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The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION
BARCELONA
17th-20th November 2013

Comparing different vibration tests proposed for li-ion batteries with vibration measurement in an electric vehicle

Presentation at *EVS27 Barcelona, Spain, November 19, 2013*

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Background

- Electric and hybrid vehicles are becoming increasingly common
- Expensive Li-ion batteries are found in these vehicles
- How do these batteries resist the environment in a car (safety – performance - life-length)
- A number of different standards for vibration testing of Li-ion batteries have been developed in recent years

Different reasons for testing

Life simulation	Function & Performance	Safety
'Light crash'	Function & Performance	Safety
'Severe crash'	-	Safety

This presentation will only be about testing for life simulation

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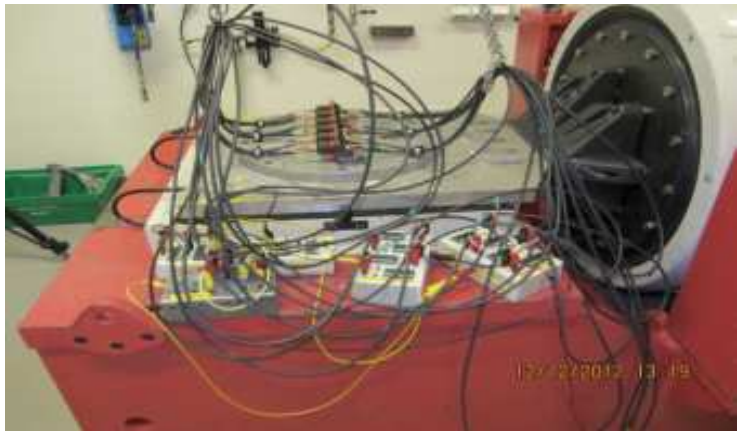
Vibration testing in the automotive industry



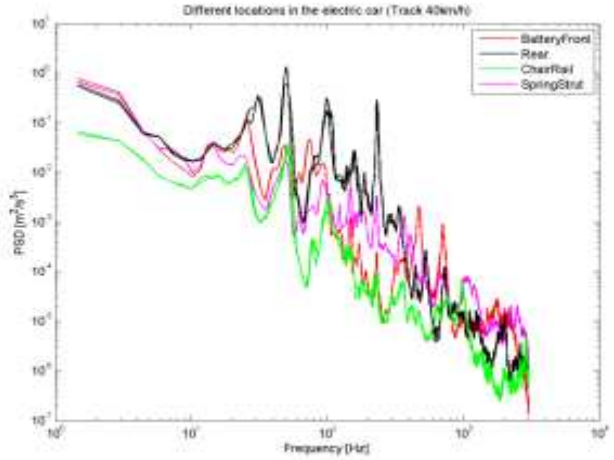
- Multiaxes servohydraulic shake tables (MAST)
- Time-histories (from test tracks) [non stationary signals]
- Low frequencies <50Hz
- Test time ~ 500h:s
- Mechanical failures (fatigue, wear , ..)

- Single axis electrodynamic vibrator
- Power Spectral Densities [stationary signals]

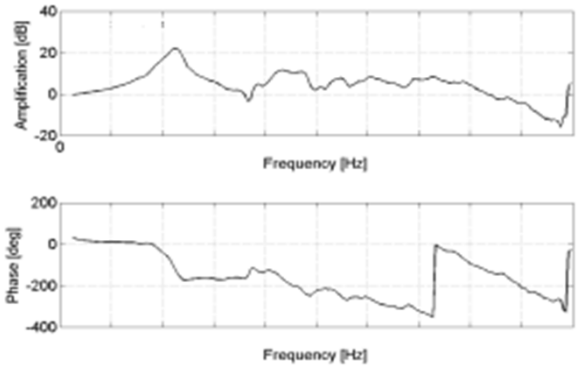
- Frequency range 5-2,000 Hz
- Test time ~2-32h
- Mechanical failure / electrical faults

A vibration test does not completely imitate reality - the purpose is that it should give the same damage as reality

