Rail Fasteners Looseness Detection by Analysing Real and Synthetic Axle-Box Acceleration Data: A Dual Approach

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CEIT

Private non-profit research centre located in San Sebastián

Founded by **Universidad de Navarra**

Multidisciplinary applied research: manufacturing, energy, transportation…

Founding member of Europe's Rail Joint Undertaking

More than **40 years** working on Railway sector:

- Railway dynamics
- Noise and vibration
- Switches and crossings
- Corrugation
- Smart maintenance
- Positioning and communications
- …

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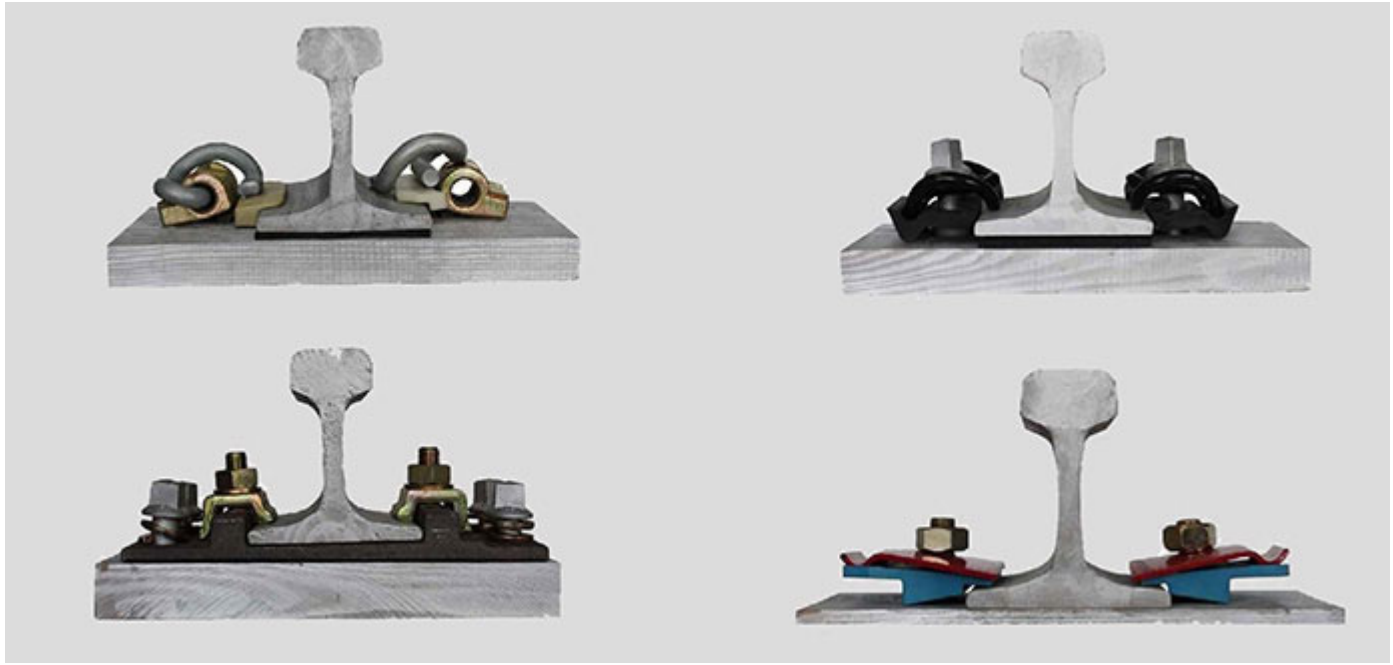
Introduction | Fastening Systems



AGICO GROUP

Rail fastening systems:

- Direct fastening systems
- Indirect fastening systems

- Threaded fastening systems
- Non-threaded fastening systems

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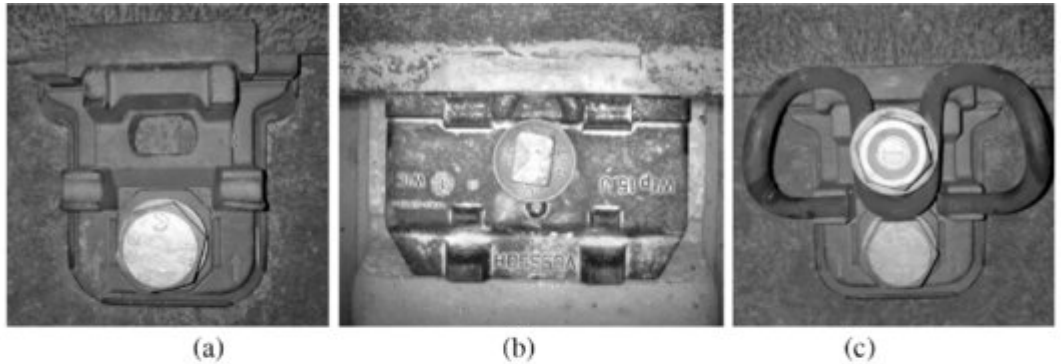
Introduction | Rail Fasteners



