# Vibration

EVS-GTR 17th

China
2019.01

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- Summary of the 16th meeting proposal and response
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# Vibration requirement in EVS-GTR

**8. REESS in-use requirements**

*(a) Vibration (paragraphs 5.4.2. and 6.2.2. of this UN GTR):*

130. The purpose of this test is to verify the safety performance of the REESS under a vibration environment which the REESS would likely experience during the normal operation of the vehicle.

131. A vibration load spectrum for lithium cells and batteries including lithium ion cells/batteries and lithium polymer cells/batteries is already defined as a type approval test procedure of dangerous goods of class 9 in the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, paragraph 38.3.4.3. (Test T3: Vibration), with an amplitude sweep ranging from 7 Hz to 200 Hz.

132. As Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria sign-off may often also be mandatory for types of REESS (such as lithium metal batteries, lithium ion batteries and lithium polymer batteries) subject to this regulation, having the opportunity to cover this test with test T3, is seen as an efficient approach.

133. However the load curve per Test T3 is assessed as too severe for automotive applications. Despite the recent lowering of the high frequency amplitude in Test T3 from 8g to 2g for "large batteries" with masses more than 12 kg, even this amplitude is still not considered representative for the typical sizes of REESS in vehicles, with a mass of 200 kg or more. Particularly the height of the amplitudes above 18 Hz is seen as unrealistic and does not correlate to the loads seen in road vehicles (except for hypothetical cases of REESS mounted close to or onto a combustion engine). Due to the stiffness of vehicle bodies in relation to the module weight frequencies, frequencies higher than 18Hz cannot be transmitted at significant energy levels.

134. This UN GTR, therefore, uses the same frequency vertices as Test T3, albeit those for smaller cells, but lowers the load curve above 18Hz and truncates it at 50Hz.

135. The test duration is also aligned with Test T3, requiring 12 transitions from the minimum to the maximum frequency and back within 15 min., resulting in a total test duration of 3 hours.

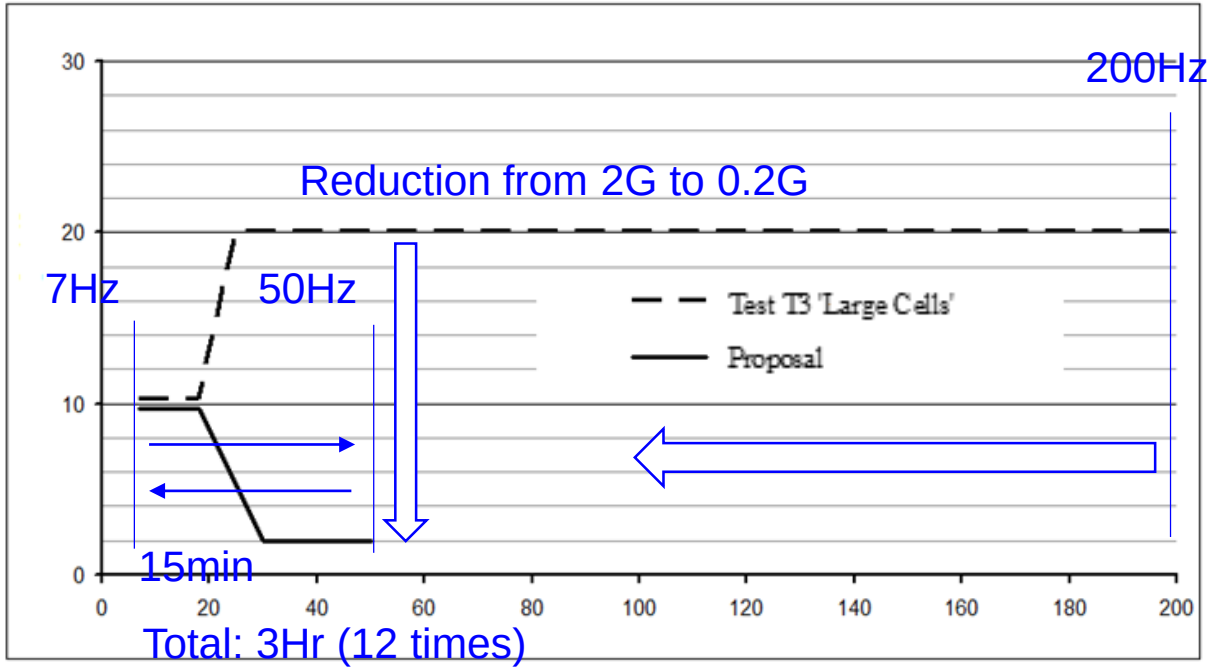
136. While Test T3 requires the test to be performed in all three spatial directions, in vehicle applications this load occurs in the vertical direction only, while the longitudinal and lateral vehicle dynamic loads are significantly lower. The vibration test therefore needs to be performed in the vertical installation direction only. When utilizing this option, the orientation of the REESS in the vehicle must be restricted accordingly; this information shall be communicated to the regulating entity by the vehicle manufacturer. The administrative procedures to ensure such a communication will be specified by the regulating Contracting Party.

