

# **Battery Pack Vibration Profile** **——research and standardization**

2018.03

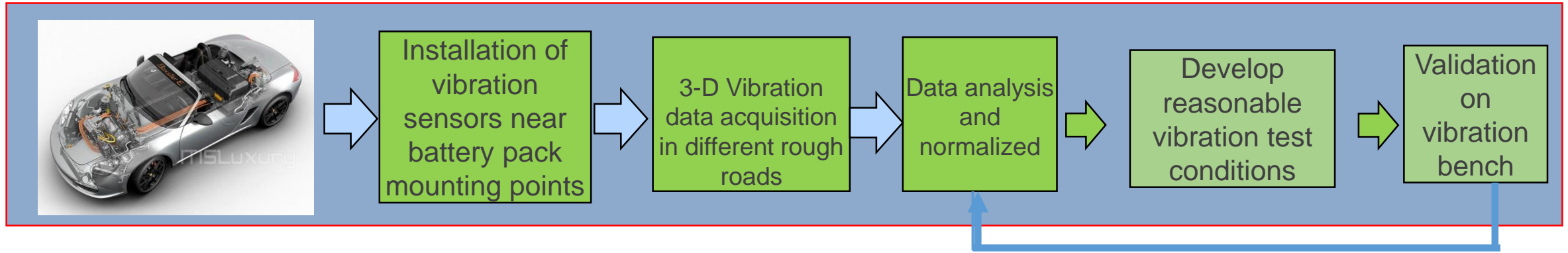
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- 2 Data Collection and Analysis
- 3 Standards
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**1**

**Review**

# Review



- ✓ Test specification : Ministry of Communications road traffic test field (Tong'xian automobile test field ) automobile product design reliability driving test specification ( trial ) (2000 edition)
- ✓ The Miner's Law was used to accelerate. The accelerated ageing coefficient is selected to be 5. And bench test time is 12 hours in each direction.

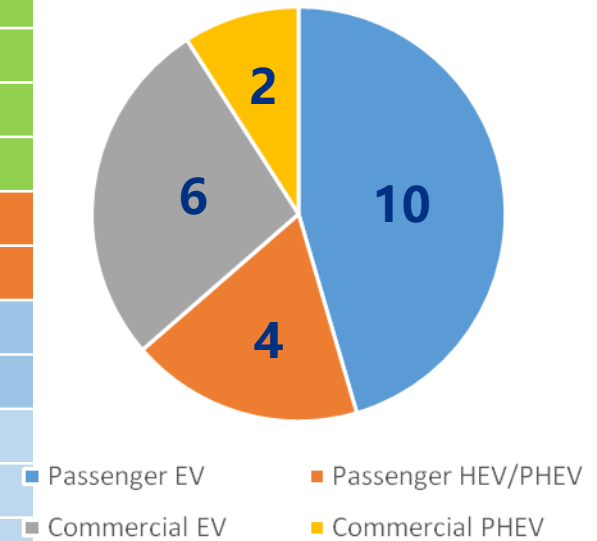
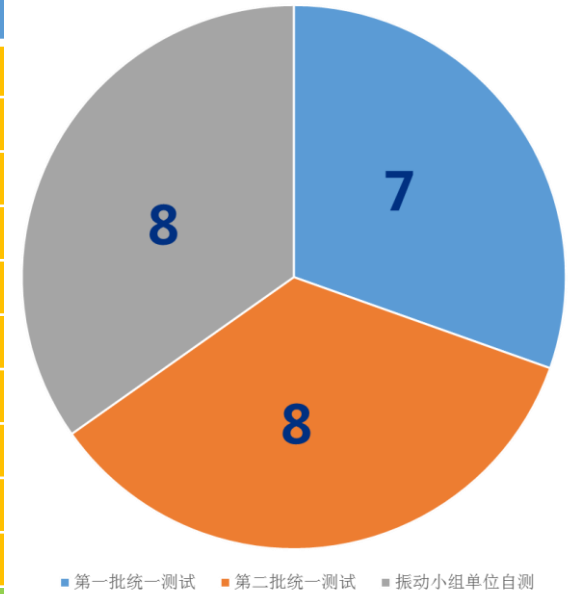
$$\left(\frac{T_t}{T_f}\right) = \left(\frac{\sigma_t}{\sigma_f}\right)^n$$

