

# Comparison of the operating behavior of resilient wheels with different radial stiffness installed in the Skoda Forcity Smart from Pilsen.

Autoren:

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# Agenda

- Introduction
- Tram ŠKODA FORCITY SMART 40T
- Resilient wheels of GHH-Radsatz
- In Service Measurements
- Results of the acceleration measurements
- Results of Acoustic measurements
- Conclusion

# Introduction

- In modern trams, resilient wheels are used in almost all current vehicle concepts.
- A distinction is made between conventional resilient wheels and high-resilient wheels with significantly lower radial stiffness.
- For the ŠKODA FORCITY SMART 40T trams in Pilsen, one vehicle was equipped with high-resilient wheels of the type **GHH® ULTRA-S** and one vehicle with wheels of the conventional type **GHH® V60**.
- This constellation makes it possible to measure and compare the influence of softer wheels on the accelerations at the wheelset, bogie and in the car body and thus on ride comfort and component loads.
- Acoustic measurements were performed in the car body and on external noise, to compare the noise emission of both wheel types.

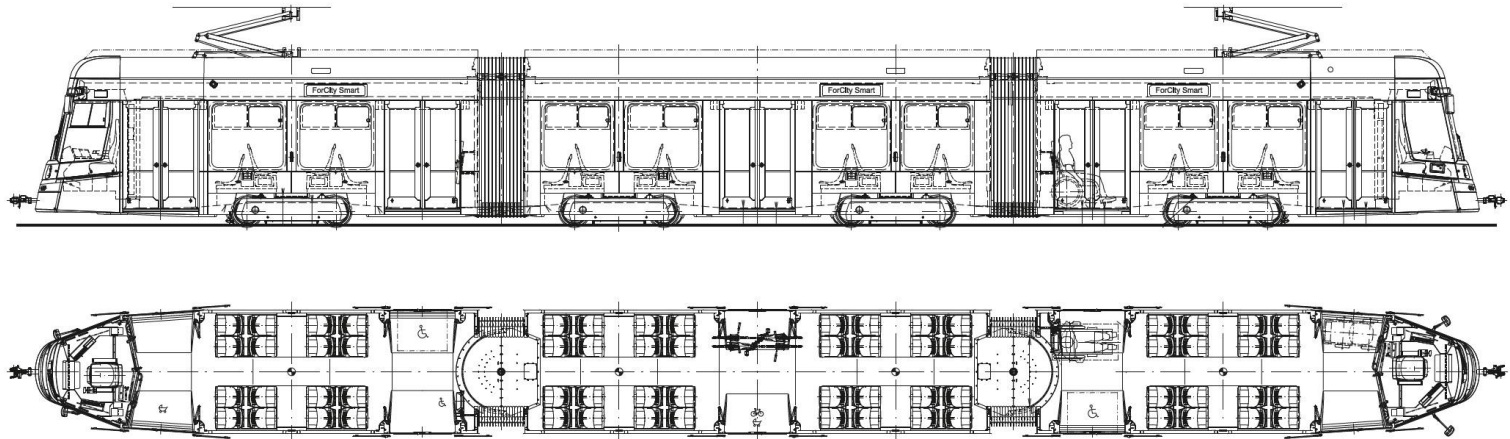
# Skoda Forcity Smart

- Bidirectional three-section tram
- Four fully rotating motorized bogies
- Bogies equipped with wheelsets
- Each wheelset powered by longitudinally oriented traction motor

## BASIC TECHNICAL DATA

## TECHNISCHE GRUNDDATEN

Number of sections	3
Total number of passengers – 4 persons/m <sup>2</sup> (incl. seated)	185 (64)
Length	29 140 mm
Width	2 500 mm
Gauge	1 435 mm
Max. speed	70 km/h
Electrification	600 V DC
Low floors	100 %



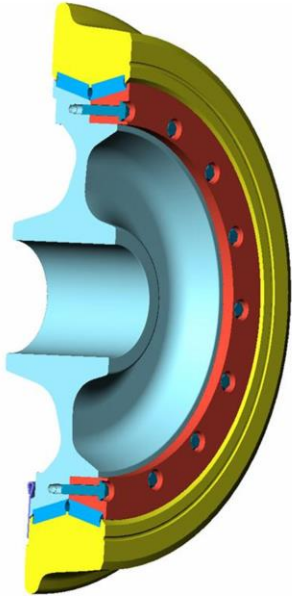
# Network of Pilsen, Tramlines



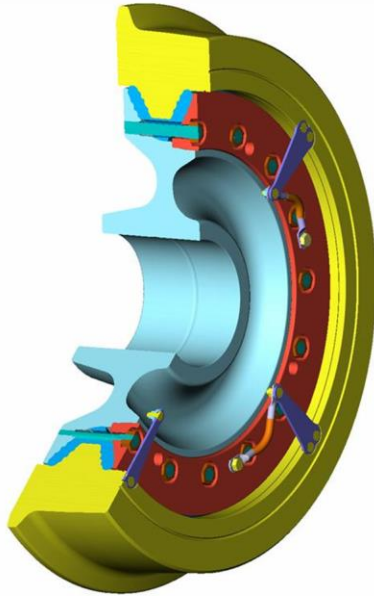
Track gauge [mm]	1435
Track length [km]	21,7
Electrification [V CD]	400
Line 1	8.0 – 8.2 km 18 stops
Line 2	8.5 -.8.7 km 22 stops
Line 4	8.2 – 8.4 km 19 stops

# Resilient wheels of GHH

**GHH®V15 / GHH®V30**

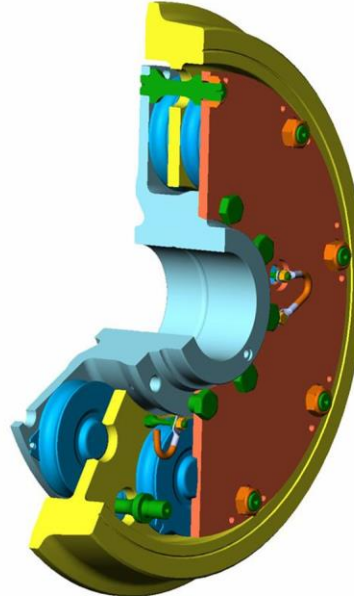


**GHH®V60**

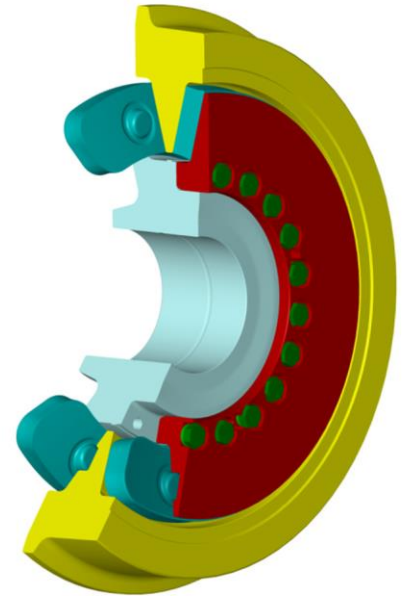


Standard Resilient Wheels

**GHH®ULTRA-P**



**GHH®ULTRA-S**



High Resilient Wheels



# Resilient Wheel GHH® V60



Diameter [mm] new/worn	600 / 520
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Radial Stiffness [kN/mm]	~270
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Axial Stiffness [kN/mm]	~170
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# High resilient GHH® *ULTRA-S*



Diameter [mm] new/worn	600 / 520
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Radial Stiffness [kN/mm]	~24
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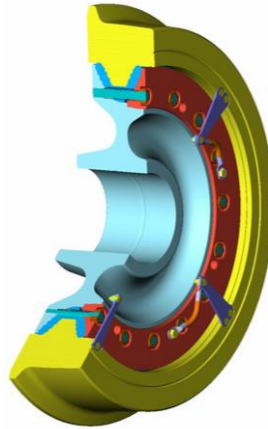
Axial Stiffness [kN/mm]	~75
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# Skoda 40T, Tram 385 and 386