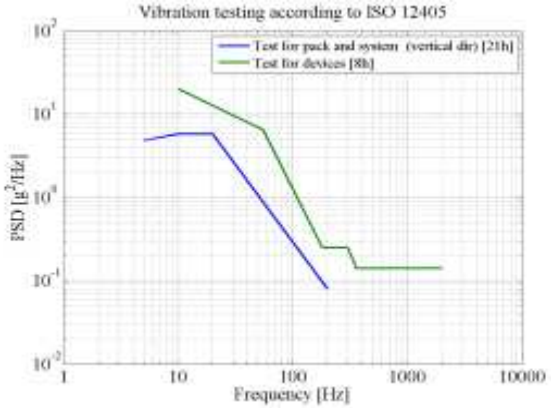
Possible vibration spectra in a car

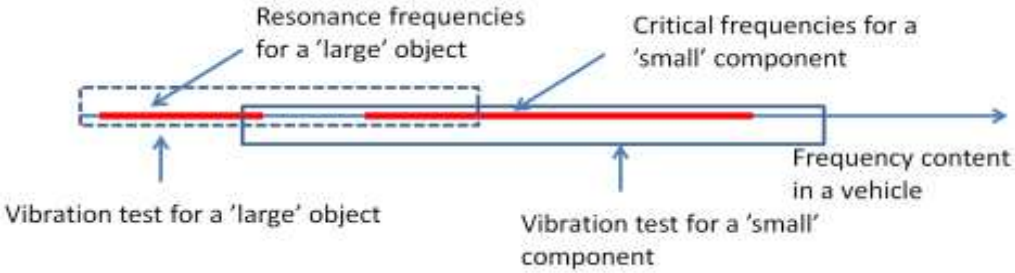


Dynamic response of a test object

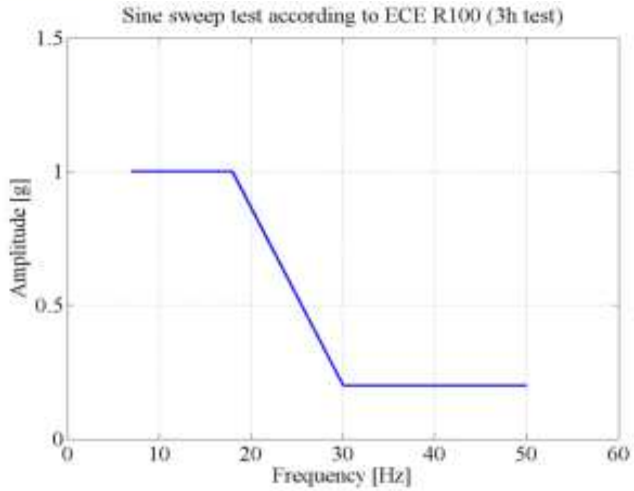


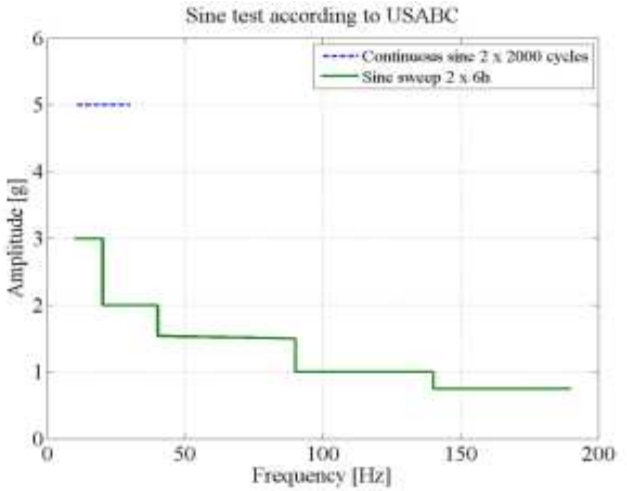
Tests for different types of objects

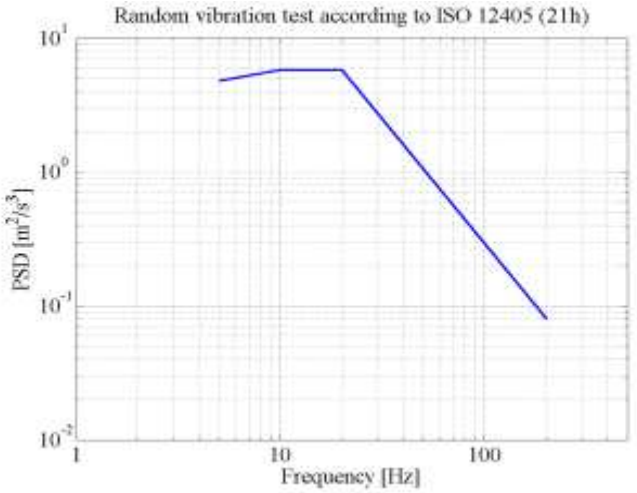


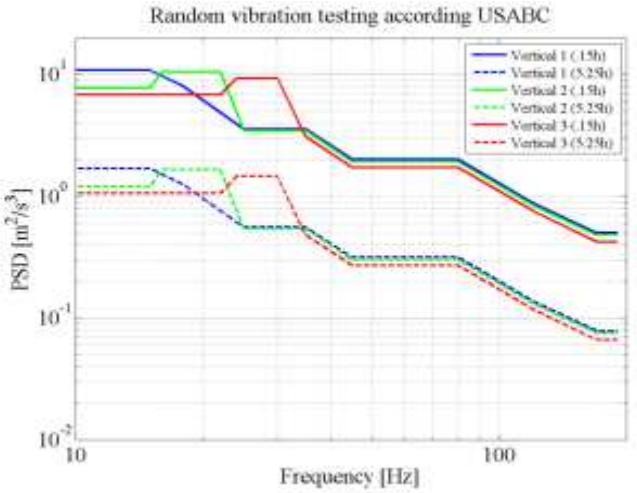


Different standards proposed for vibration testing of packs / systems (vertical direction)

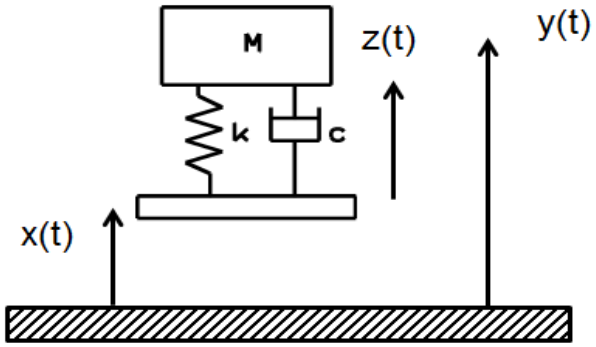