137. In many cases, the vehicle manufacturer assesses the vehicle's durability with full vehicle simulation, either by running a rough road test track or by simulating the lifetime fatigue on a 4-poster vibration rig. These methods provide a vehicle specific assessment of the durability of all vehicle components and should be accepted in this context.

138. To finalize the certification of the REESS, a standard cycle has to be performed, to verify that the mechanical loads have not had any negative effect on the electrical function.

- **The safety erformance of the REESS under a vibration environment during the normal operation of the vehicle.**
- **Cover this test with T3 from UN38.3 but with some modification of frequency range, acceleration and vibration directions.**
- **Rough road test track or simulated 4-poster vibration are accepted.**

# Vibration requirement in EVS-GTR




| Item | UN38.3 | EVS-GTR No.20 / ECE R100 |
|---|---|---|
| Frequency range | 7-200Hz | 7-50Hz |
| Vibration directions | Z、Y、X | Z |
| Acceleration | 1G，2G | 1G，0.2G |

# Vibration requirement in EVS-GTR

## ■ Is vibration in EVS-GTR No.20 reasonable?

**☐ Rationale for vibration profile modified from UN transportation regulation.**

- UNR100 requires twelve times of 15-minute amplitude sweep from 7Hz to 50Hz. Why can it guarantee the durability over the vehicle service life? Does one 15-minute sweep represent one year vehicle driving? What is the rationale?
- 2G was reduced to 0.2G, 200Hz was reduced to 50Hz and three vibration directions were changed to one. What is the rationale for these changes? Is it based on actual vehicle test data? What are the test conditions and test results?

# Vibration requirement in EVS-GTR

## ■ Is vibration in EVS-GTR No.20 reasonable?

**□ Sinusoidal vibration profile has only one acceleration value on each frequency.**

- ➢ It differs from real world vehicle conditions. If an acceleration more than 0.2G occurs at a frequency higher than 30Hz in real world situations, the sinusoidal vibration profile is not appropriate for the evaluation.
- ➢ For the real world vehicle operation conditions. Each frequency has a certain range of acceleration values calculated based on probability distribution. The peak value may be higher than the sinusoidal vibration though it occurs less frequently.

# Summary of the 16th meeting proposal and response

## ■ The proposal

- ➢ The vibration test method in GTR is not entirely reasonable, so it is necessary to develop a reasonable vibration test method.

## ■ The main different views and response

- ➢ Vibration failure is reliability issues, not safety issues.
- ✓ Vibration is already in GTR, it's a safety issue.
- ✓ Vibration may cause connection failure and safety problems such as short-circuit.
- ➢ Existing ECE R100 and GTR vibration method has been used for many years, did not cause accidents, so there is no need to modify and adjust.
- ✓ Auto-manufacturers usually evaluate and ensure the durability with their own component vibration test based on actual vehicle test data. That is the reason why their battery systems are OK in the market. Not just designing products according to GTR vibration requirements.