Systematic state-of-the-art review

- 495 articles found (2012-2023)
- 200 articles reviewed
- 90 articles analysed and extracted

covidence

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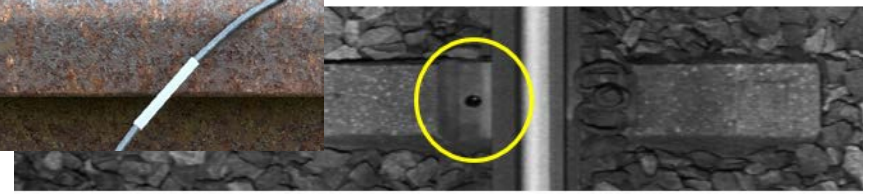
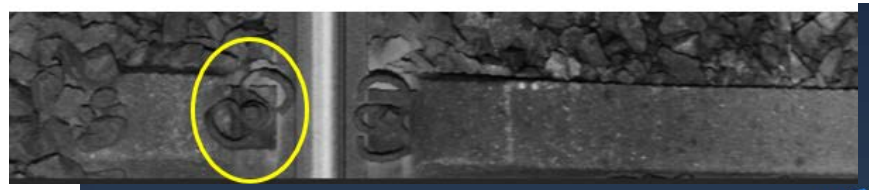
Methodology | Four steps

- **Modal analysis**: evaluation of rail reaction to different torque situations (impact hammer test)
- **Real acceleration signals**: analysis of real axle box acceleration signals in a section of track where loose fasteners have been detected using a vision device (Leonardo vehicle, by STRUKTON RAIL)
- **Virtual acceleration signals**: creation of a virtual model of track and vehicle, reproducing the loose fasteners conditions and analysis of data provided by virtual sensors (ABAQUS, SIMPACK)
- **Algorithms**: development of different algorithms to detect loose fasteners and validation of model, with both real and synthetic data (MATLAB)