# 2

## **Data Collection and Analysis**

# Data Collection and Analysis

序号	车辆类型	车长 (m)	轴距 (m)	胎压 (bar)	满载 (kg)	电池包位置	传感器数量
Veh.1	Passenger, EV	4025	2500	2.3/2.3/R14	1720	Bottom	9
Veh.2	Passenger, EV	4190	2490	2.5/2.5/R14	1450	Bottom	4
Veh.3	Logistics, EV	5700	3850	2.3/2.3/R16	4100	Bottom	5
Veh.4	Passenger, EV	4554	2700	2.3/2.3/R18	2205	Bottom	4
Veh.5	Passenger, EV	4346	2650	2.3/2.3/R18	2081	Bottom	4
Veh.6	Passenger, EV	4572	2670	2.4/2.4	1790	Bottom	4
Veh.7	Minicar, EV	3200	2150	2.2/2.2	995	Bottom	4
Veh.8	Minicar, EV	2811	1765	2.2/2.2	955	Bottom	4
Veh.9	Passenger, EV	4815	2720	245/40 R20	2575	Bottom	7
Veh.10	Passenger, EV	4631	2650	205/50 R17	1975	Bottom	6
Veh.11	Passenger, PHEV	4873	2850	2.3/2.3/R17	2025	Trunk	3
Veh.12	Passenger, HEV	4630	2700	2.3/2.3/R16	1776	Back of rear seat	4
Veh.13	Passenger, HEV	4915	2775	2.3/2.3/R17	2042	Back of rear seat	2
Veh.14	Passenger, PHEV	4740	2670	2.3/2.3/R16	2091	Bottom	4
Veh.15	Bus , PHEV	10500	---	9.2/9.0	16500	Upper	4
Veh.16	Bus , PHEV	8545	---	---	12600	Engine	4
Veh.17	Bus , EV	8010	---	---	11200	Bottom	4
Veh.18	Bus , EV	10480	---	---	16500	Bottom	4
Veh.19	Bus , EV	12000	6050	295/80 R22	18000	Trunk	4
Veh.20	Bus , EV	12000	---	---	18000	Bottom	4
Veh.21	cargo vans , EV	4500	3050	3.5/4.3	2510	Bottom	4
Veh.22	cargo vans , EV	4071	2700	175/70 R14	2140	Bottom	5



# Data Collection and Analysis

## ➤ Passenger Vehicle



## ➤ Cargo vans

## ➤ Commercial vehicle





# Data Collection and Analysis

step

① data acquisition

- drive condition
- Measuring position

② Data analysis

- Data extraction
- Frequency analysis

③ Data is normalized

- Set travel time
- Acceleration factor setting
- Normalize
- PSD-21h(m/s<sup>2</sup>)<sub>rms</sub>

④ develop vibration conditions

- Test PSD

One loop (passenger car)				
		①	②	③=①/② /1000
序号	强化路	长度 (m)	车速(km/h)	行驶时间 (h)
1	扭曲路乙	85	10	0.0085
2	石块路丙	300	40	0.0075
3	石块路乙	989	40	0.024725
4	石块路乙	989	40	0.024725
5	卵石路乙	335	50	0.0067
6	砂石路	815	40	0.020375
7	搓板路丙	300	50	0.006
8	石块路丙	300	40	0.0075
9	长波路	90	50	0.0018

Extended to required distance

①*X	③*X
行驶寿命里程 (m)	行驶寿命 (h)
60690	6.069
214200	5.355
706146	17.65365
706146	17.65365
239190	4.7838
581910	14.54775
214200	4.284
214200	5.355
64260	1.2852

Take Tong Xian test ground car product stereotypes reliability driving test specification (2000)

X value is different for different vehicles:

- Passenger car X=714;
- Minicar X=476
- Cargo Van X=1274
- Bus X=882

300,000km for whole Vehicle

Only the intensified road vibration has an impact on the battery pack, and the high-speed road surface vibration does not affect the battery pack. Therefore, the battery pack that meets the specifications of the enhanced road test can meet the vehicle traveling requirements as determined by the specification.