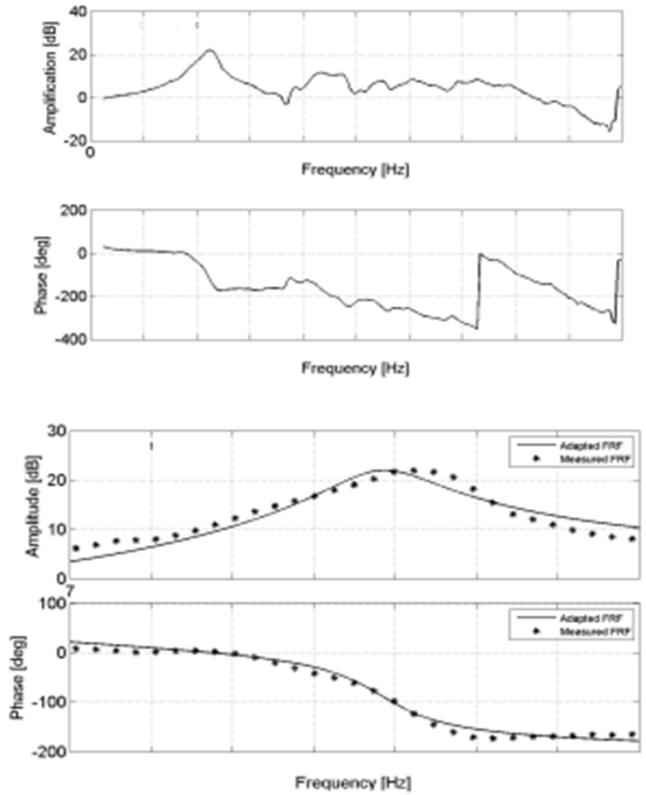




Dynamic response of a real system and of a mathematic model of a system



The simplest model of a dynamic system, the SDOF system (Single Degree of Freedom system)



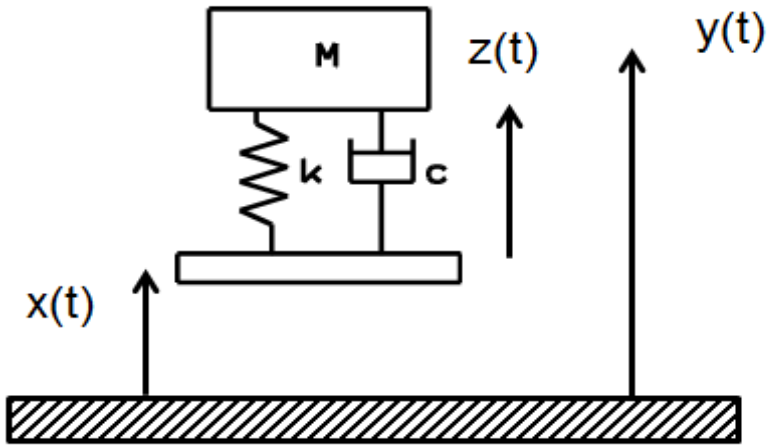
Dynamic response of a real system approximated with the response of a SDOF system

Conclusion:
A real (complicated) system can around (its lowest) resonance frequency be approximated with a SDOF system

How to analyze vibrations??