# Data from vehicle operation

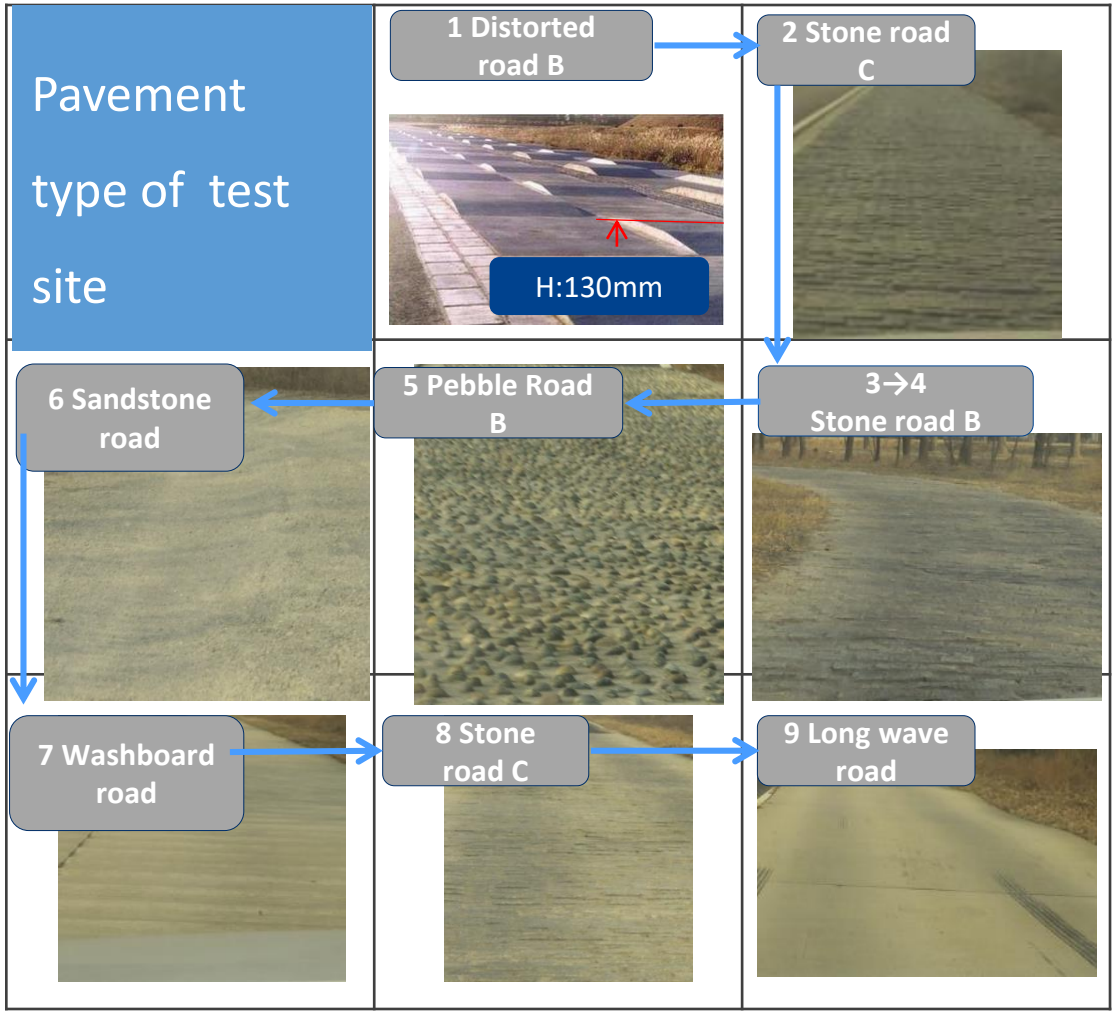
*Procedure*

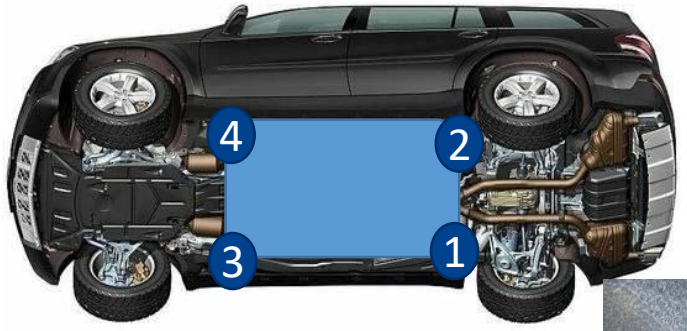
①data collection

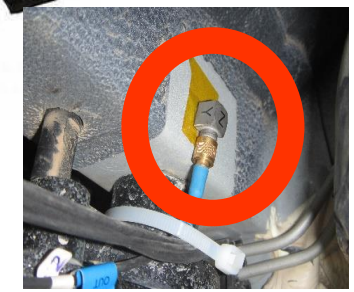
②data analysis

③data normalization

④test condition



**Sensor installation location**

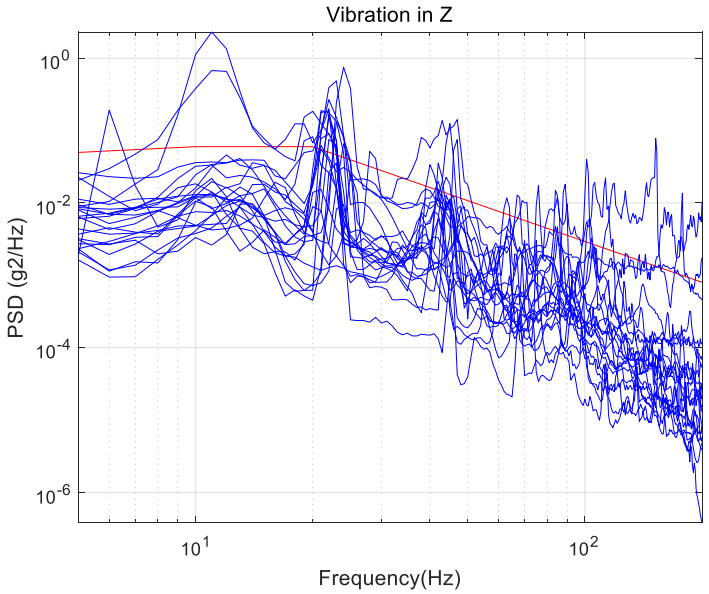
**Data of 22 vehicles (including 13 passenger cars and 9 commercial vehicles)**

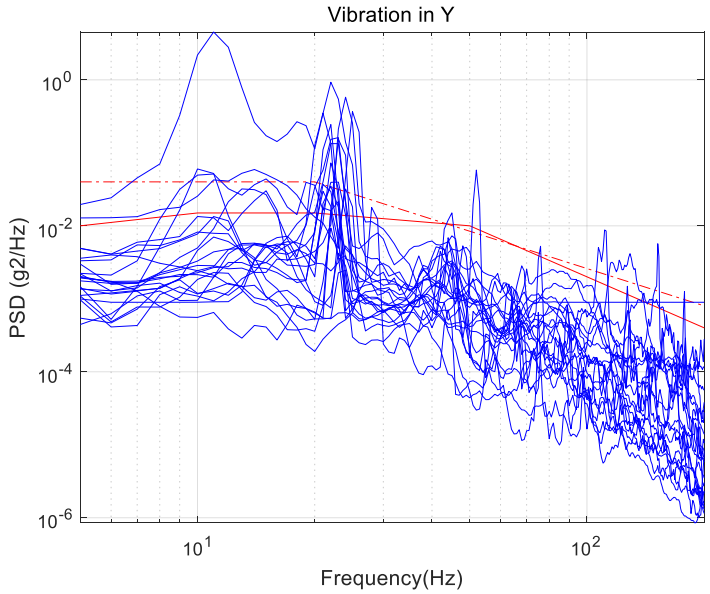