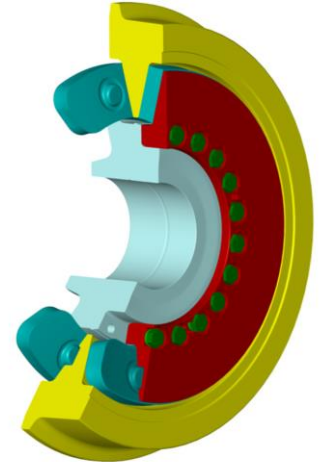
GHH® V60



Tram 385, GHH® V60

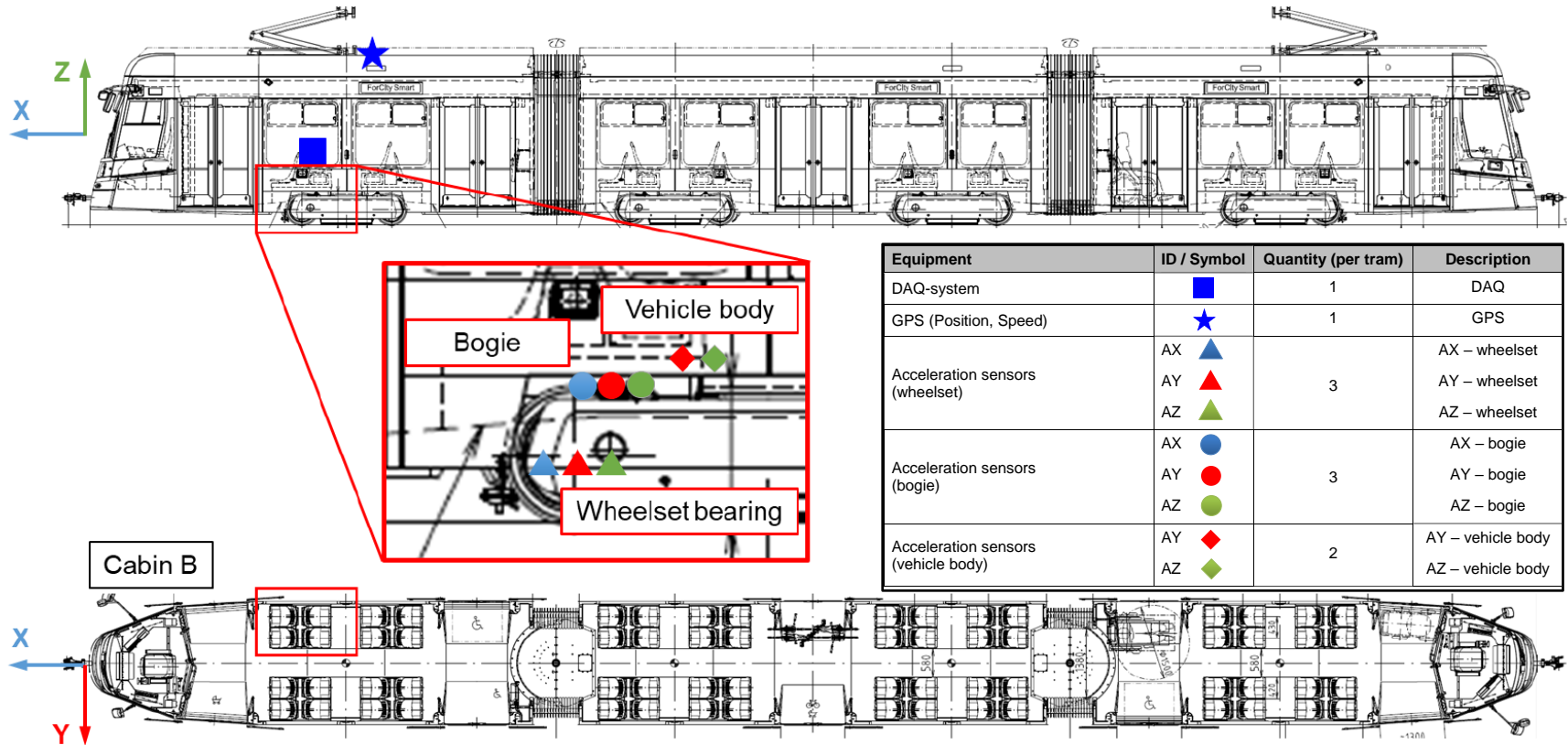


GHH® ULTRA-S

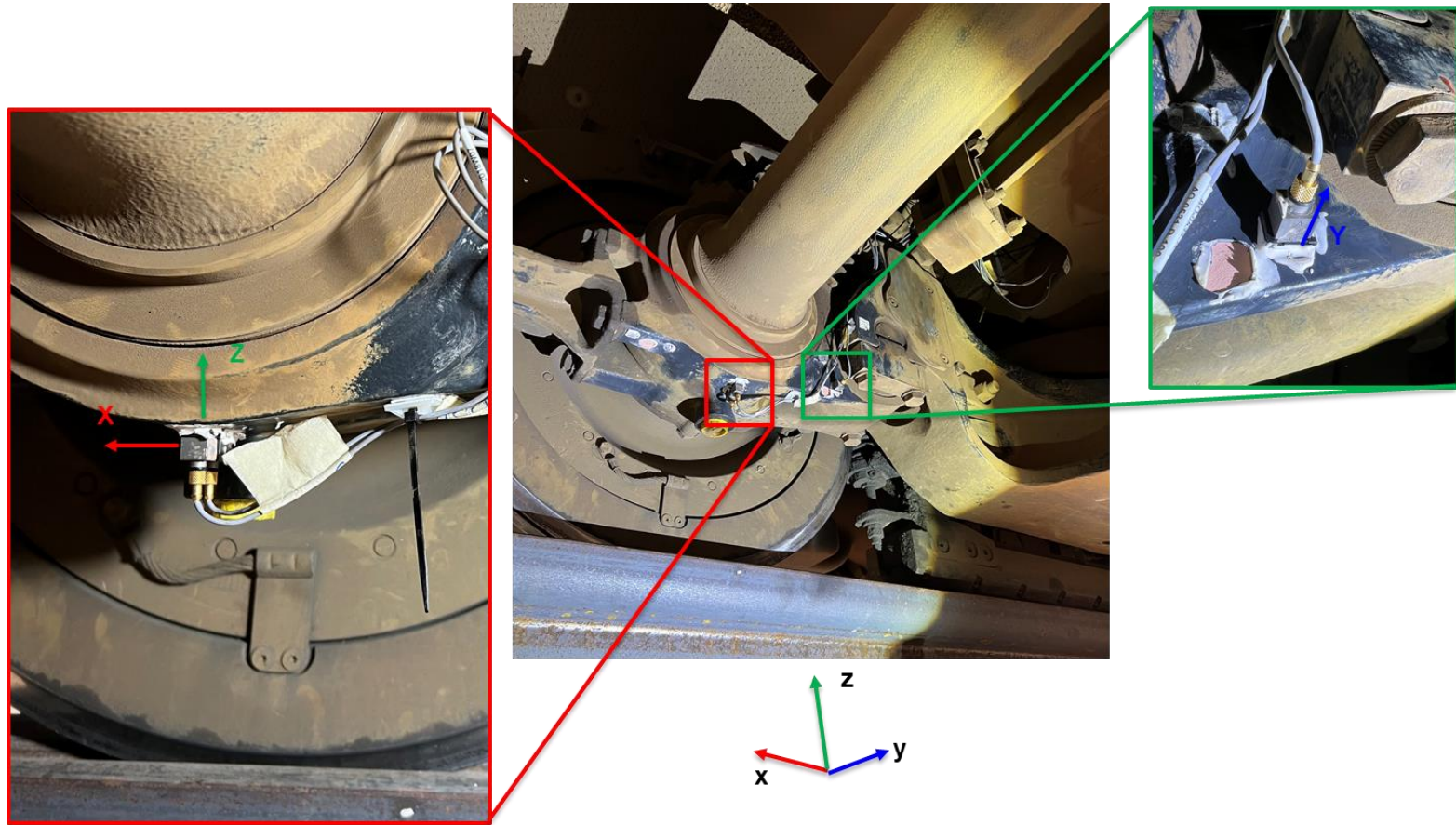


Tram 386, GHH® ULTRA-S

# Measurement positions of accelerations

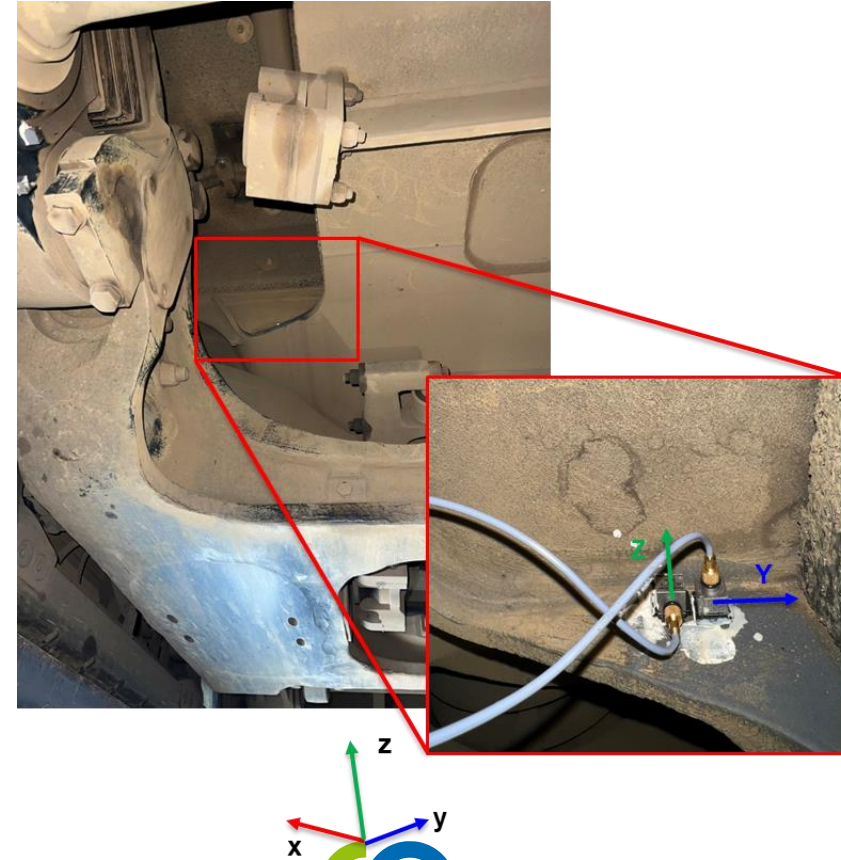
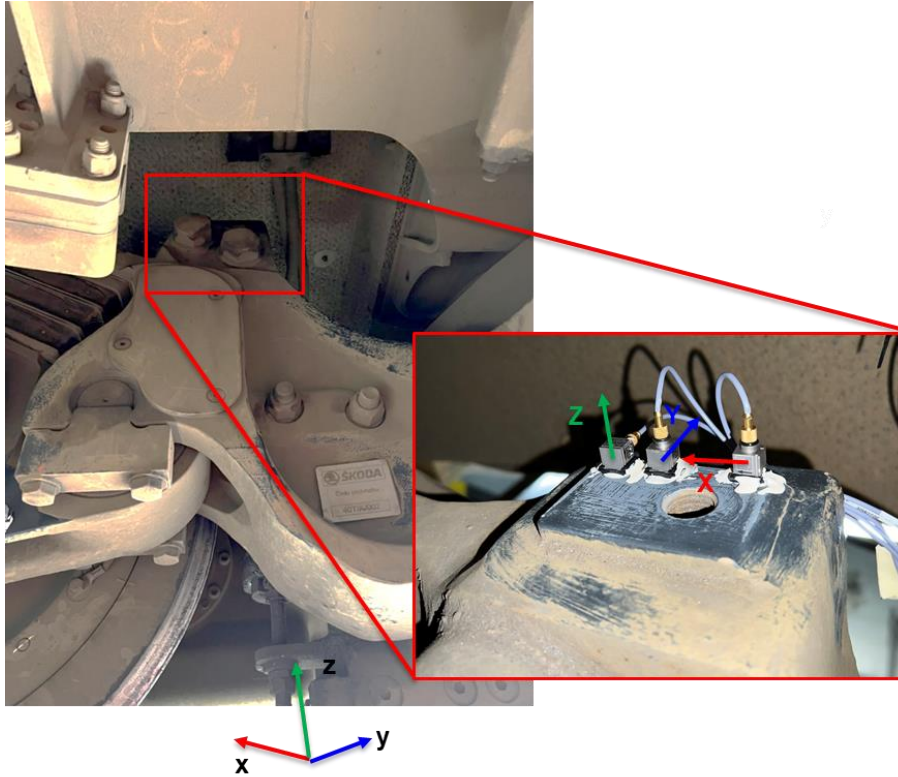