Power Spectral Density (PSD) is mathematically well defined and often used to specify a stationary random vibration test, but it has limitations:

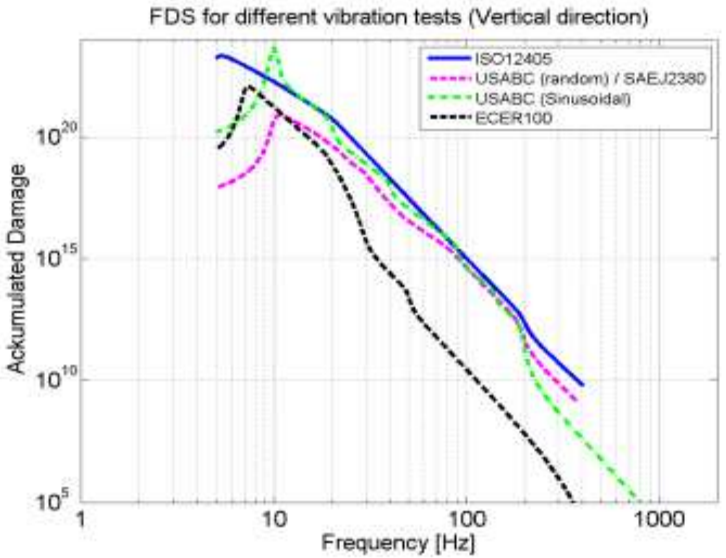
- Not useful for non stationary vibrations
- Can not compare sine and random
- Does not take expose time into account

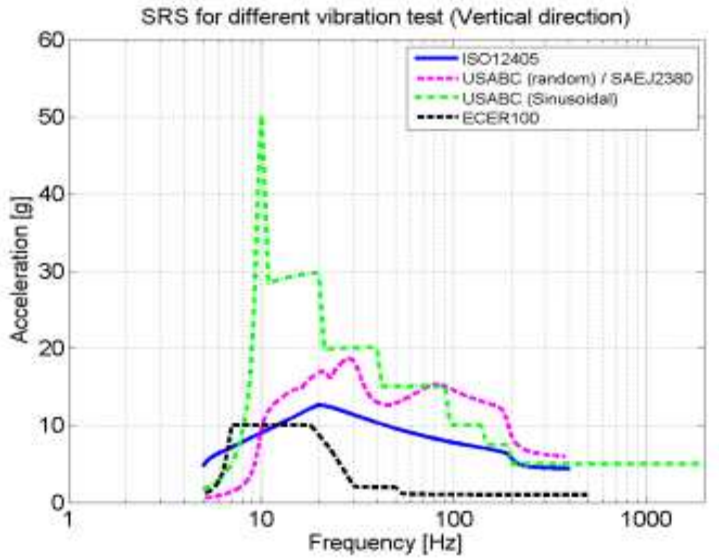


Instead of using the PSD, investigate the damage on SDOF models of the test object subjected to the vibration:

- Damage caused by maximum acceleration (mainly electric disturbances) Shock Response Spectrum [max of y] **SRS**
- Damage caused by fatigue (mechanical damage) Fatigue Damage Spectrum [cycle counting z(t) + damage law] **FDS**

FDS and SRS for different vibration tests in vertical direction for packs / systems





- For a test object with a low resonance frequency (<10Hz) the ISO test is the most severe test
- The ECE R100 test is less severe than the other tests, specially if the test object has a resonance frequency above 20Hz (NB this test is only done in vertical direction)
- The USABC sinusoidal test has very high SRS corresponding to the 5g / 2000 cycles test at fixed frequency