☐ The proposal in 14th meeting showed more detailed information

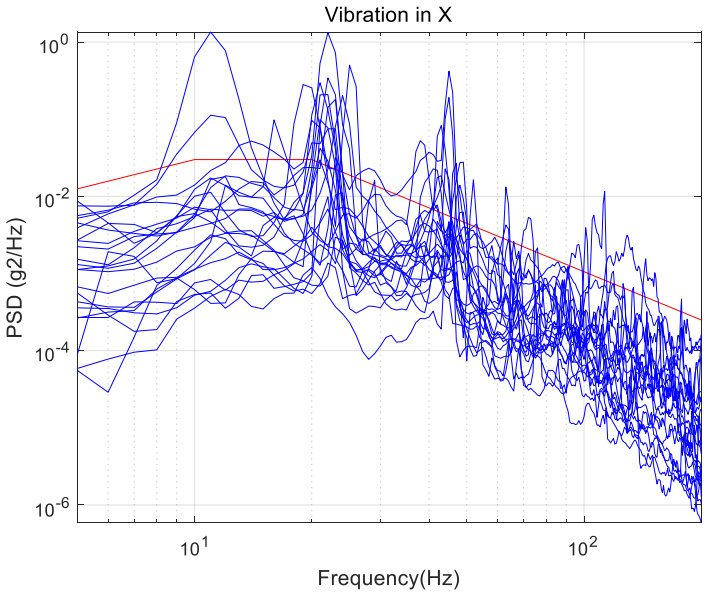
# Data from vehicle operation

## From data of 22 vehicles

- There are still load strength above 50Hz, which should not be ignored
- Vibration loads in x and y directions are almost 50%-70% of the loads in z direction, which should not be ignored