# Data Collection and Analysis

*step*

① data acquisition

- drive condition
- Measuring position

② Data analysis

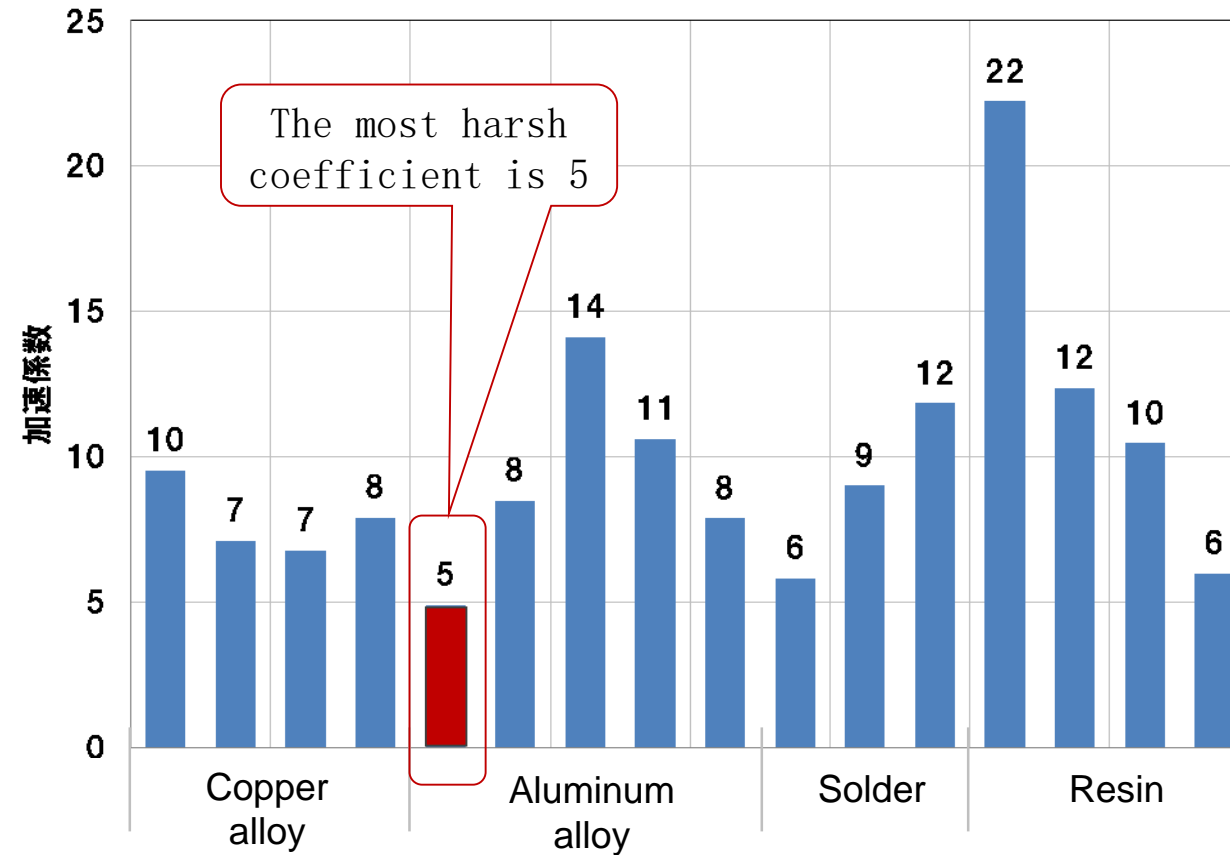
- Data extraction
- Frequency analysis

③ Data is normalized

- Set travel time
- **Acceleration factor setting**
- Normalize
- $\text{PSD-21h(m/s}^2\text{)}_{\text{rms}}$

④ develop vibration conditions

- Test PSD



- Refer to ISO DIS 19453-3
- Key component composition materials, using the lowest value (the most stringent)

# Data Collection and Analysis

step

① data acquisition

- drive condition
- Measuring position

② Data analysis

- Data extraction
- Frequency analysis

③ Data is normalized

- Set travel time
- Acceleration factor setting
- **Normalize**
- **PSD-21h(m/s<sup>2</sup>)<sub>rms</sub>**

④ develop vibration conditions

- Test PSD

200Hz		before Accelerated calculation ①			after Accelerated calculation ②	
NO	← Bad road	Vibration energy(g)	Life time(h)	MAX-Vibration energy(g)	NEW-Life time(h)	
1	Distortion road B	0.32835805	6.117	0.79436445	0.073820642	
2	Belgian road C	0.68983775	5.397	0.79436445	2.665558393	
3	Belgian road B	0.68195701	14.234	0.79436445	6.637628641	
4	Belgian road B	0.62569791	14.234	0.79436445	4.315702337	
5	Cobble-stone road B	0.16758758	4.318	0.79436445	0.001804649	
6	Sand stone road	0.25275621	14.68	0.79436445	0.047878025	
7	Washboard Road C	0.1847631	4.318	0.79436445	0.002939135	
8	Belgian road C	0.79436445	4.318	0.79436445	4.318	
9	Long wave road	0.25247094	1.295	0.79436445	0.004199792	
Total			68.91	③	18.06753161	
				④Regularization	21	

Frequency (Hz)	PSD (g <sup>2</sup> /Hz)
5	0.60221
6	0.71665
7	0.82560
8	1.01077
·	·
·	·
·	·
198	0.0016
199	0.0017
200	0.0016

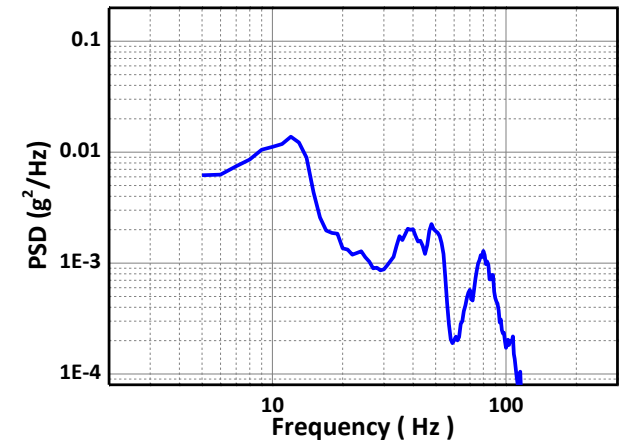
- miner' law ( ①→②、③→④ )