Comparing the standardized tests with real driving

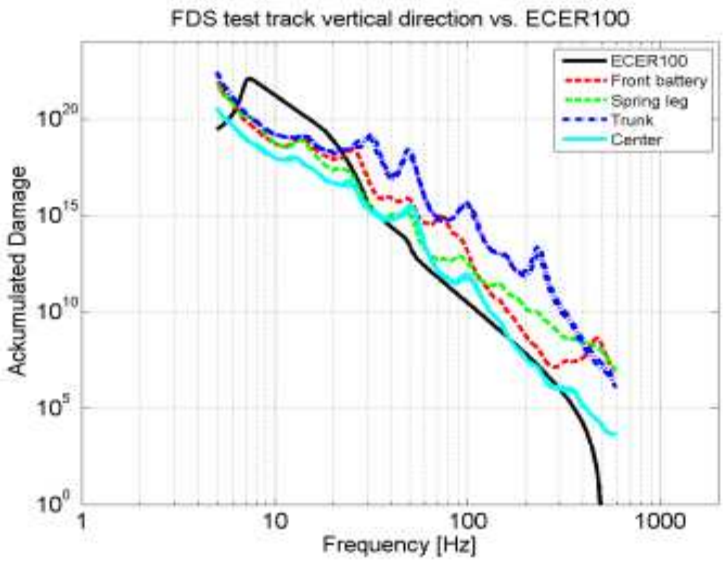
One gasoline vehicle (GV) and one electric vehicle (EV) Volvo C30 instrumented with accelerometers at corresponding positions

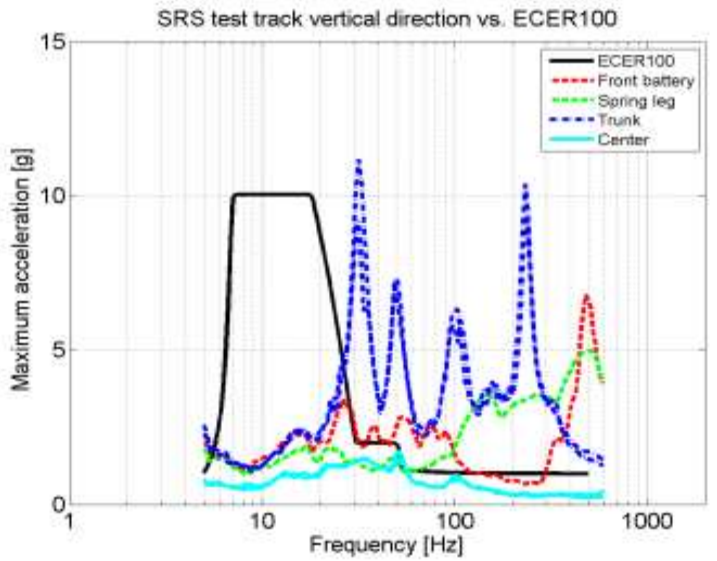
Driving on a rumble strip test track

Assumption: 1h each week during 15year $\Rightarrow$ 800h used as a life time

- Comparing vibrations in GV and EV (not in this presentation)
- Comparing vibrations during a 'real life' with vibrations at test (this presentation)

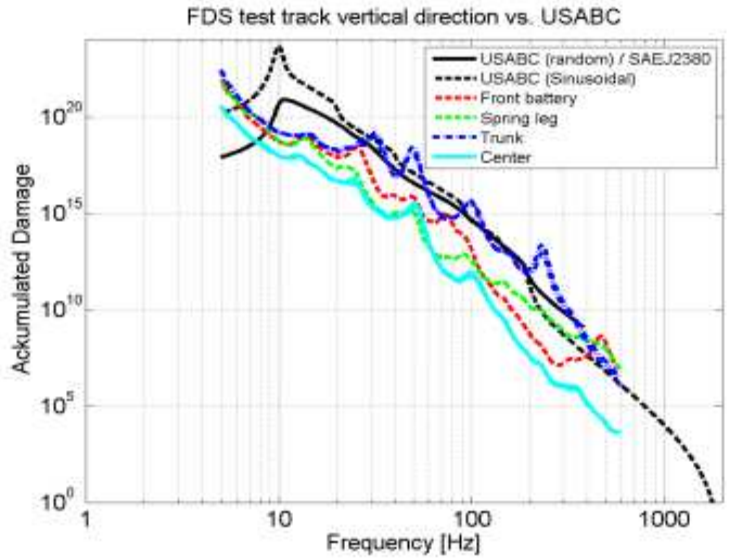
Comparing field measurements with the ECE R100 standard