# Measurement of accelerations on wheelset bearing

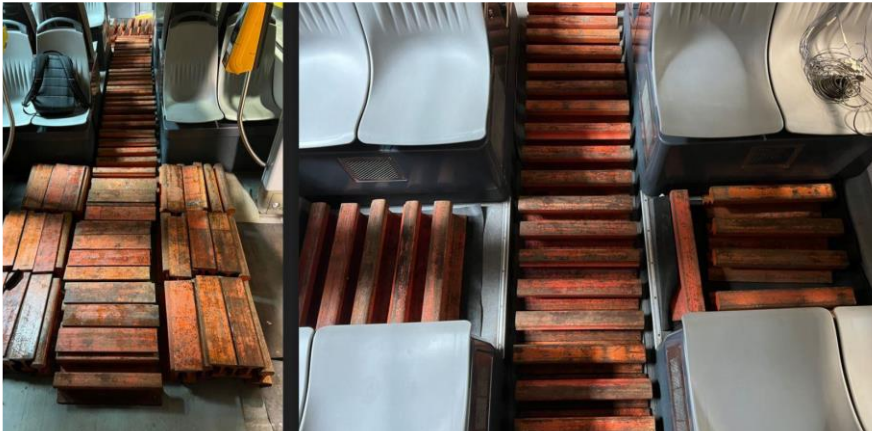
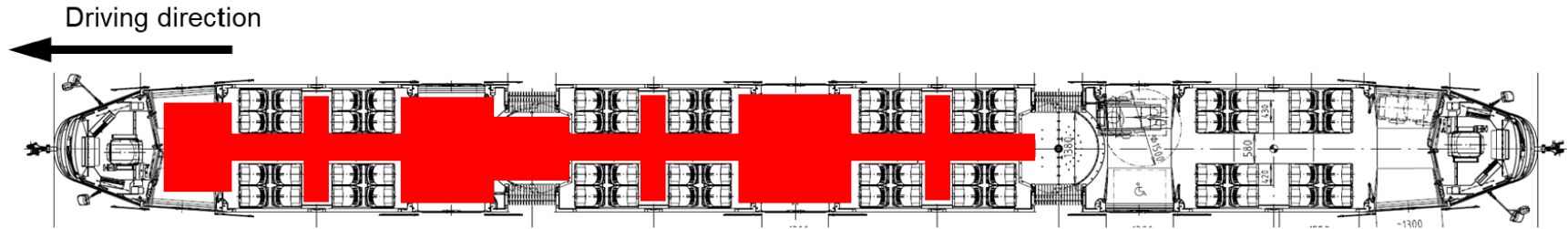




# Measurement of accelerations on bogie and vehicle body



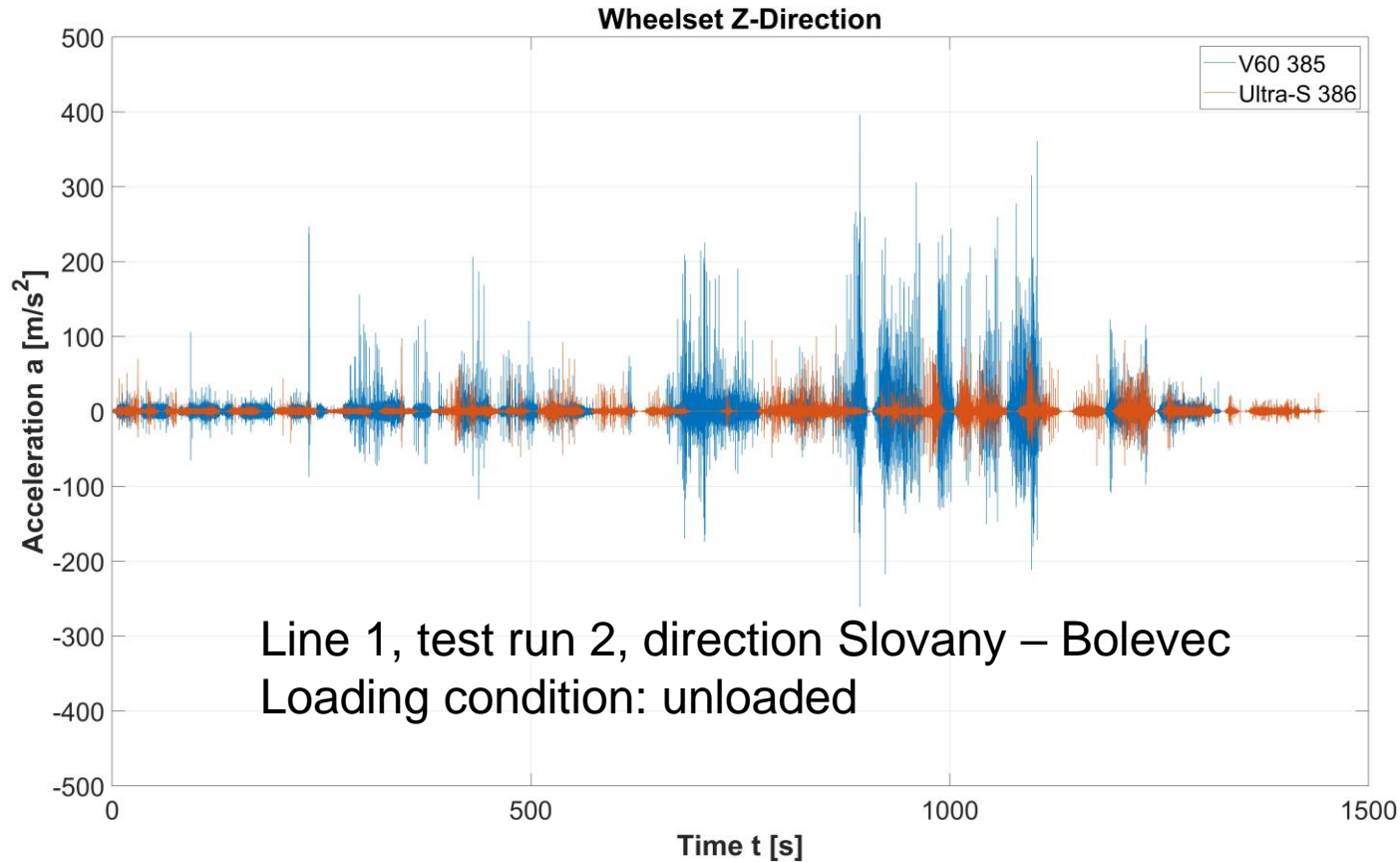
# Loading Conditions



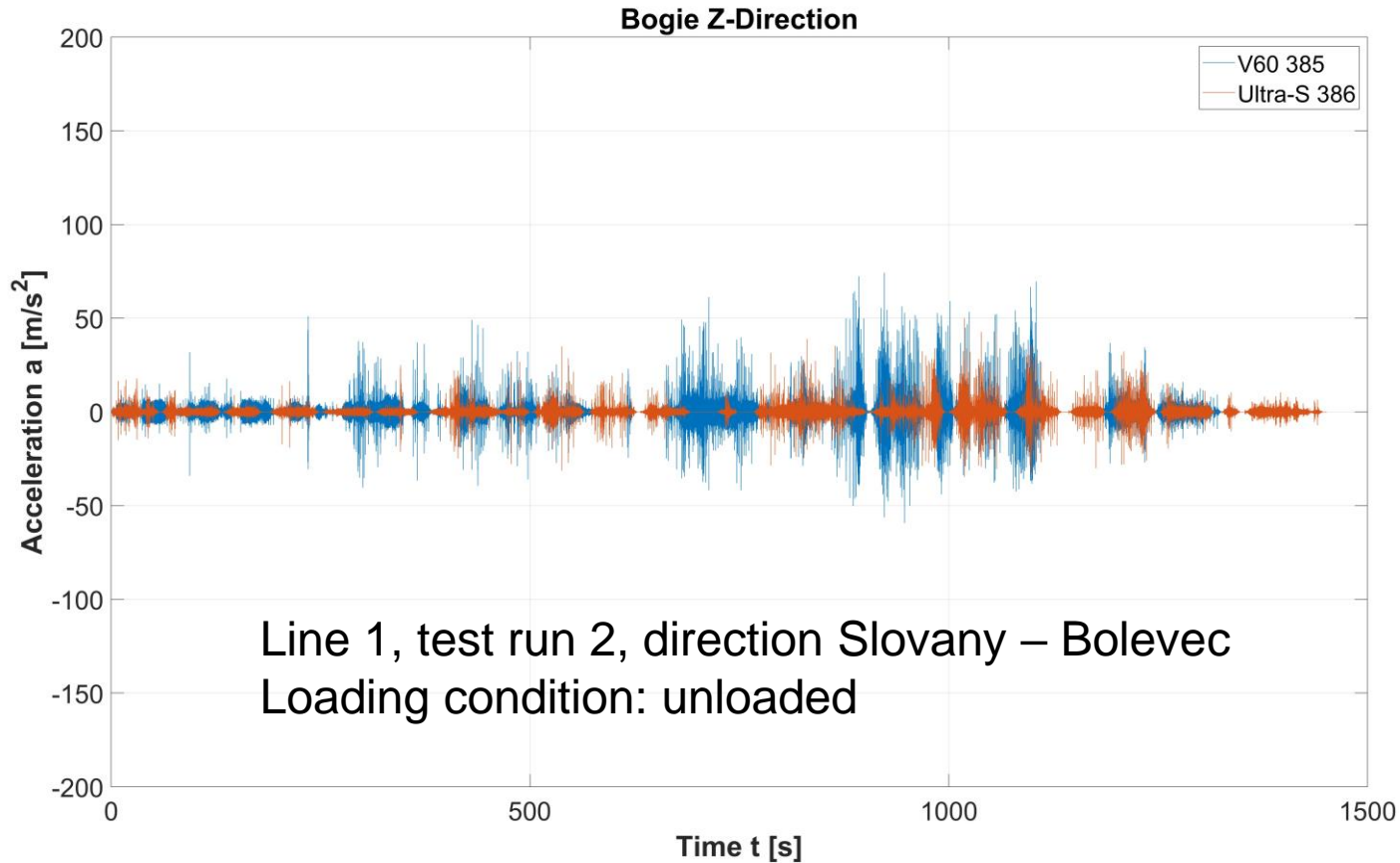
Condition	Axles load [kN]
Empty	69,4
Loaded [3 P/m <sup>2</sup> )	83,5