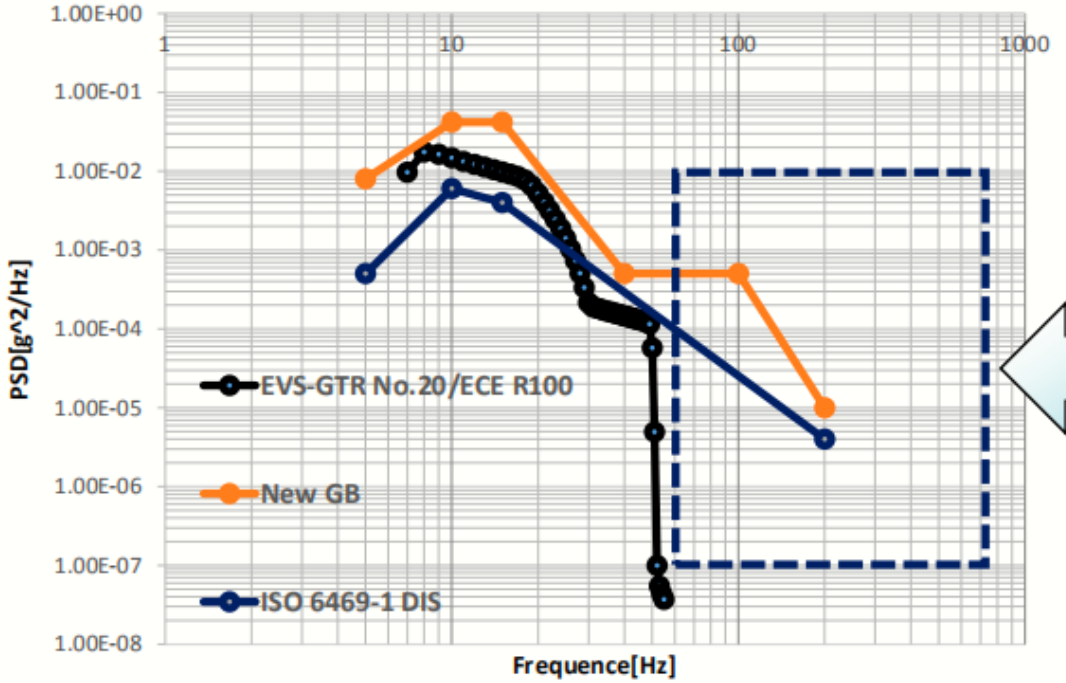




- The proposal in 14th meeting showed more detailed information

# Example analysis of EV battery

## ■ The GTR vibration cannot cover all vibration load in reality

➢ Convert the GTR profile into PSD (12h, based on fatigue damage equivalence principle) and do the comparison in the same figure. (GTR PSD/GB/ISO6469)



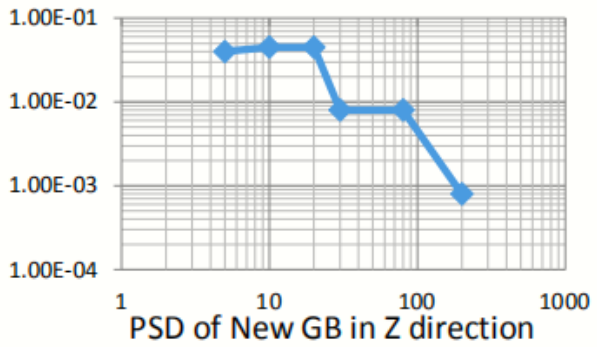

Main difference:
There are no load strength where the frequency is higher than 50Hz in EVS GTR vibration profile.

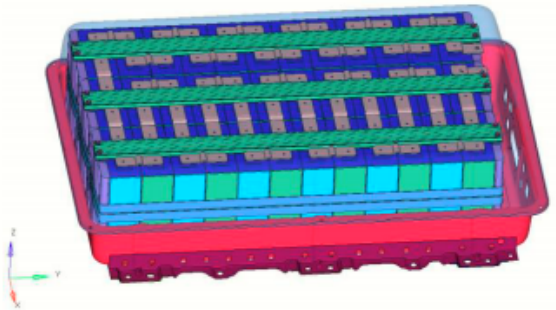
➢ ISO6469 and new GB profile are all obtained from real vehicle measurement statistical data;

➢ So **frequency range** of EVS GTR vibration profile can not cover all vibration load in reality.