$$\left(\frac{T_t}{T_f}\right) = \left(\frac{\sigma_t}{\sigma_f}\right)^n$$

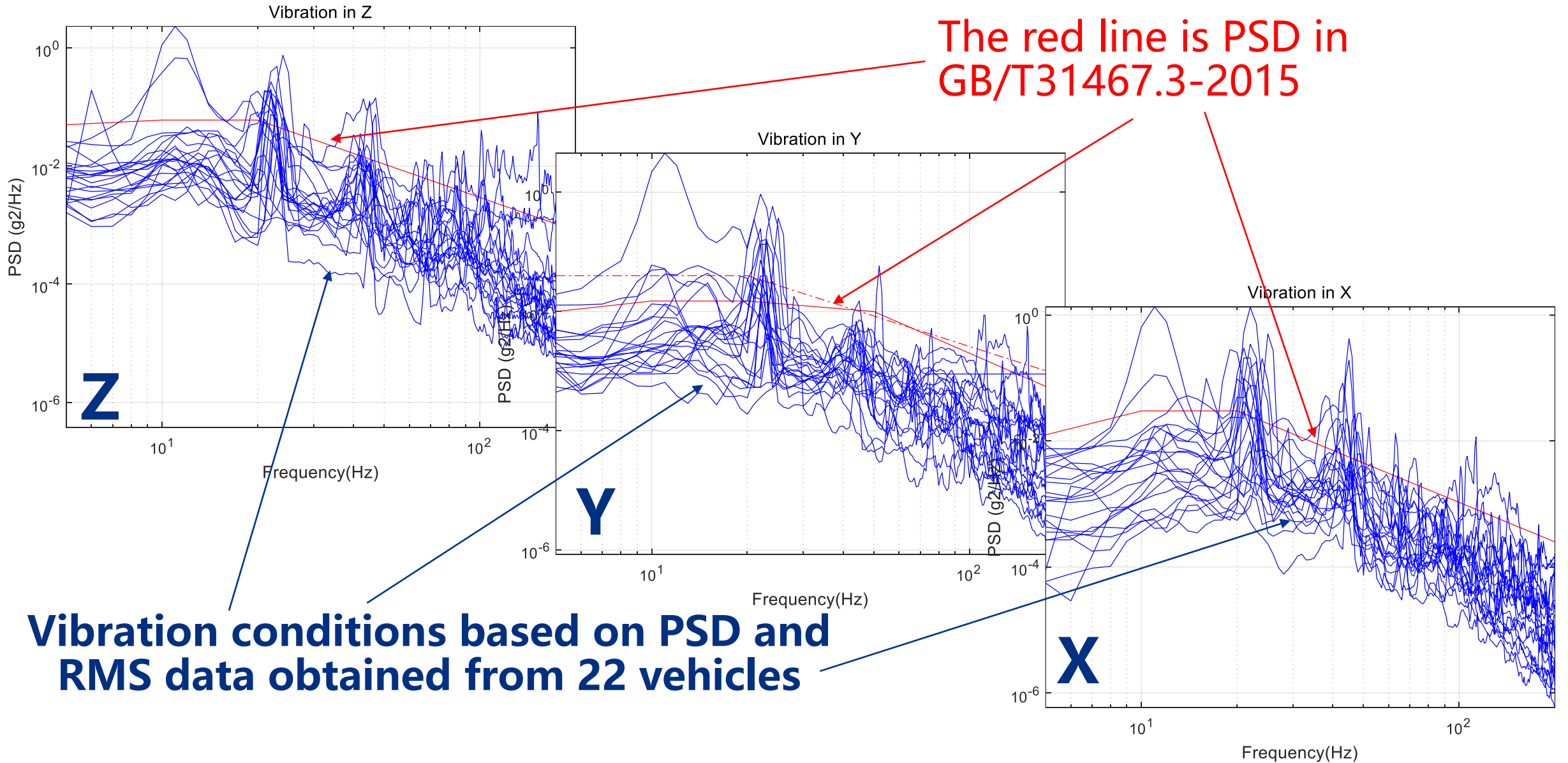
12h in XYZ

- The relationship between RMS and PSD is as follow:

$$(g)_{rms} = \sqrt{\Sigma(PSD \times \Delta Hz)}$$



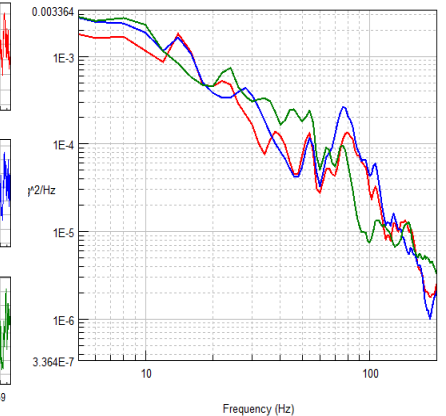
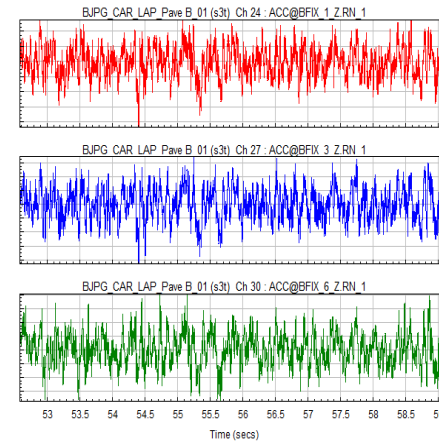
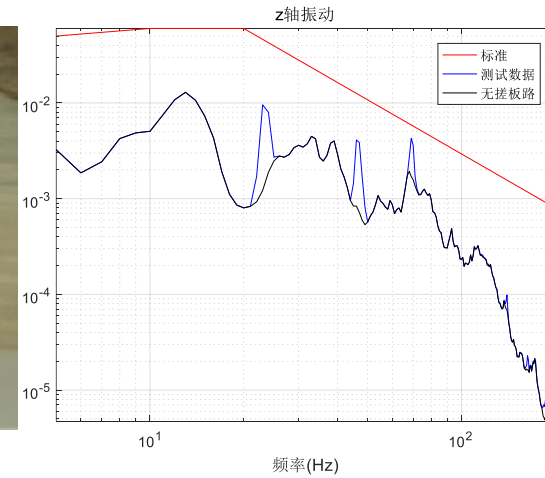
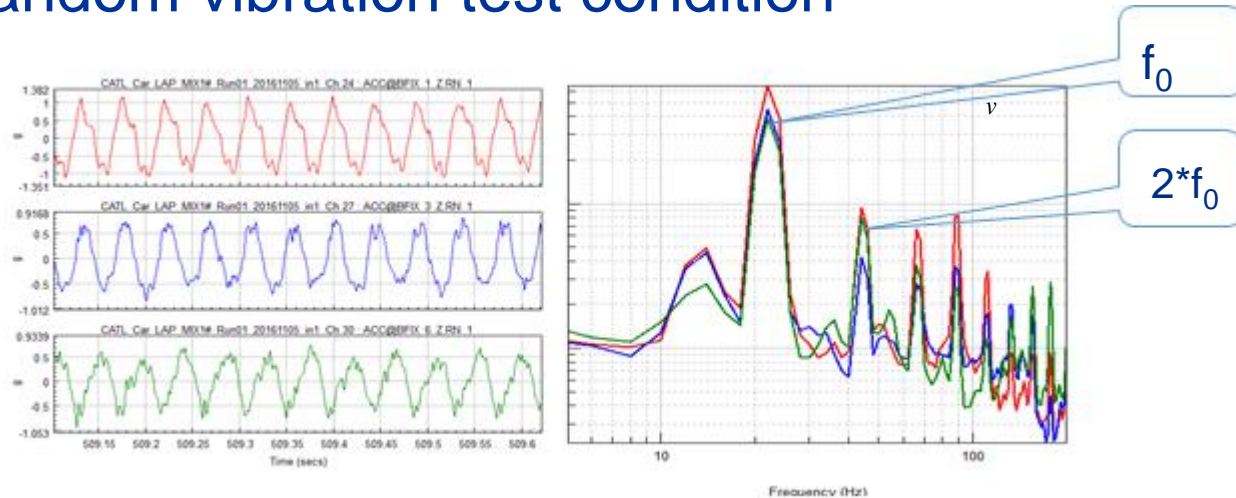
# Data Collection and Analysis