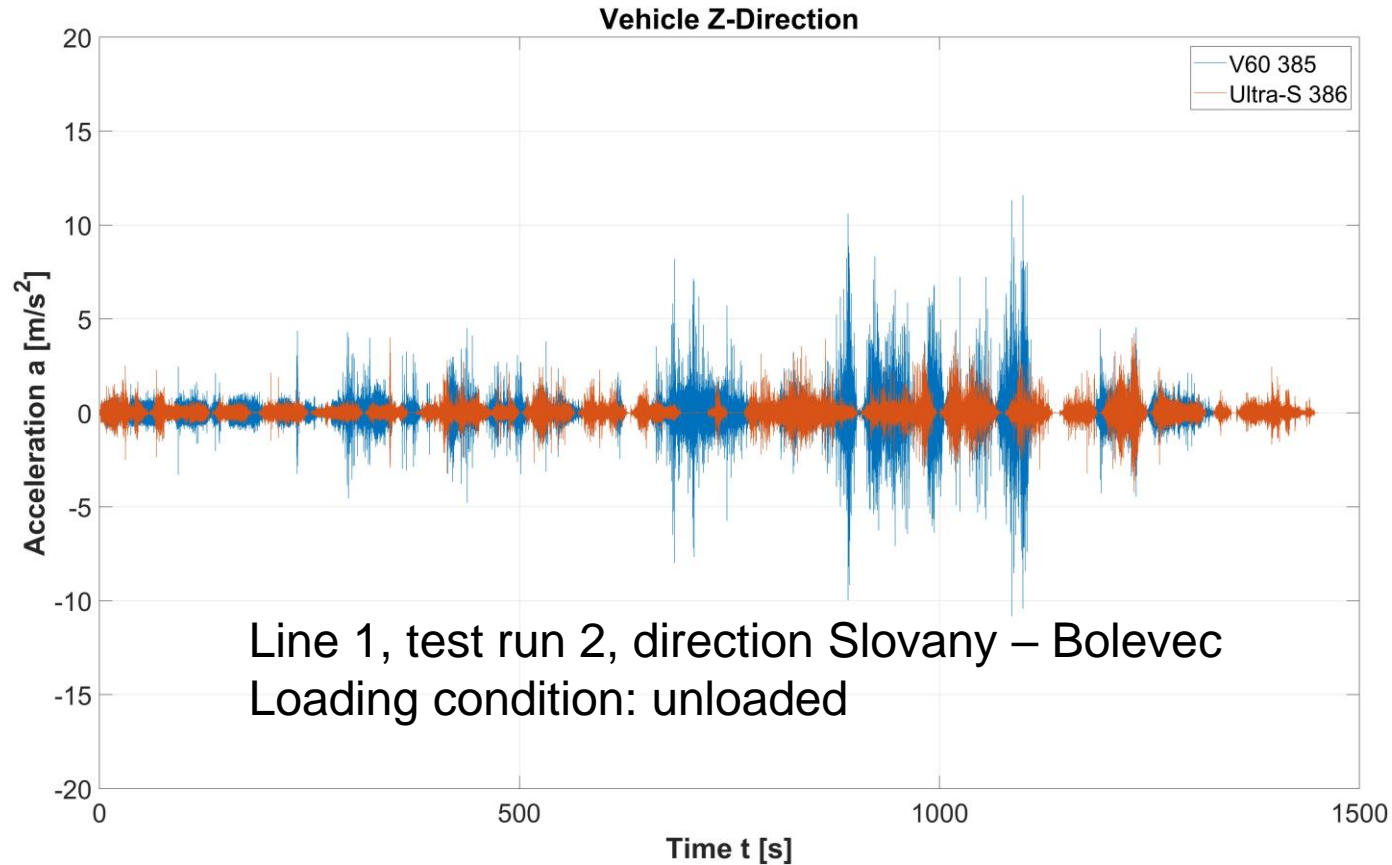
# Acceleration of wheelset bearing over time, Z-direction



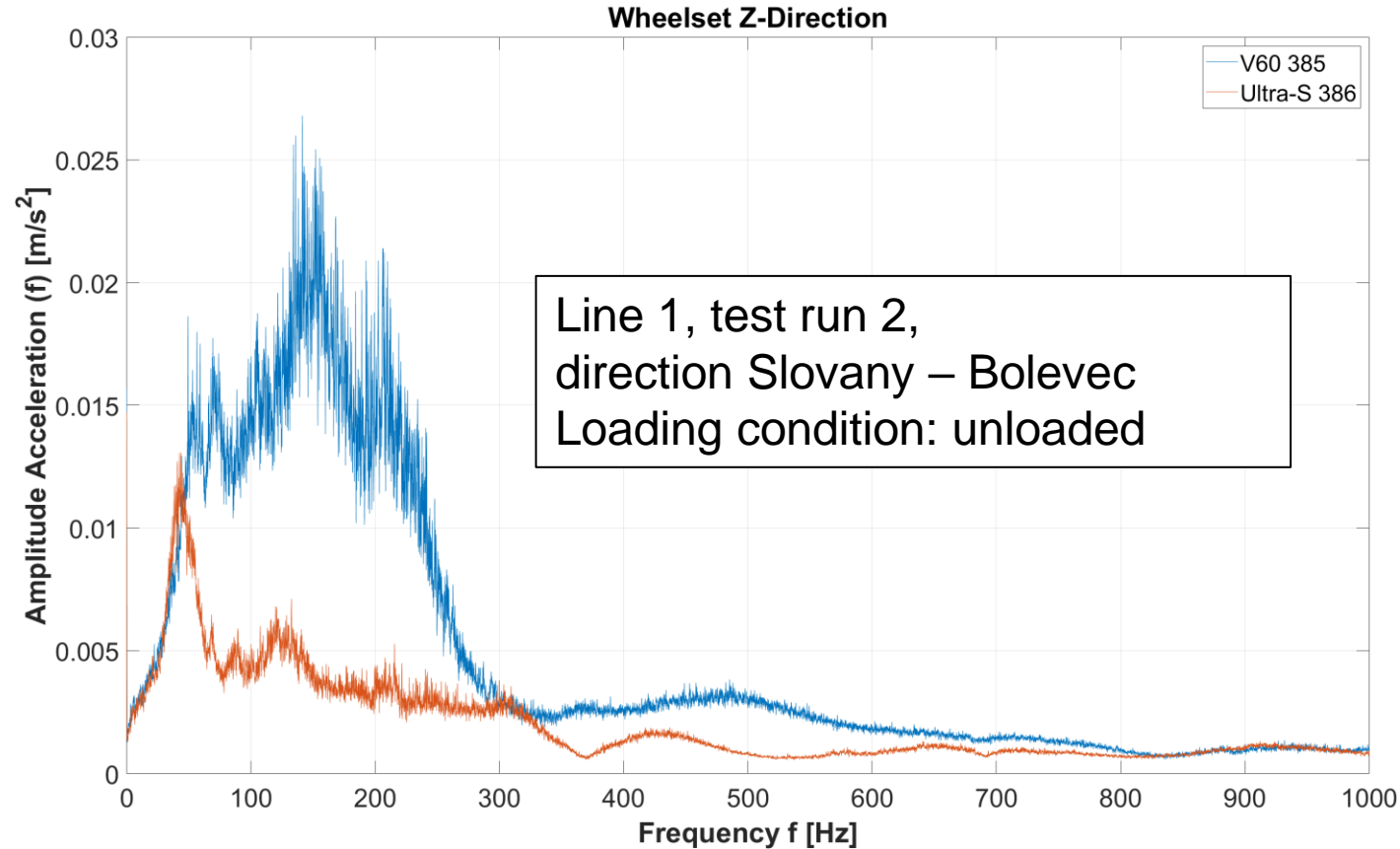
# Acceleration of bogie over time, Z-direction



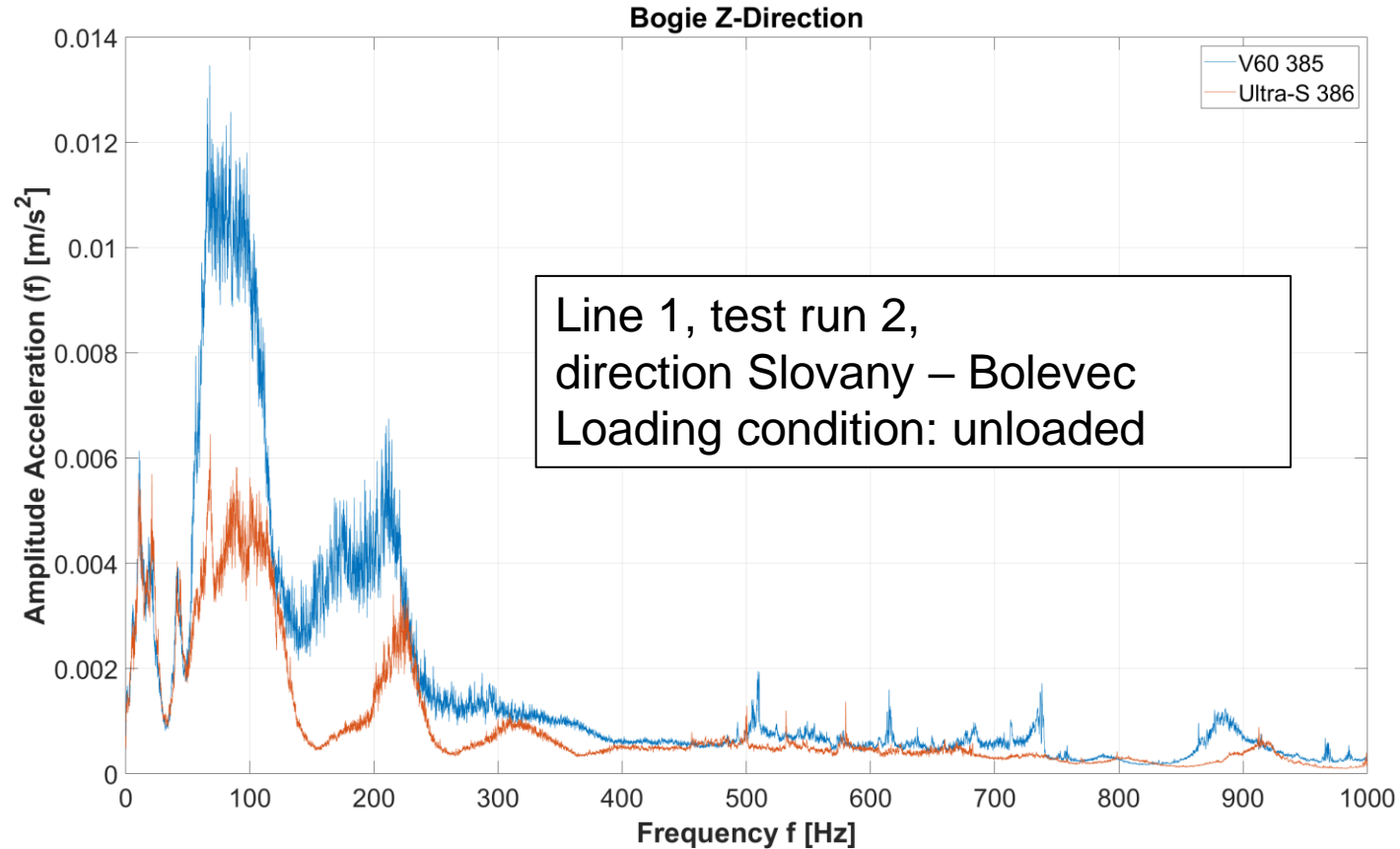
# Acceleration of vehicle body over time, Z-direction