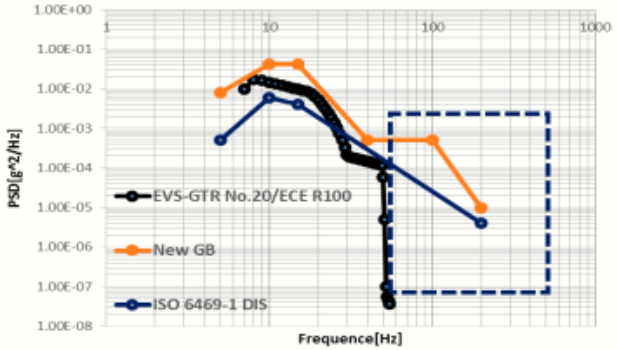
# Example analysis of EV battery

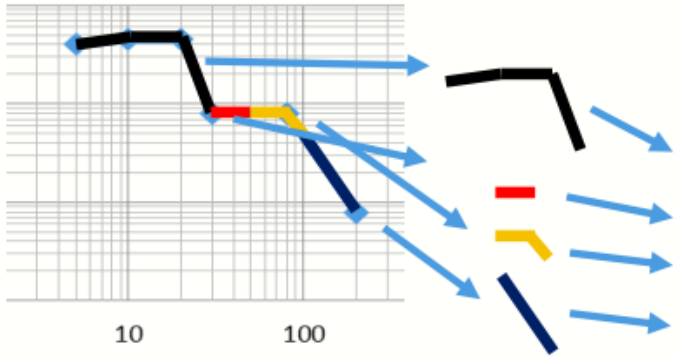
## It's PSD around the dominant frequency that really work



**Dominant frequency: 60Hz**



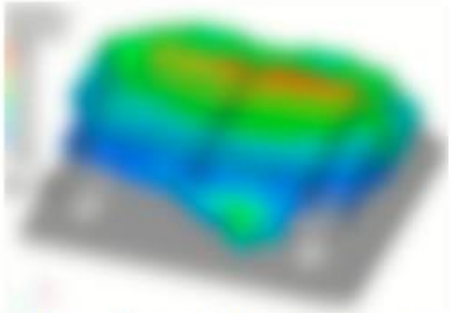




| | Load | Max RMS stress under the Z direction vibration (Mpa) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Housing | Beam1 | Cover | Beam2 | Bracket | **Bus bar** | Glue |
| 1 | 0-30Hz | 3.1 | 2.73 | 65.81 | 1.97 | 0.08 | **0.008** | 0.004 |
| 2 | 30-50Hz | 0.4 | 0.43 | 9.39 | 0.21 | 0.01 | **0.003** | 0.0004 |
| **3** | **50-100Hz** | **84.07** | **111.04** | **35.8** | **247.4** | **117.3** | **9.0** | **0.574** |
| 4 | 100-200Hz | 8.61 | 7.77 | 4.52 | 14.39 | 7.07 | **0.95** | 0.052 |

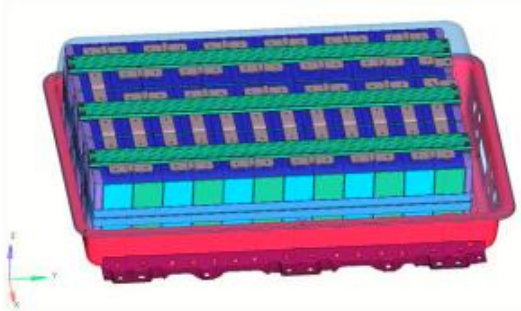
- Dominant frequency section contribute most of the fatigue damage
- Vibration with frequency range below 50hz can not expose design defect of pack whose dominant frequency is higher than 50hz.

# Example analysis of EV battery

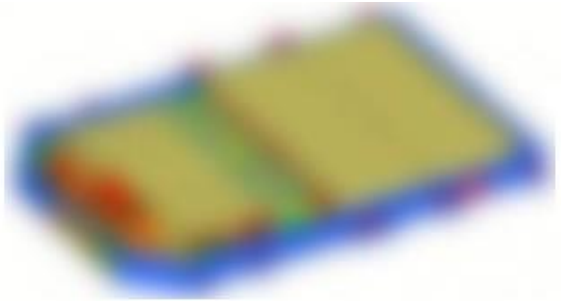
## Several examples of pack design and their dominant frequency



