega}{\Omega_0}\right)^{-w} or, \Phi(n) = \Phi(n_0)\left(\frac{n}{n_0}\right)^{-w}$$

Road Classes	A	B	C	D	E	F	G	H
σ $(10^{-}3)m$	2	4	8	16	32	64	128	256
$\Phi(\Omega_0)$ $(10^{-}6)m$	1	4	16	64	256	1024	4096	16384

Table 1: *Road classes table*

IV. TEST EQUIPMENT

4.1. Test device:

4.1.1. Accelerometer

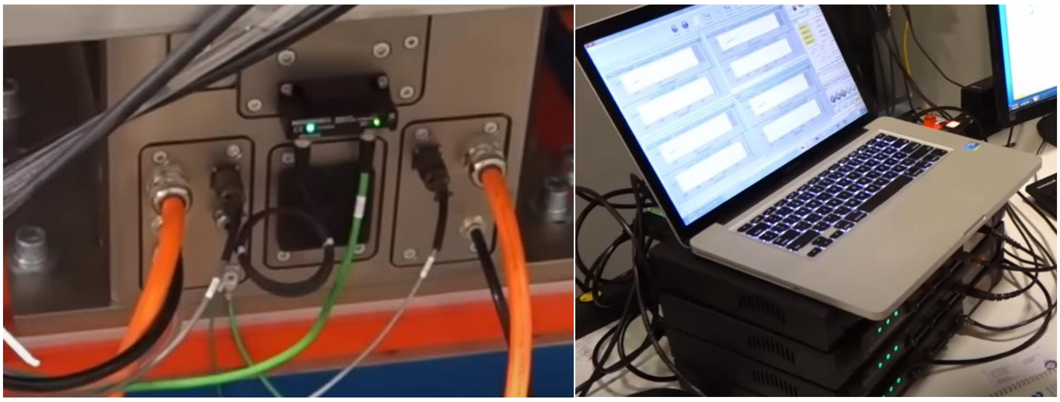

Figure 1: *Accelerometer*

Some key performance parameters for an accelerometer are regulated by MIL-STD-810H Standard as follows:

- Frequency Response: A flat frequency response within ± 5 percent across the frequency range of interest is required.
- Transverse sensitivity should be less than or equal to 5 percent.
- Nearly all transducers are affected by high and low temperatures.. Temperature sensitivity deviations at the test temperature of interest should be no more than ±5 percent relative to the temperature at which the transducer sensitivity was established.

- Base Strain sensitivity should be evaluated in the selection of any accelerometer.

4.1.2. Vibration exciter

The accuracy in providing and measuring vibration environments is highly dependent on fixtures and mountings for the test item, the measurement system and the exciter control strategy. Select a control strategy that will provide the required vibration at the required location(s) in or on the test item.

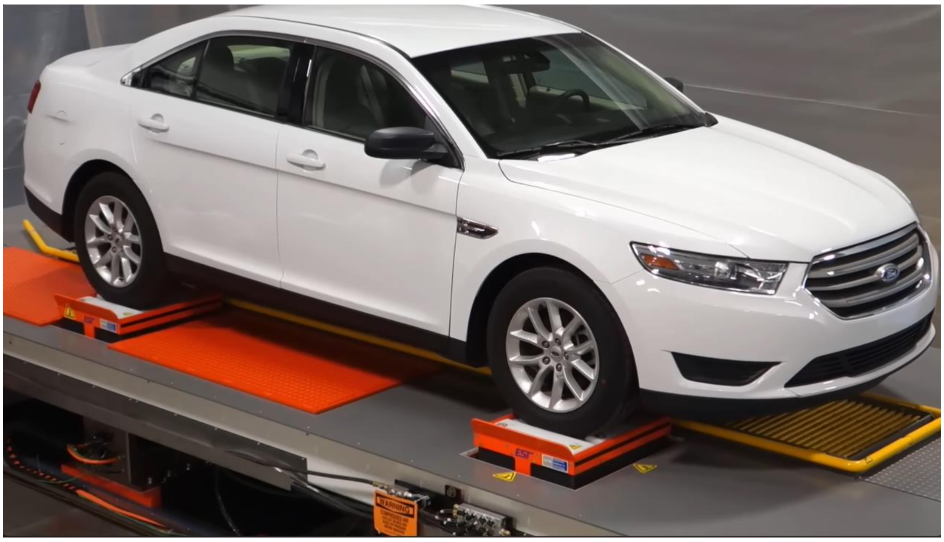

Figure 2: *Vibration exciter*

Select a control strategy that will provide the required vibration at the required location(s) in or on the test item:

1. *Acceleration input control strategy:* The vibration excitation is controlled to within specified bounds by sampling the vibratory motion of the test item at specific locations
2. *Force control strategy:* Dynamic force gages are mounted between the exciter/fixture and the test item. Exciter motion is controlled with feedback from the force gages to replicate field measured interface forces.
3. *Acceleration limit strategy:* Input vibration criteria are defined as in “Acceleration input control strategy”. In addition, vibration response limits at specific points on the materiel are defined (typically based on field measurements).
4. *Acceleration response control strategy:* Vibration criteria are specified for specific points on, or within the test item. Control accelerometers are mounted at the vibration exciter/fixture interface. Monitoring accelerometers are mounted at the specified points within the item.