# Acceleration of wheelset bearing, FFT, Z-direction

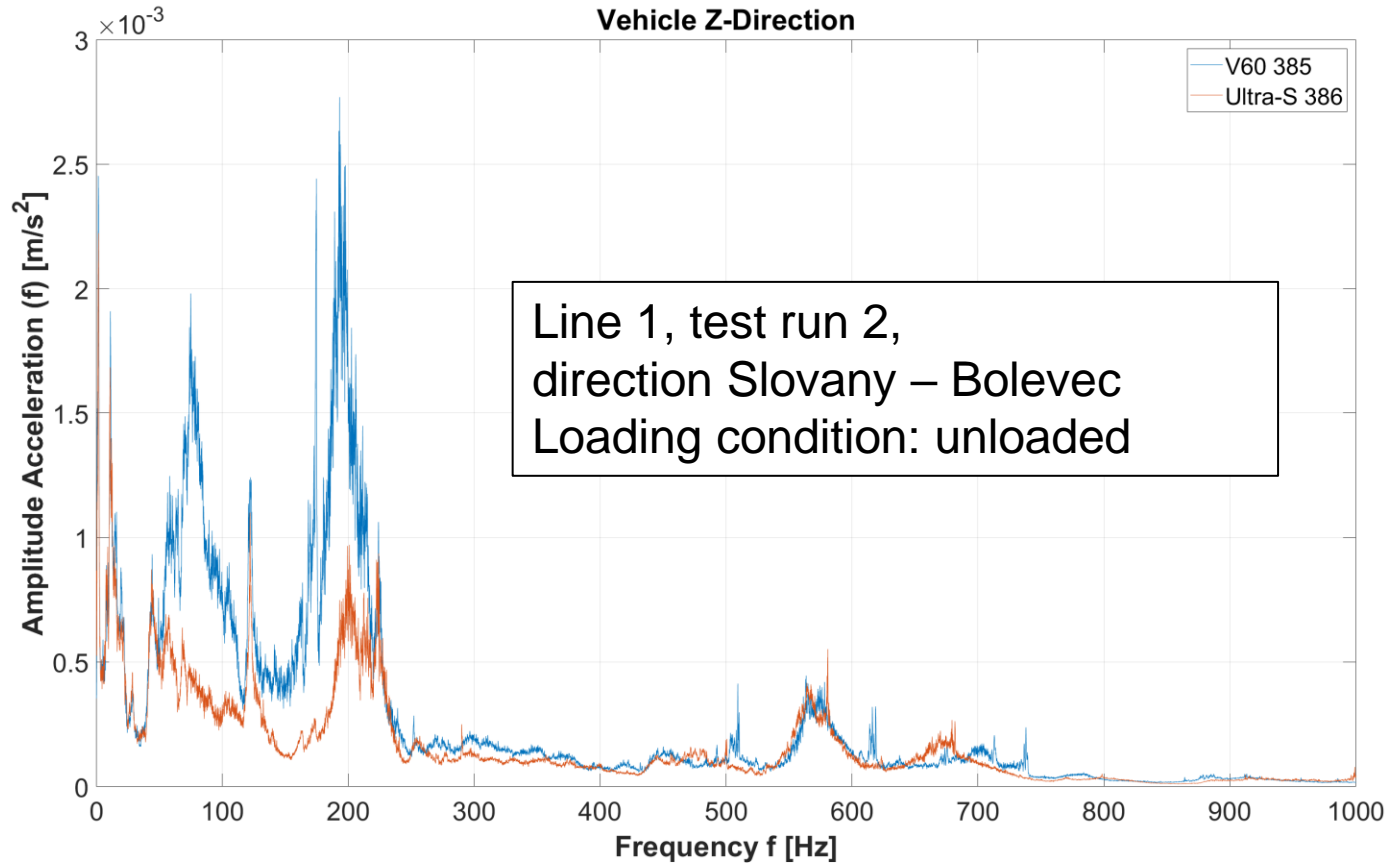


# Acceleration of bogie, FFT, Z-direction

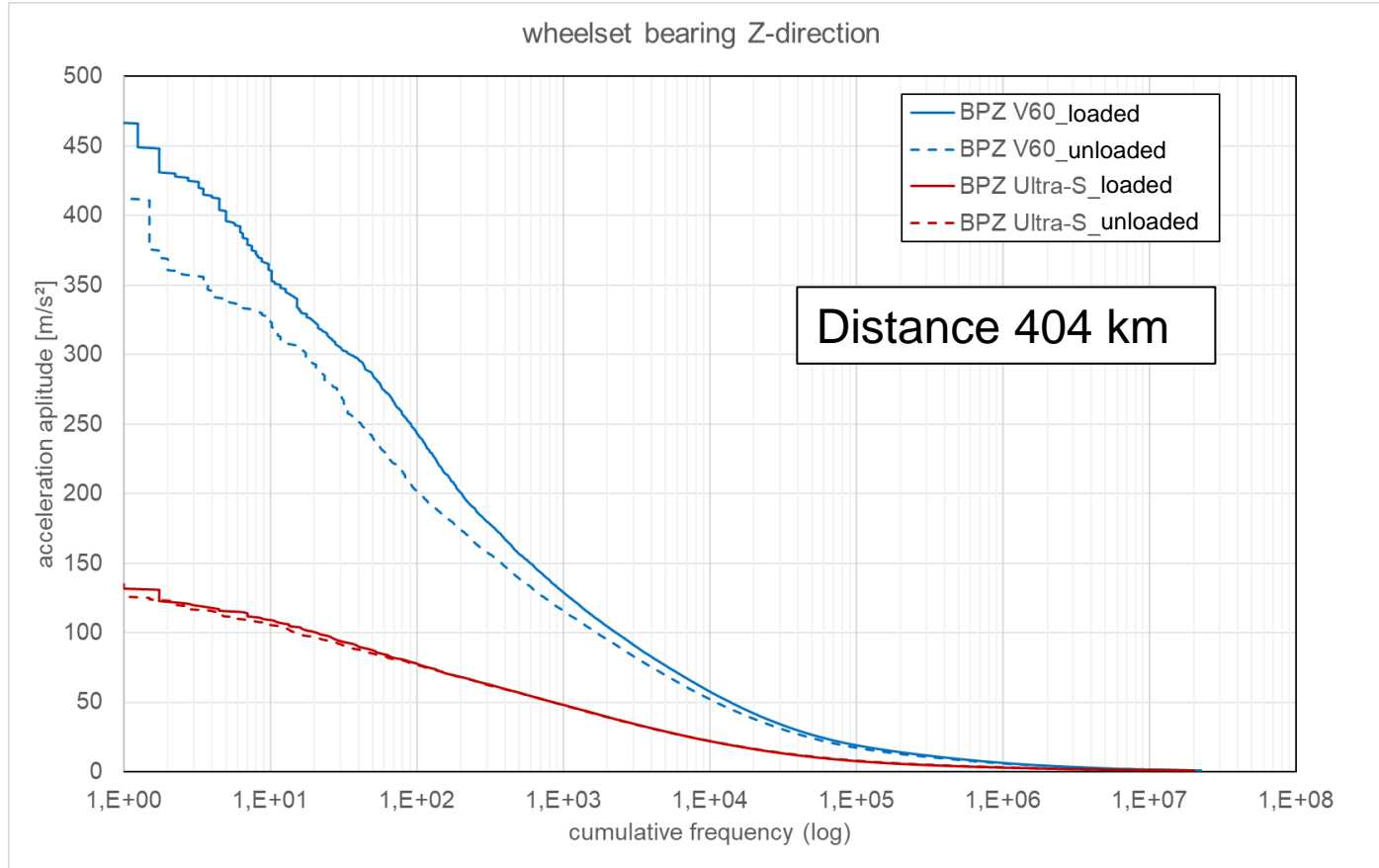




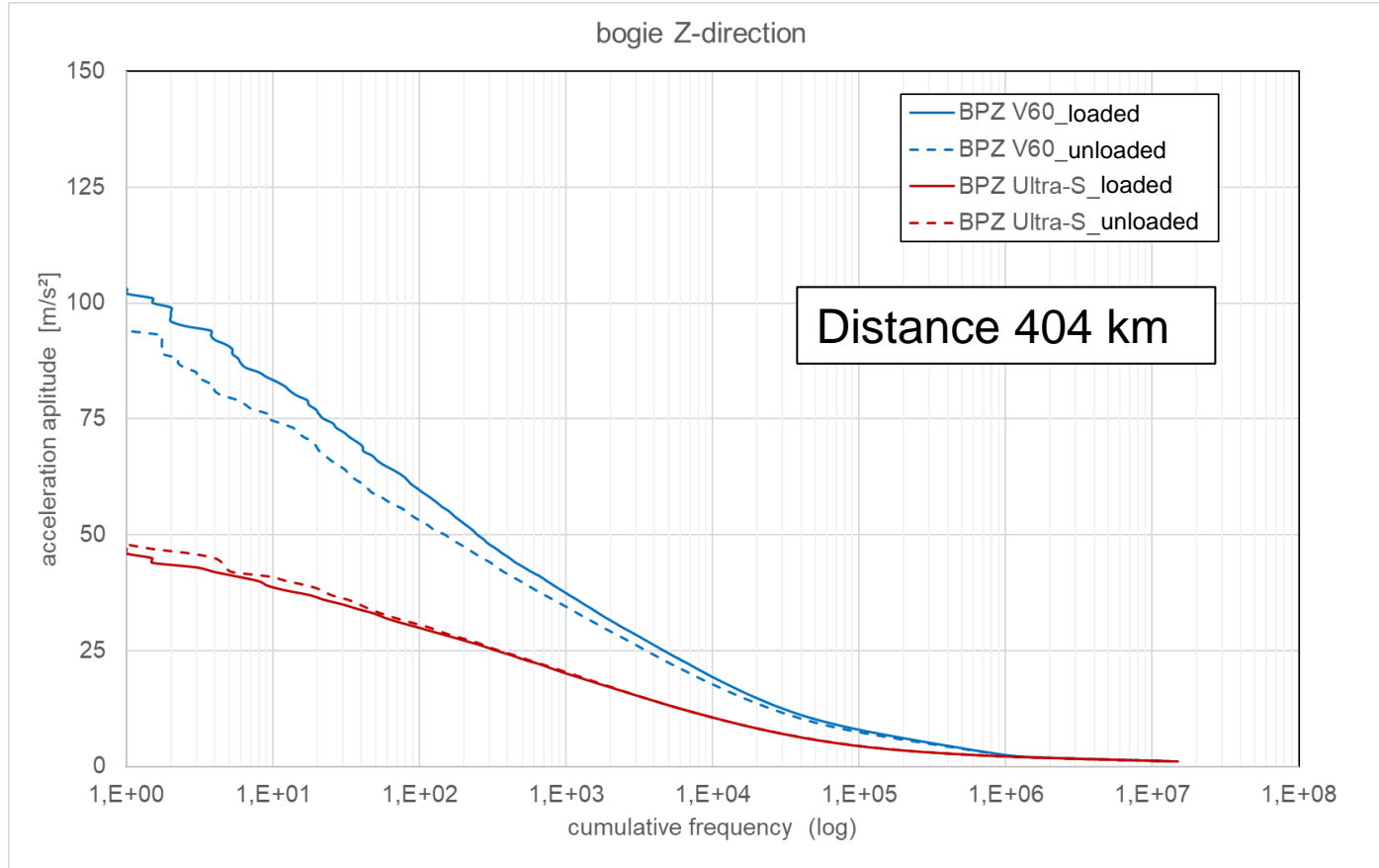
# Acceleration of vehicle body, FFT, Z-direction