# Data Collection and Analysis

## 1. Corrugation road

- ✓ The data of corrugation road was extracted separately to carry out the constant frequency vibration, and the other roads surface data were developed to obtain random vibration test condition



- ✓ Excitation frequency  $f = v/\lambda$ , here  $\lambda=0.58m$

v(km/h)	10	20	30	40	50	60	70
f(Hz)	4.8	9.6	14.4	19.2	24.0	28.7	33.5

# Data Collection and Analysis

## 2. Vehicle Classification

According to the vibration energy distribution situation and the actual position of the battery pack, the vehicles was divided into passenger cars and commercial vehicles, respectively. The analysis of cargo vans was unified into passenger cars.

## 3. Vehicle Classification

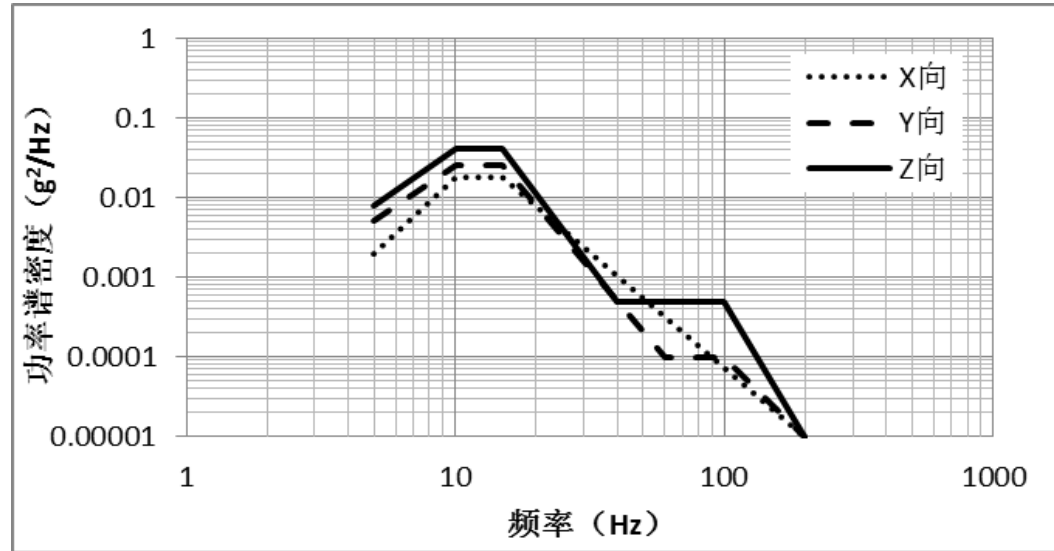
Direction	MAX	AVG	Median	MIN	Direction	MAX	AVG	Median	MIN
Z	1.3468	0.6364	0.4821	0.2060	Z	1.1358	0.7260	0.6328	0.4038
Y	0.8922	0.4378	0.3539	0.1486	Y	0.8706	0.5646	0.4935	0.2268
X	1.1094	0.4910	0.3568	0.1253	X	0.8145	0.5128	0.4437	0.1867