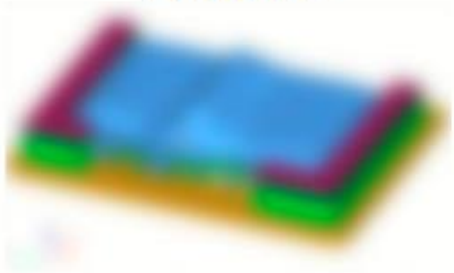
Dominant frequency:
Z/67.6Hz



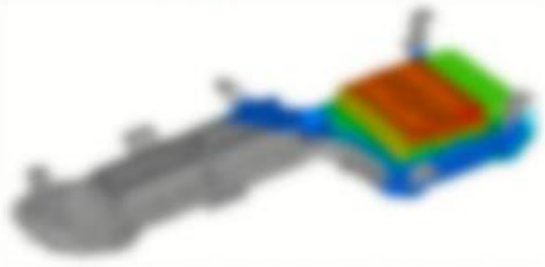
Dominant frequency:
Z/63.6Hz



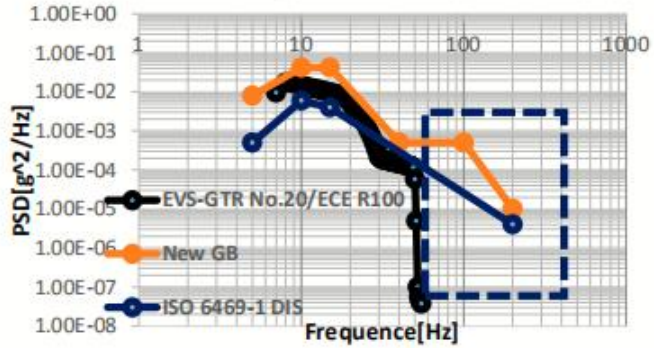
Dominant frequency:
Z/69.1Hz



Dominant frequency:
Z/62Hz



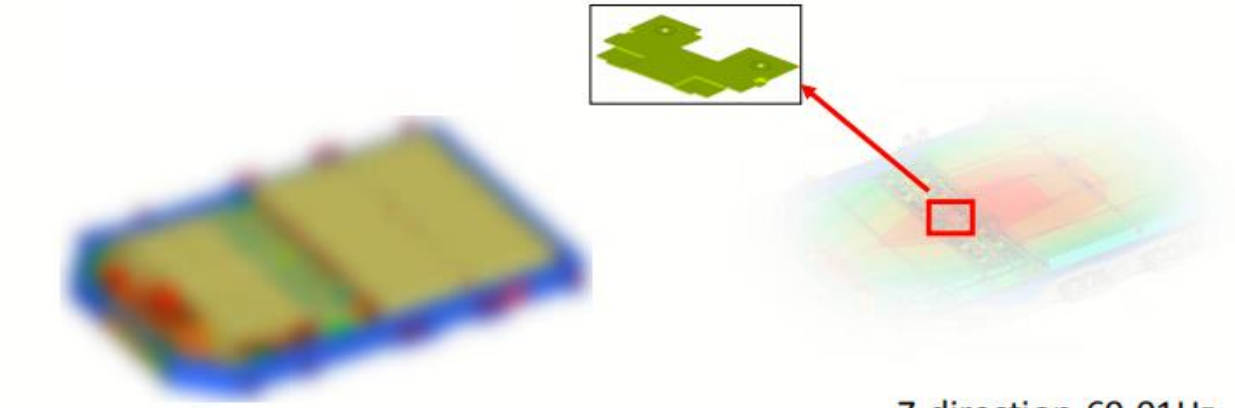
Dominant frequency:
Y/57Hz



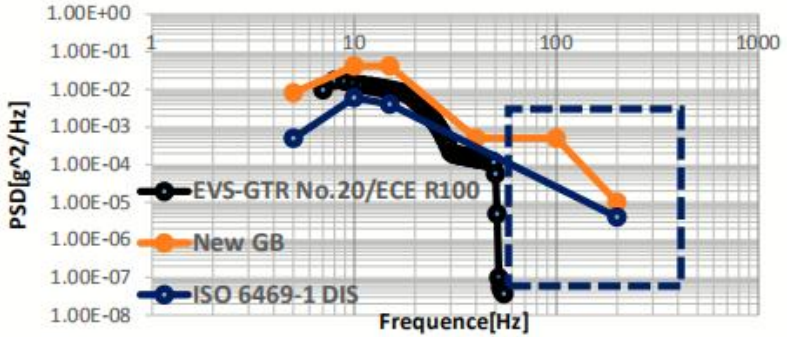

- There are lots of pack design whose dominant frequency is higher than 50Hz especially for PHEV and HEV.
- It is very hard for current EVS GTR vibration profile to expose these pack's design defect.