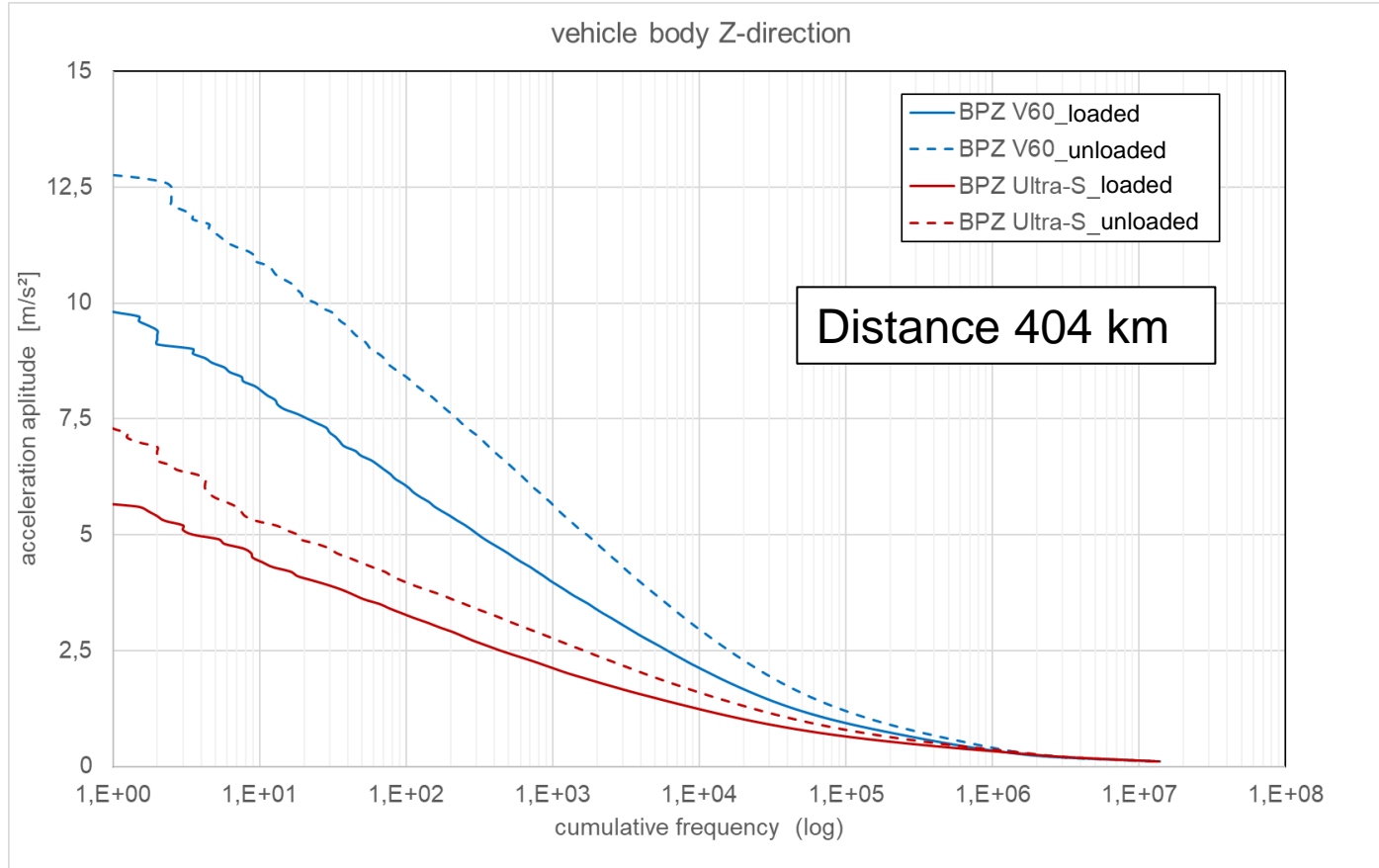
# Acceleration of wheelset bearing, Range Pair Counting, Z-direction



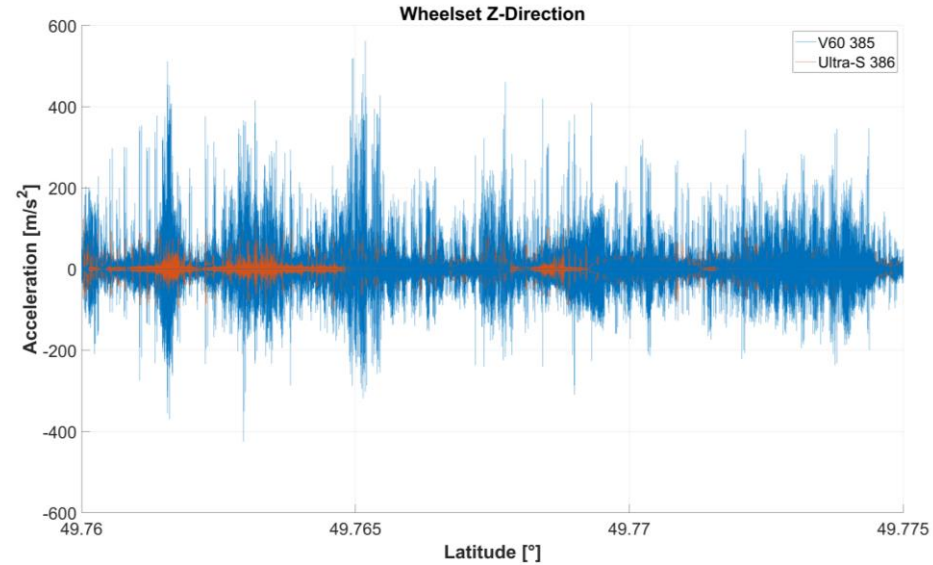
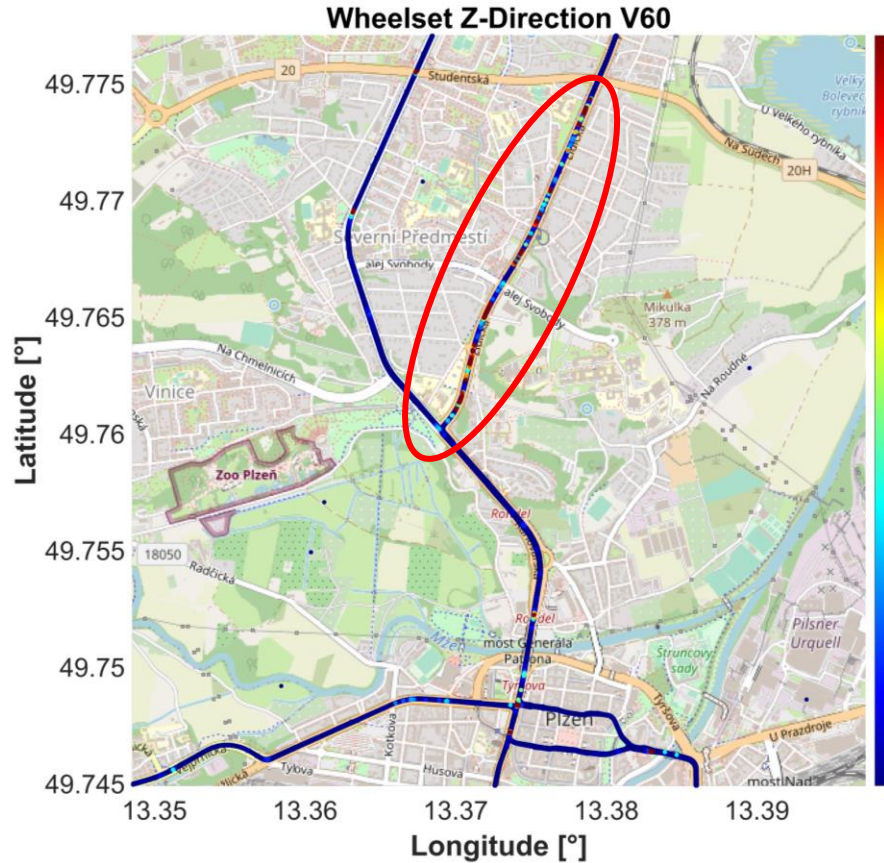
# Acceleration of bogie, Range Pair Counting, Z-direction