3

**Standards**

# Standards

## ➤ Commercial Vehicle

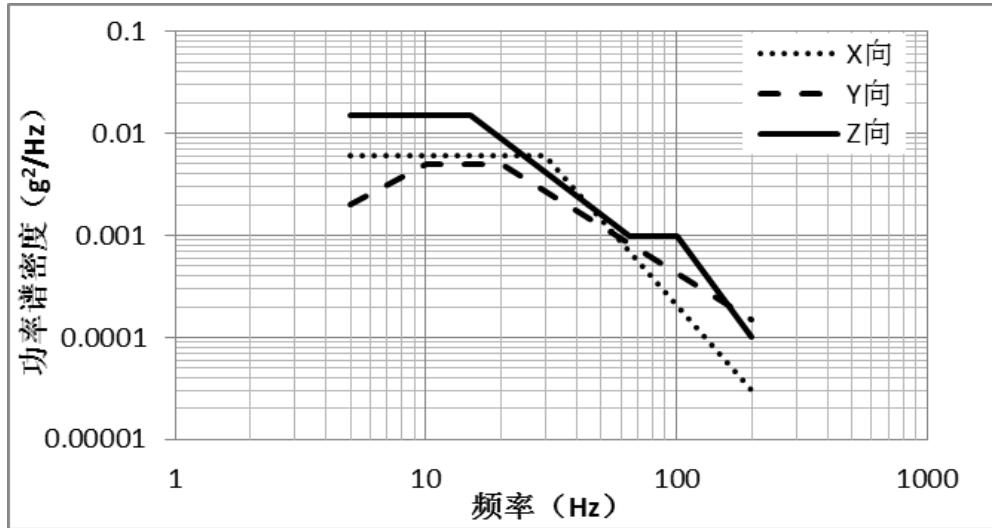


Random				
Frequency Hz	Z-axis ( PSD ) $g^2/Hz$	Y-axis ( PSD ) $g^2/Hz$	X-axis ( PSD ) $g^2/Hz$	
5	0.008	0.005	0.002	
10	0.042	0.025	0.018	
15	0.042	0.025	0.018	
40	0.0005	/	/	
60	/	0.0001	/	
100	0.0005	0.0001	/	
200	0.00001	0.00001	0.00001	
RMS	0.73 g	0.57 g	0.52 g	
Time	12 h	12 h	12 h	
Constant Frequency				
Amplitude	$\pm 1.5$ g	$\pm 1.5$ g	$\pm 2.0$ g	
Frequency	20 Hz	20 Hz	20 Hz	
Time	2 h	2 h	2 h	



# Standards

## ➤ Passenger Vehicle



Random			
Frequency Hz	Z-axis ( PSD ) g <sup>2</sup> /Hz	Y-axis ( PSD ) g <sup>2</sup> /Hz	X-axis ( PSD ) g <sup>2</sup> /Hz
5	0.015	0.002	0.006
10	/	0.005	/
15	0.015	/	/
20	/	0.005	/
30	/	/	0.006
65	0.001	/	/
100	0.001	/	/
200	0.0001	0.00015	0.00003
<b>RMS</b>	0.64 g	0.45 g	0.50 g
<b>时间</b>	12 h	12 h	12 h
Constant Frequency			
<b>Amplitude</b>	±1.5 g	±1.0 g	±1.0 g
<b>Frequency</b>	24 Hz	24 Hz	24 Hz
<b>Time</b>	1 h	1 h	1 h

# Standards

## ➤ Requirements

After the vibration test, the Lithium-ion battery packs or systems need to meet the requirements as following:

- the minimum monitoring units' voltage without sharp change (absolute value of the voltage difference is not greater than 0.15 V);
- no leakage
- no shell rupture
- no fire
- no explosion
- Insulation resistance after the test is not less than 100  $\Omega$  / V.