# Example analysis of EV battery

## ■ The GTR vibration cannot cover all vibration load in reality



Z-direction-69.01Hz

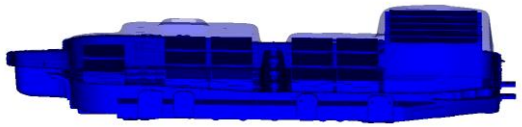


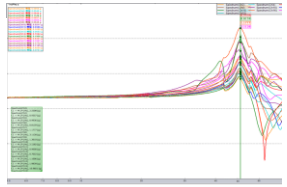

| | | | |
|---|---|---|---|
| **Conclusion** | According to the simulation results:<br>➢ **EVS-GTR No.20/ECE R100:** Bus bar **passed;**<br>➢ **New GB(Section that below 50Hz):** Bus bar **passed;**<br>➢ **New GB(200Hz):** Bus bar **failed;** | | |
| **Results** | **Work Condition** | | **Max. 3σ Stress(MPa)** |
| | | | Bus bar（Al1060-O） |
| | **EVS-GTR No.20/ECE R100** | **Z** | 9.68 |
| | **New GB(Section that below 50Hz)** | **Z** | 16.41 |
| | **New GB(200Hz)** | **Z** | 30.24 |

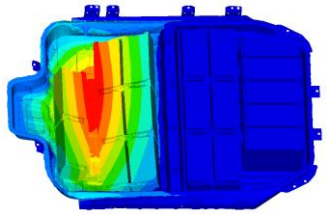

➢ **EVS-GTR and section of New GB below 50Hz can not expose the design defect of pack whose dominant frequency is higher than 50Hz, if this design defect can lead to bus bar fatigue failure, then will cause safety problem.**

# Example analysis of EV battery

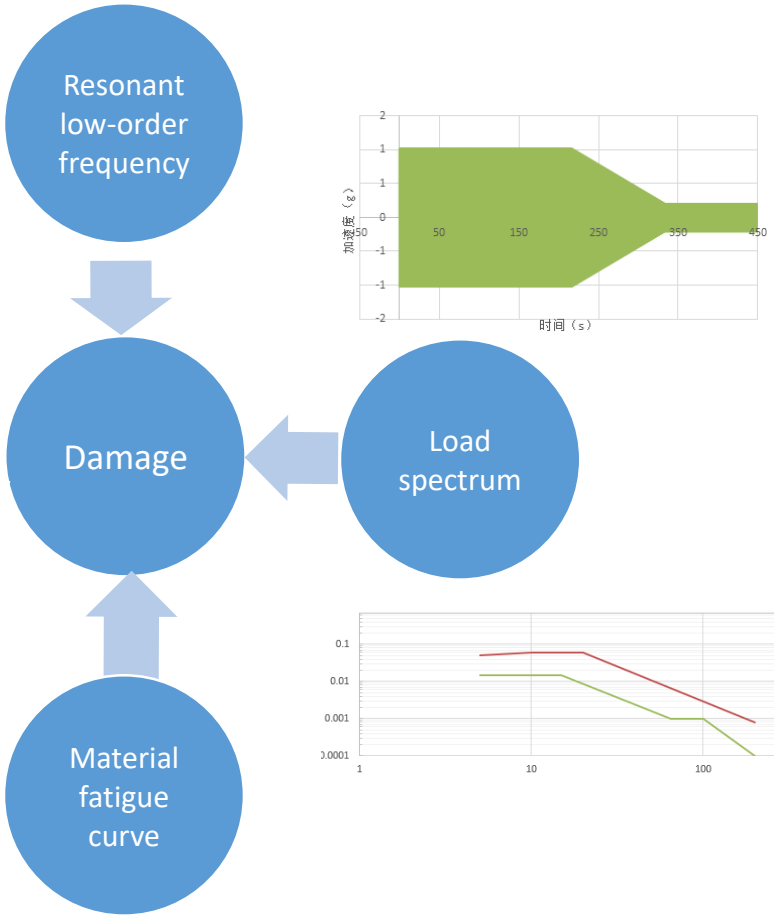
- **The damage of road spectrum is much lager than that of GTR**
  - **One example**







| Condition | Damage |
|---|---|
| From road spectrum | $9.655*10^{-4}$ |
| GTR | $1.527*10^{-6}$ |



# Example analysis of EV battery

## ■ The GTR vibration cannot cover all vibration load in reality

**■Test result：**

➢Passed the EVS-GTR but failed in the road spectrum test

Vibration test photo

Screw loose， Cracking of conductive metal parts and structural parts

Pass the EVS-GTR

Fail in the road spectrum test

# Conclusion

- There are many unreasonable aspects in theory and practice with the EVS-GTR No. 20 vibration method.
- A regulation composed of global organizations and supported by professional and technical experts is obliged to develop a more reasonable vibration test method.

# Thanks for your attention!