# Acceleration of vehicle body, Range Pair Counting, Z-direction



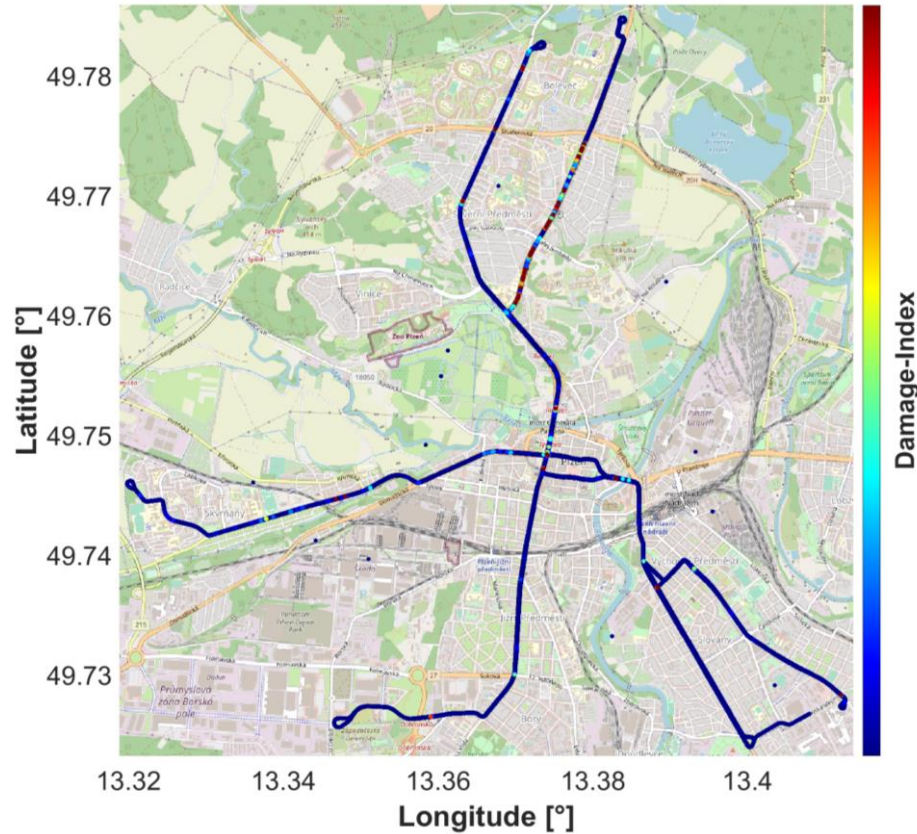
# Acceleration of wheelset bearing, Damage Sum, Z-direction



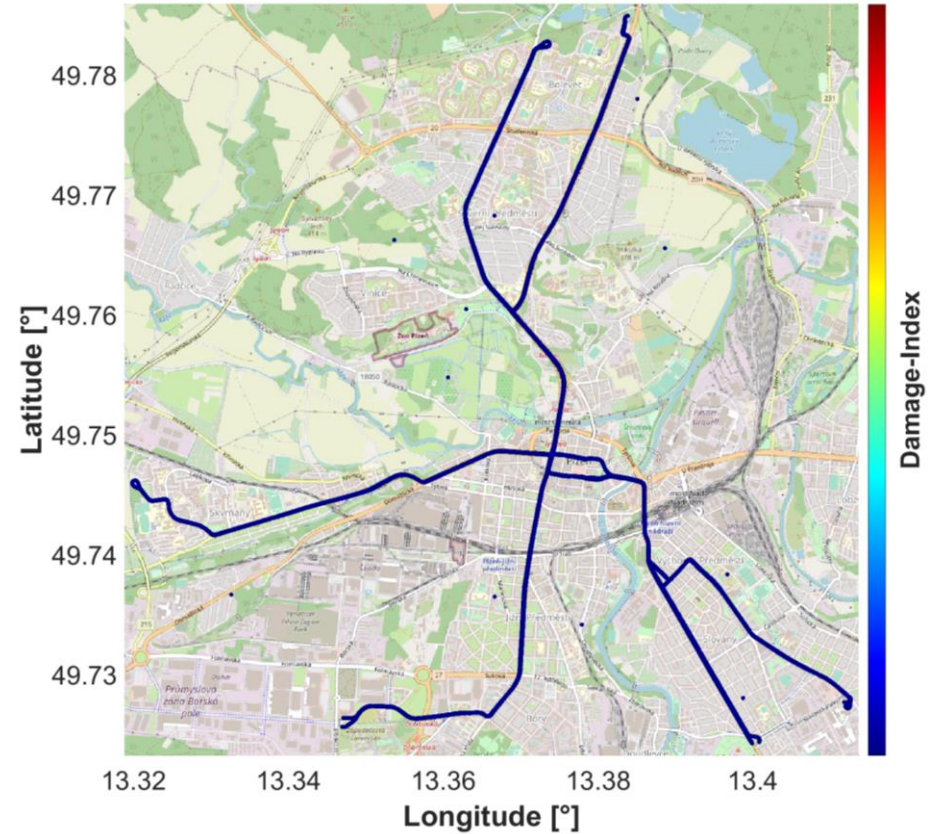


# Acceleration of wheelset bearing, Damage Sum, Z-direction

Wheelset Z-Direction V60

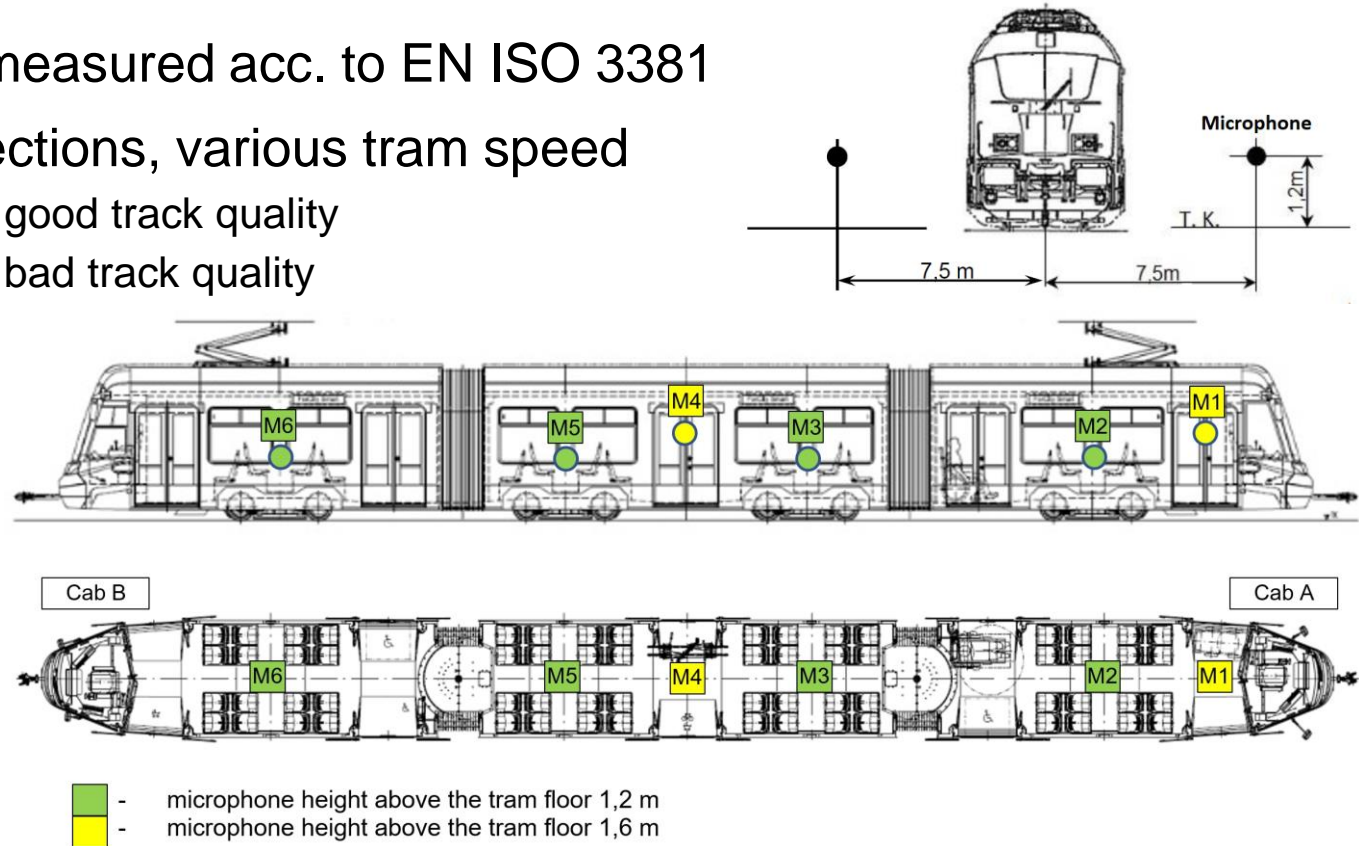


Wheelset Z-Direction Ultra-S



# Measurement of Acoustics – Description of measurement

- External noise measured acc. to EN ISO 3095
- Internal noise measured acc. to EN ISO 3381
- 4 measuring sections, various tram speed
  - straight line – good track quality
  - straight line – bad track quality
  - curved line
  - crossing