**4**

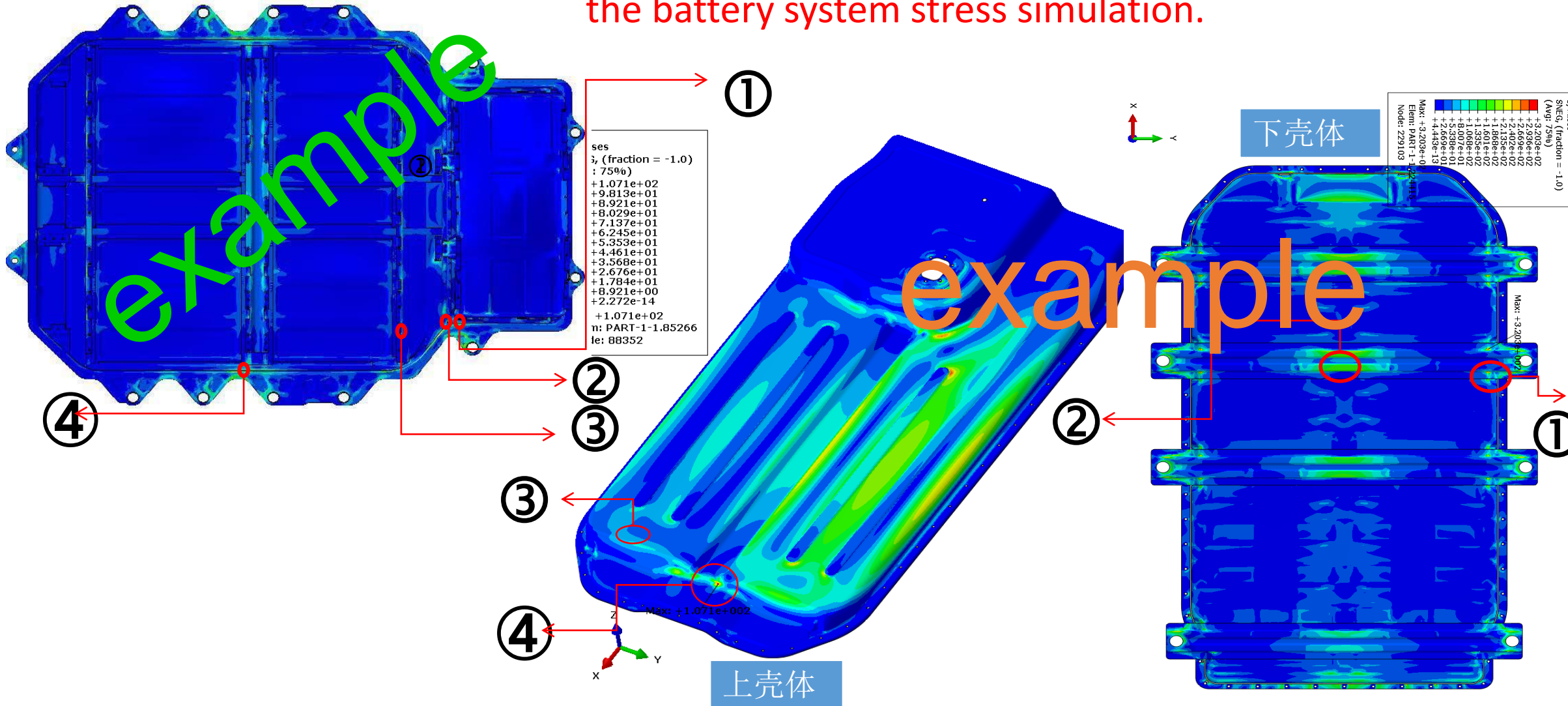
**Experiment**

# Experiment

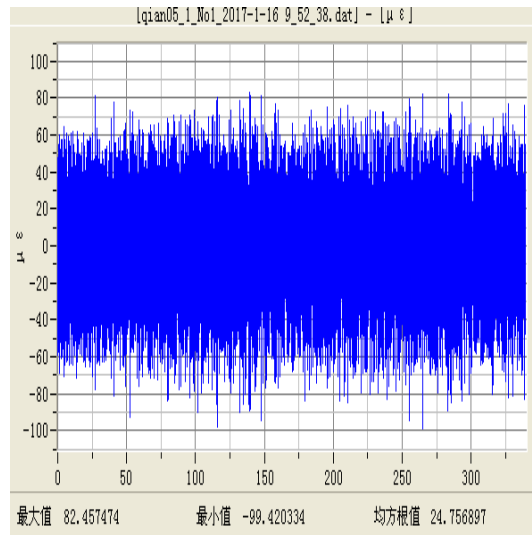
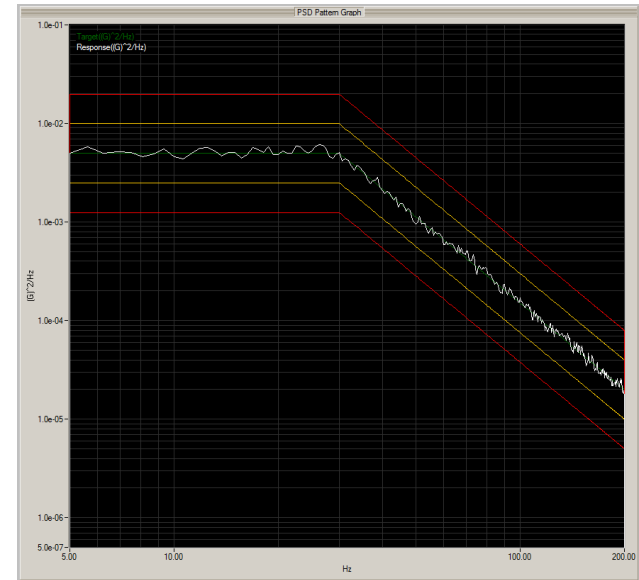
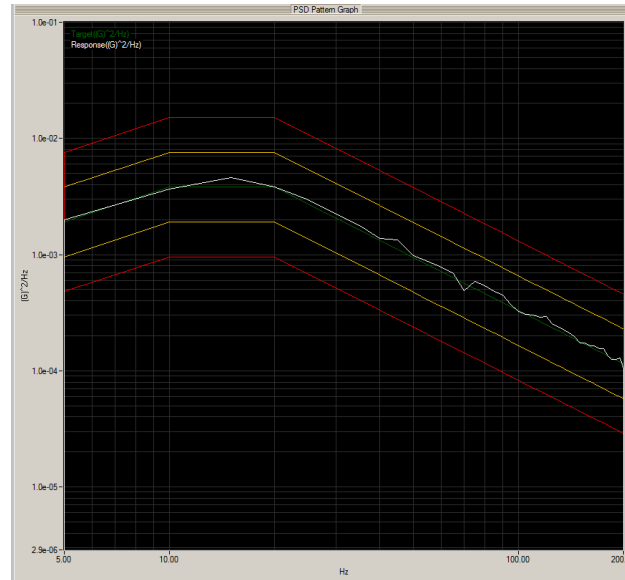
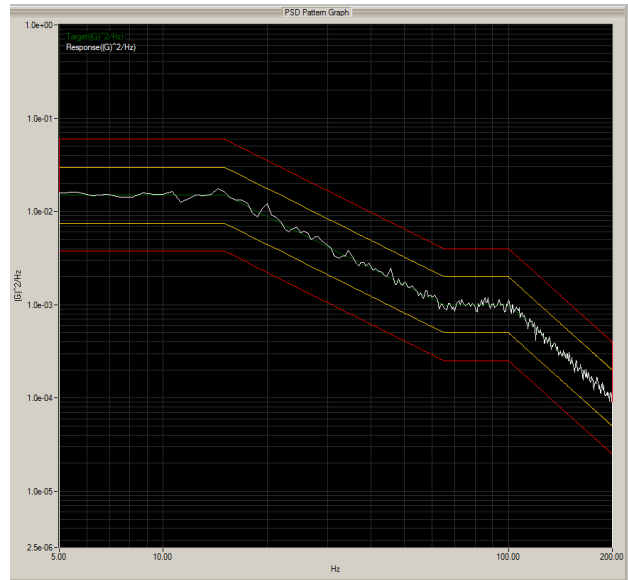
## ➤ Preparation