4.2. Test instrumentation:

No.	Instrumentation	Measuring parameter	Illustrating images
1	Thermo Hygrometer	Humidity (% RH) and air temperature (°C)	
2	Vehicle weighing scale	Vehicle weigth (kg)	
3	Tire pressure gauge	Tire pressure (PSI/kPa)	
4	Tape measure	Length, width and height (mm)	
...	...	...	...

Table 2: *Measuring instrumentation*

V. TEST METHOD

Method 1 – The vehicle is subjected to a free-fall drop test from a height h within the range of 60mm to 120mm, ensuring that the chassis does not touch the suspension system's travel restriction dock when the wheels touch the ground. In special case, heights outside the range of 60mm to 120mm may be chosen.

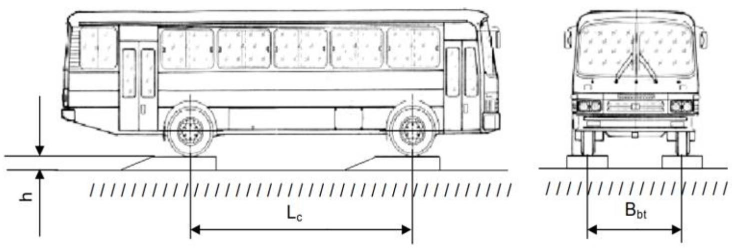

Figure 3: *Schematic diagram for generating vibration according to first method*

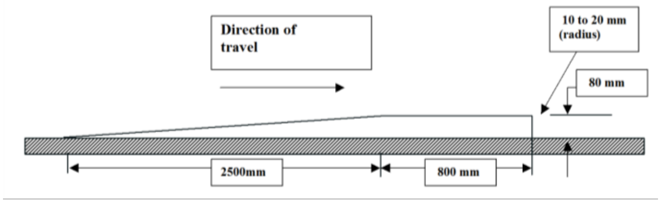

Figure 4: *The ramps with profile is described in Annex II of Council Directive 96/53/EC (Council of the European Union 1996)*

Method 2: Compress the chassis from 60 mm to 120 mm from the original position so as not to touch the suspension travel restriction dock. Stop compressing abruptly to create vibrations.

Method 3: Random vibration

Random vibration testing involves subjecting a product or system to a broad spectrum of vibration frequencies simultaneously, mimicking real-world conditions. It allows engineers to evaluate the response and durability of the device under unpredictable vibrations encountered during transportation, or general use. As the amplitude and phase of such a signal are, by definition, random, just as the vibrations surrounding us, this test type does a much better job of simulating real-life noise impacts.

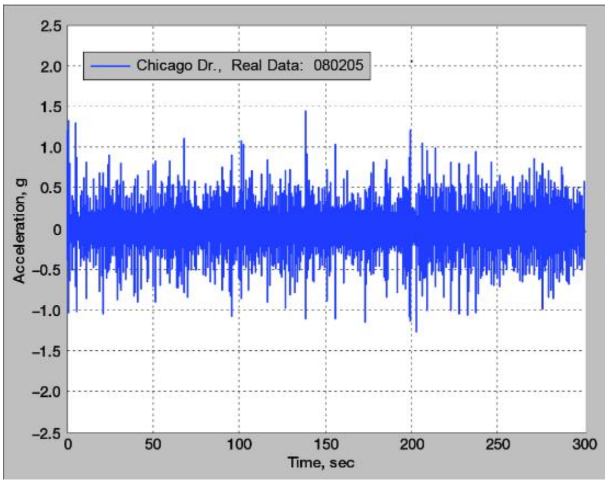

Figure 5: *Acceleration time history data collected on a vehicle*

Method 4: Sinusoidal Vibration

The most common type of sine testing involves a logarithmic frequency sweep holding a specified acceleration constant. A sine signal generator can be used to play the test frequencies through our vibration products. An oscilloscope and accelerometer can be used to view and confirm the sinusoidal motion. This type of testing usually will cycle up and down repetitively between frequency limits for a specified time or number of sweep cycles to ensure that adequate reliability levels are attained.