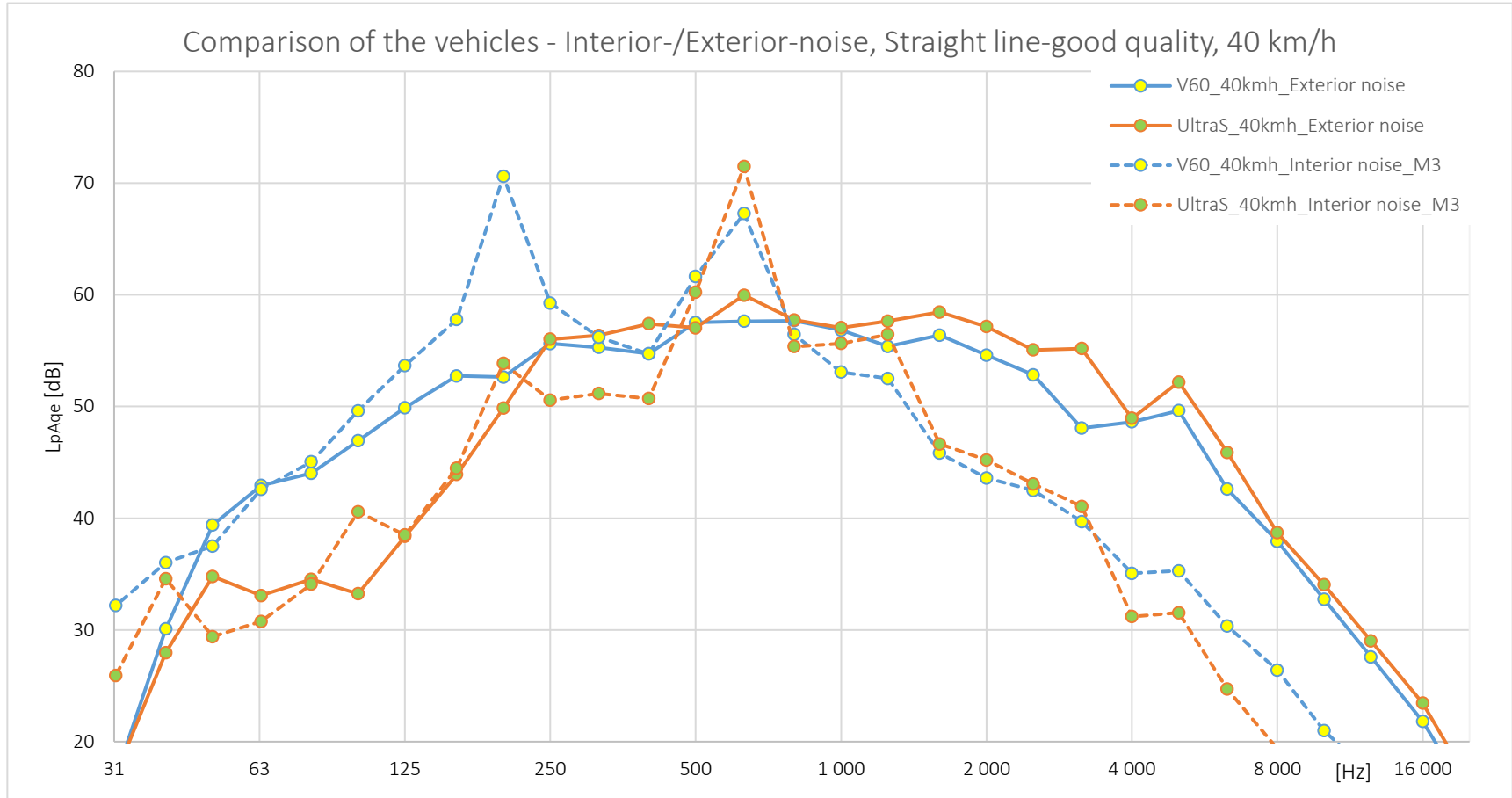


# Measurement of Acoustics - Results

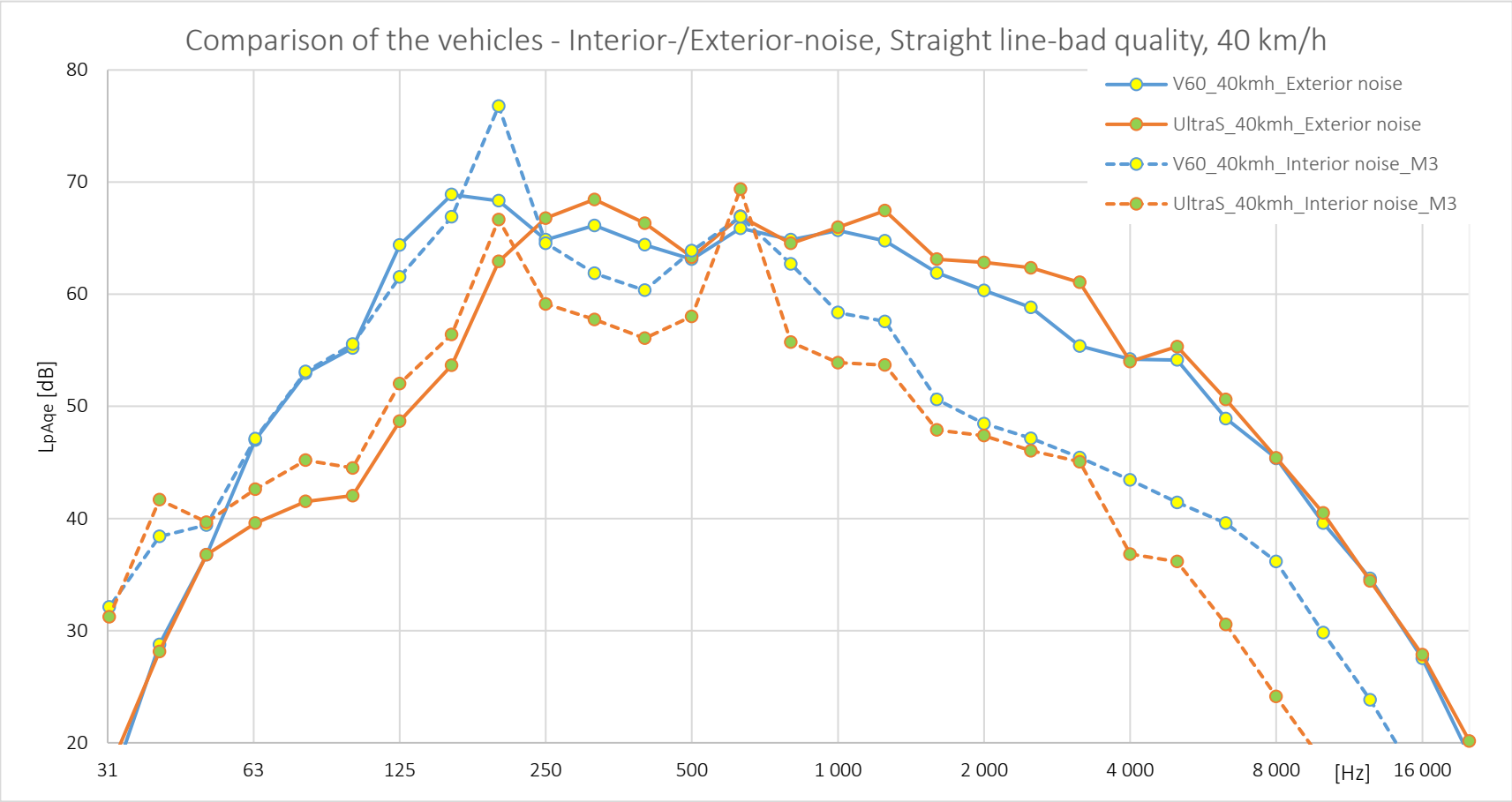
Exterior noise			
Measuring section	Tram speed [km/h]	$\Delta L_{pAeq}$ [dB] ( $L_{pAeq}$ UltraS- $L_{pAeq}$ V60)	$\Delta L_{pAFmax}$ [dB] ( $L_{pAFmax}$ UltraS- $L_{pAFmax}$ V60)
Straight line -good track quality	40	1	1,3
	60	0,9	1
	70	1,4	1,4
Straight line -bad track quality	40	-0,1	-1,2
	60	2,3	2,1
	70	0,6	1
Curved line	15	1,7	6,4
	10	1,5	-5,5
Crossing	15	0,3	0,7

Interior noise													
Measuring section	Tram speed [km/h]	$\Delta L_{pAeq}$ [dB] ( $L_{pAeq}$ UltraS- $L_{pAeq}$ V60)						$\Delta L_{pAFmax}$ [dB] ( $L_{pAFmax}$ UltraS- $L_{pAFmax}$ V60)					
		M1	M2	M3	M4	M5	M6	M1	M2	M3	M4	M5	M6
Straight line -good track quality	40	-2,0	-4,7	-1,9	-1,5	-2,6	3,1	-0,7	1,3	-1,4	1,6	-4,7	1,7
	55	-2,1	-3,6	-9,5	-2,8	-6,7	-3,9	3,7	-2,8	-11,4	-3,7	-10,5	-2,7
Straight line -bad track quality	40	-7,3	-8,0	-6,9	-7,2	-9,1	-8,6	-5,3	-6,0	-12,7	-8,1	-10,1	-5,7
	55	-5,3	-5,7	-8,5	-5,9	-8,0	-4,0	-5,2	-5,1	-9,3	-4,0	-11,2	-1,3
Curved line	15	-4,6	-5,7	-6,3	-5,2	-5,4	-3,7	-5,4	-5,4	-6,8	-6,7	-7,3	-2,5
Crossing	15	-4,7	-4,9	-8,7	-5,5	-4,4	-3,5	-5,4	-5,2	-9,9	-3,7	-5,3	-1,8

# Measurement of Acoustics - Results



# Measurement of Acoustics - Results



## Conclusion

- With the **GHH® Ultra-S** wheels, the acceleration amplitudes at the wheelset bearing are lower by a factor of 3 in comparison to the **GHH® V60** wheels.
- A reduction of 50% has been measured on the bogie and the car body.
- The positive effect on component loading and ride comfort was confirmed
- Noise level inside the vehicle is significantly reduced by the **GHH® Ultra-S** wheels

# Q&A



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