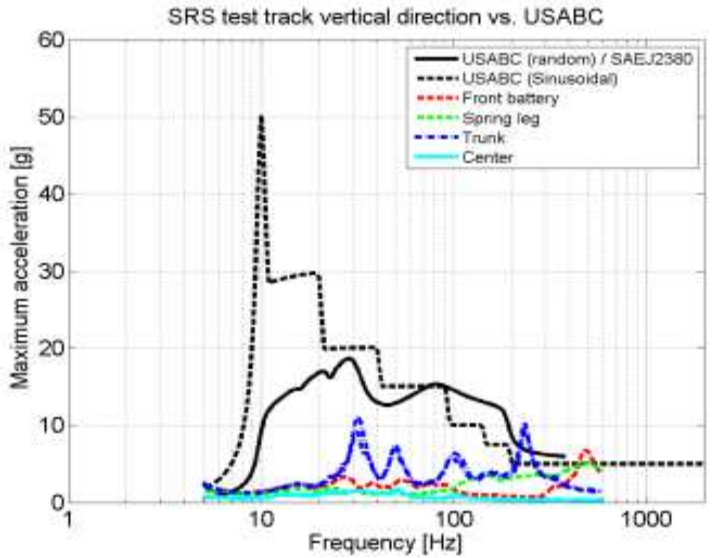




- ECE R100 has only a vertical vibration test
- For frequencies above 20Hz 'real life' generates more damage than a test (both FDS and SRS)

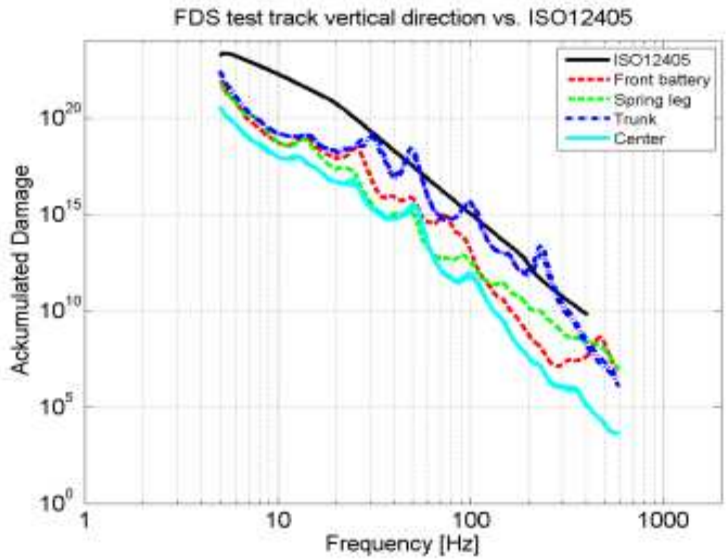
Comparing field measurements with the USABC standards (Sine and random)

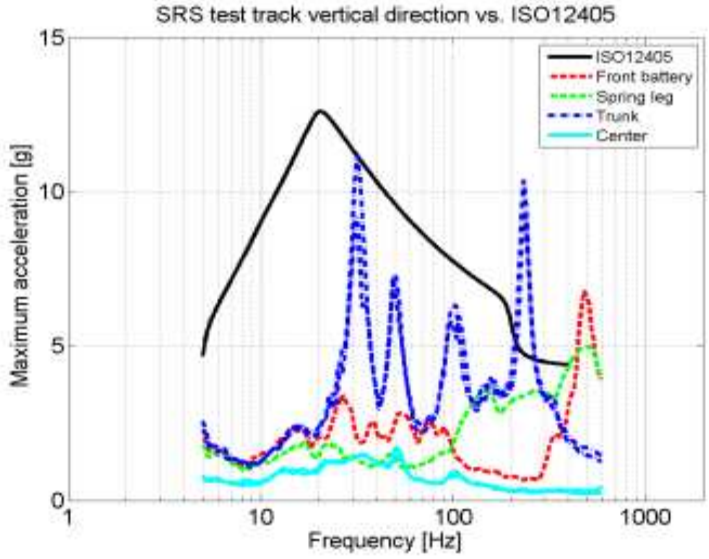




- More damage during 'real life' for the very low frequencies
- There are positions inside the car, i.e. 'Trunk' where the damage during 'real life' is higher than at the test
- As the tests are time forced by increasing the levels the SRS at the test are higher than during 'real life'. The test can be too conservative

Comparing field measurements with the ISO 12405 standard





- ISO 12405 is the only test which covers the very low frequencies
- There are positions inside the car, i.e. 'Trunk' where the damage during 'real life' is higher than at the test
- There is a peak in the SRS which is higher at 'real life' than during the test, but ISO 12405 also includes shock testing of devices which probably will cover this peak