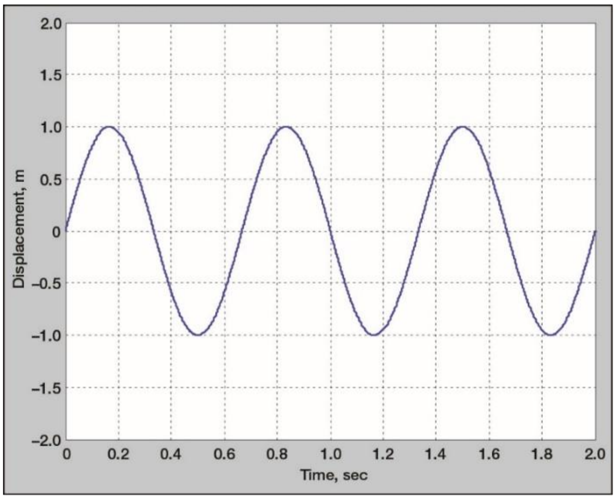

Figure 6: *A sinusoidal waveform.*

VI. TEST PROCEDURE

Vibration test profiles may be omitted from an overall test series depending on relative profile severity. Profile severity comparisons shall include fatigue damage potential (test duration and bandwidth), vibration amplitude, and spectral content within the profile bandwidth. Analytical estimates of fatigue damage potential should be made on the basis of simple, well-understood models of the materiel, when and if possible.

6.1. Pre – test

Before starting a test, review pretest information in the test plan to determine test details (procedure(s), test item configuration(s), levels, durations, vibration exciter control strategy, failure criteria, item operational requirements, instrumentation requirements, facility capability, fixture(s), etc.).

a. Select appropriate vibration exciters and fixtures.

b. Select appropriate data acquisition system (e.g., instrumentation, cables, signal conditioning, recording, analysis equipment).

c. Operate vibration equipment without the test item installed to confirm proper operation.

d. Ensure the data acquisition system functions as required.

6.2. During test

- Step 1: Conduct a fixture modal survey or resonance search, if required, and verify that fixture design is compliant with test condition.
- Step 2: Mount the test item to the test fixture in a manner dynamically representative of the life cycle event simulated.

  Position to mount measuring end:

  - For the non-suspended part: mount it on the axle being measured.

- For the suspended part: mount it on the vehicle floor above the axle. If measuring end cannot be mounted on the vehicle floor, it can be mounted in a nearby position that is able to describe the vibration of the suspended part being measured.

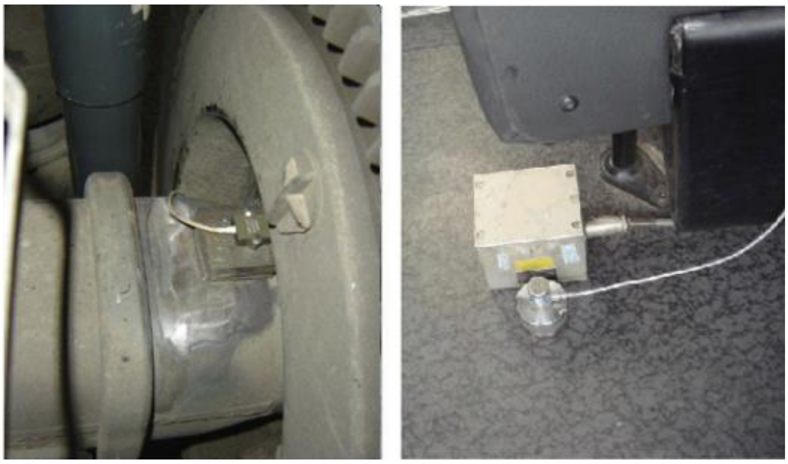

Figure 7: *Installed position of the measuring end on the vehicle floor (above the axle)*

- Step 3: Conduct a test item modal survey or resonance search, if required.
- Step 4: Perform a visual inspection of the test setup.
- Step 5: Apply low level vibration to the test item/fixture interface. If required, include other environmental stresses.
- Step 6: Verify that the vibration exciter, fixture, and instrumentation system function as required.
- Step 7: Apply the required vibration levels to the test item/fixture interface. Apply additional environmental stresses as required.
- Step 8: Monitor vibration levels and, if applicable, test item performance continuously through the exposure.

6.3. Result processing

(1) Summary and chronology of test events, test interruptions, and test failures.

(2) Discussion and interpretation of test events.

(3) Functional verification data.

(4) Test item modal analysis data.

(5) All vibration measurement data.

(6) Documentation of any test requirement variation.

(7) Any changes from the original test plan.

(8) Record of combined environment parameters (i.e., temperature and humidity).