Stress Sensors positions:

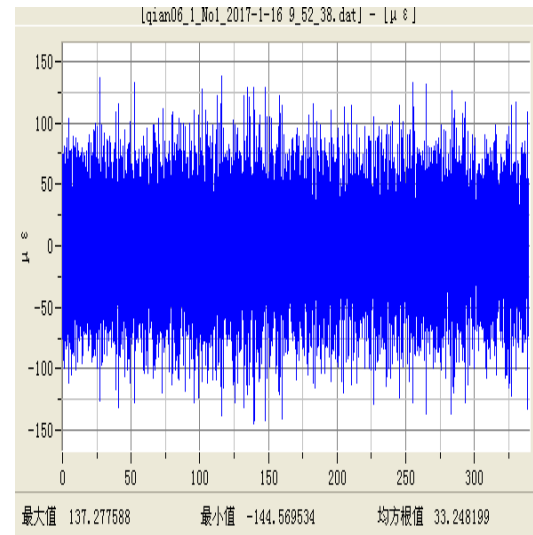
The MAX stress points are according to the results of the battery system stress simulation.



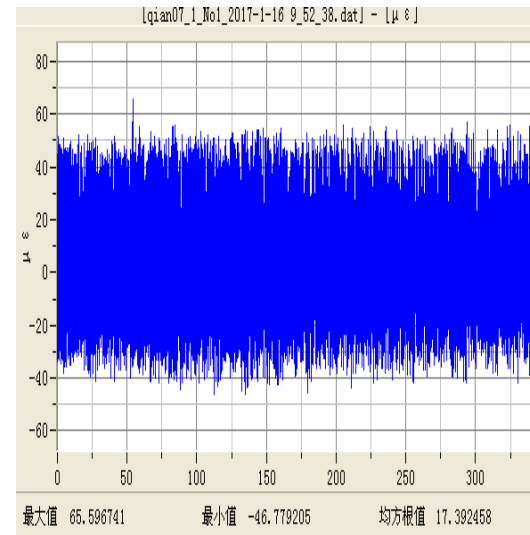
# Experiment



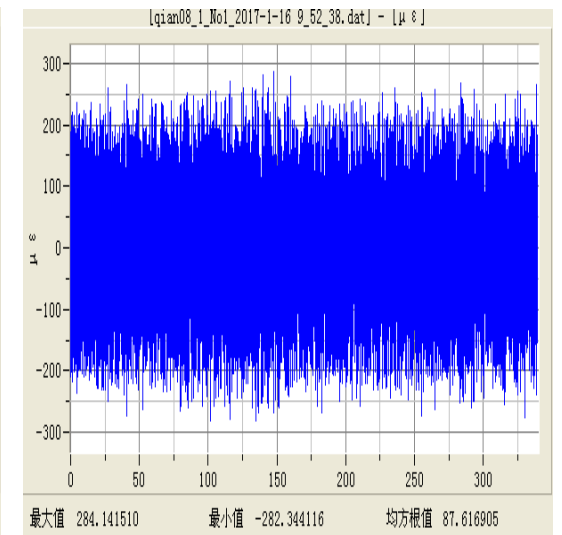
Z-random-1



Z-random-2



Z-random-3



Z-random-4

# Experiment

N.0	Sample type	Yield Strength (MPa)	Direction	MAX Stress (MPa)
1	Passenger EV	420-520	Z-random	65.2
			Z-constant frequency	23.9
			Y-random	39.5
			Y-constant frequency	18.8
			X-random	8.3
			X-constant frequency	2.6
2	Passenger EV	160	Z-random	88
			Z-constant frequency	80
3	Passenger EV	142 (upper case)	Z-random	77.3
		340 (bottom)	Z-constant frequency	130.0
4	Bus EV	Under test		
5	Passenger PHEV			
6	Cargo vans			
7	Passenger EV	Data analyzing		



Thanks