VII. TEST EVALUATION

Report on the results of determining the natural vibration frequency and damping coefficient of the vehicle's suspension system according to Annex A of 22TCN 336:2006 standard

Test item		Test result			
		1^{st}	2^{nd}	3^{rd}	Average
Natural frequency of the vehicle body f_1 ,(Hz)	Front axle Rear axle				
Damping coefficient ψ of vehicle body ψ	Front axle Rear axle				
Natural frequency of the vehicle axle f_2,(Hz)	Front axle Rear axle				

Table 3: *Test result report table*

* For the method 1 and 2: According to QCVN 09:2015/BGTVT standard for the suspension system: The natural frequency of the suspended part of the full-loaded passenger vehicle shall not exceed 2.5 Hz.

* For the method 3 and 4: According to the MIL-STD-810H: The tolerances associated with the test severity parameters are not to be used to overtest or undertest the test item. If tolerances are not met, the difference observed should be noted in the test report:

Specific Tolerances For All Random Vibration Tests (including the broadband component of mixed random and sinusoidal vibration tests and the fixed and swept narrowband components of mixed broadband and narrowband random vibration tests)		
Parameter	**Tolerance**	
Number (n) of independent statistical degrees of freedom (DOF) for control of the specified ASD.	n > 120	
Composite Control: Maximum deviation of the composite control ASD in relation to the specified ASD.[1]	± 3 dB below 500 Hz ± 6 dB above 500 Hz ± 10% overall grms	
Multi-point Control: Maximum deviation of any individual control channel ASD in relation to the specified ASD.[2,]	Average Control ± 6 dB below 500 Hz ± 9 dB above 500 Hz ± 25% overall grms	Extremal Control - 6 dB / + 3 dB below 500 Hz - 9 dB / + 6 dB above 500 Hz ± 25% overall grms
Cross-axis Motion: ASD measured with the same number of DOF as in the test axis, along the mutually orthogonal directions, in relation to the in-axis specified ASD.	Less than 50% below 500 Hz Less than 100% above 500 Hz Less than the relevant specified ASD for the given cross-axis.	
Frequency sweep rate	± 10% of stated rate	
Test time duration	± 5% of stated duration	
Amplitude distribution of the instantaneous values of the random vibration measured at the drive signal.	Nominally Gaussian (Refer to paragraph 2.4 for amplitude distribution discussion)	

Table 4: *Random Vibration Test Tolerances*

1. Composite Control is defined as: The ASD computed as either the average, maximum, or minimum (depending on control method) of all feedback channels deemed as control channels in a multi-point control scenario or the single control channel in a single-point control scenario.
2. If using minimum control, the negative tolerance will be that of the Composite Control.

<table>
<tr><td colspan="3">Specific Tolerances For All Sinusoidal Tests (including fixed, swept and stepped sine tests as well as the fixed and swept sinusoidal components of mixed random and sinusoidal tests)</td></tr>
<tr><th>Parameter</th><th colspan="2">Tolerance</th></tr>
<tr><td>Frequency</td><td colspan="2">± 0.1 %</td></tr>
<tr><td>Composite Control: Maximum deviation of the composite control[1] tone level(s) in relation to the specified tone level(s).</td><td colspan="2">± 10%</td></tr>
<tr><td>Multi-point Control: Maximum deviation of the individual control channel tone levels in relation to the specified tone level(s).[2]</td><td>Average Control
± 25% below 500 Hz
± 50% above 500 Hz</td><td>Maxi Control
+10% / -25% below 500 Hz
+10% / -50% above 500Hz</td></tr>
<tr><td>Cross-axis Motion: Tone levels measured along the mutually orthogonal directions, in relation to the in-axis specified level(s).</td><td colspan="2">Less than 50% below 500 Hz
Less than 100% above 500 Hz
Less than the relevant specified levels for the given cross-axis.</td></tr>
<tr><td>Frequency sweep rate</td><td colspan="2">± 10% of stated rate</td></tr>
<tr><td>Test time duration</td><td colspan="2">± 5% of stated duration</td></tr>
<tr><td>Difference between the unfiltered signal and filtered acceleration signal[3]</td><td colspan="2">± 5% on the grms values[4]</td></tr>
</table>

Table 5: *Sinusoidal Vibration Test Tolerances*

1. Composite Control is defined as: The Line Spectrum computed as either the average, maximum, or minimum (depending on control method) of all feedback channels deemed as control channels in a multi-point control scenario or the single control channel in a single-point control scenario.
2. If using minimum control, the negative tolerance will be that of the Composite Control.
3. Distortion of the sinusoidal signal can occur particularly when using hydraulic actuators. If distortion of the sinusoidal signal is suspected, the unfiltered signal and filtered acceleration signal should be compared. A signal tolerance of ±5 percent corresponds to a distortion of 32 percent
4. The grms of a sinusoid equals 0.707 times peak g. It is not related to grms of a random (g2 /Hz) spectrum; do NOT use this to compare sine criteria (g) to random criteria (g2 /Hz).