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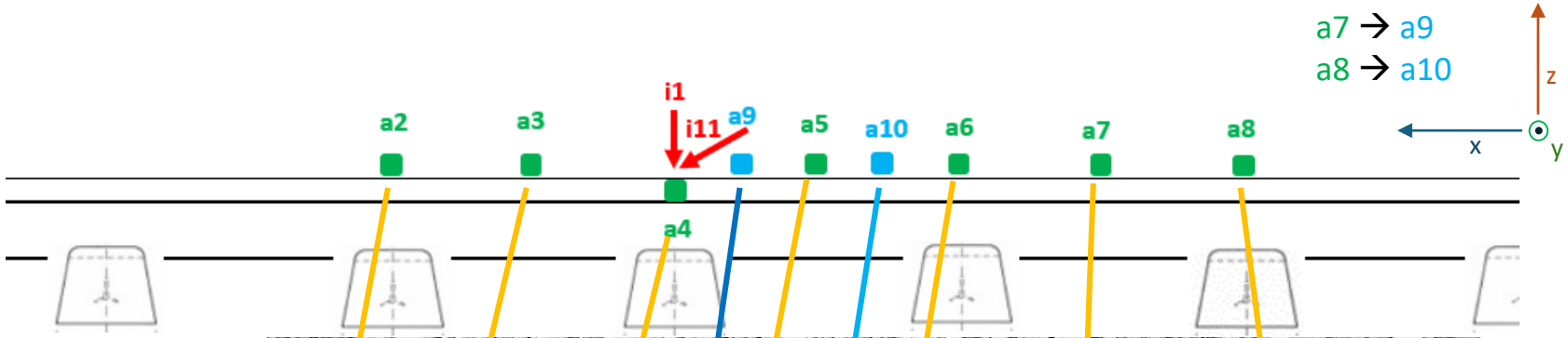
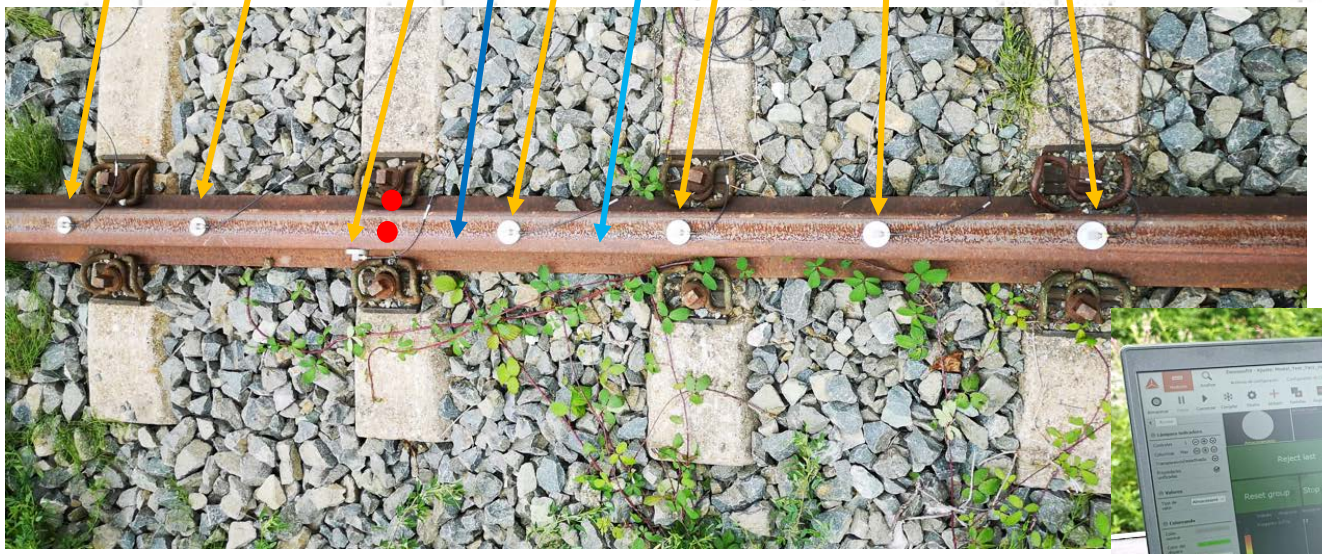
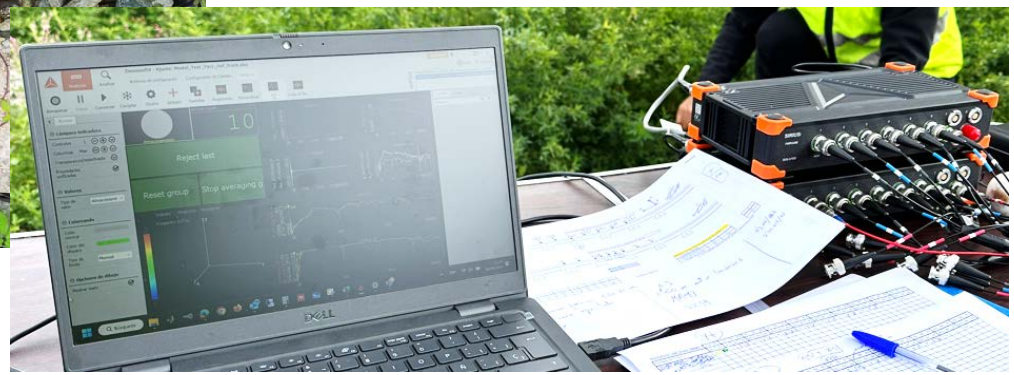
Methodology | Modal Analysis







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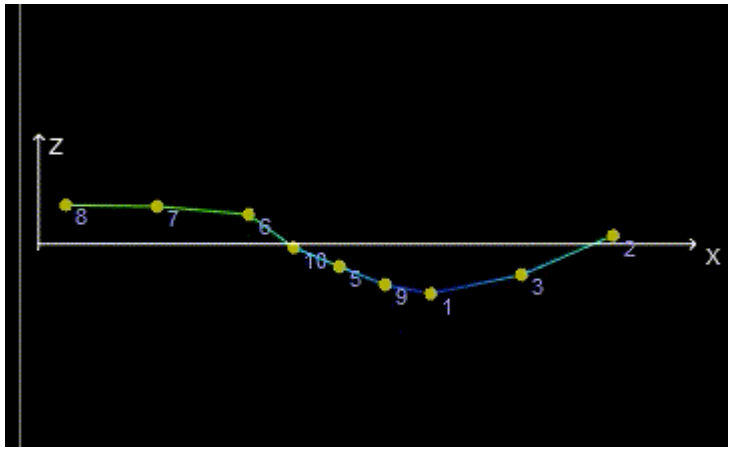
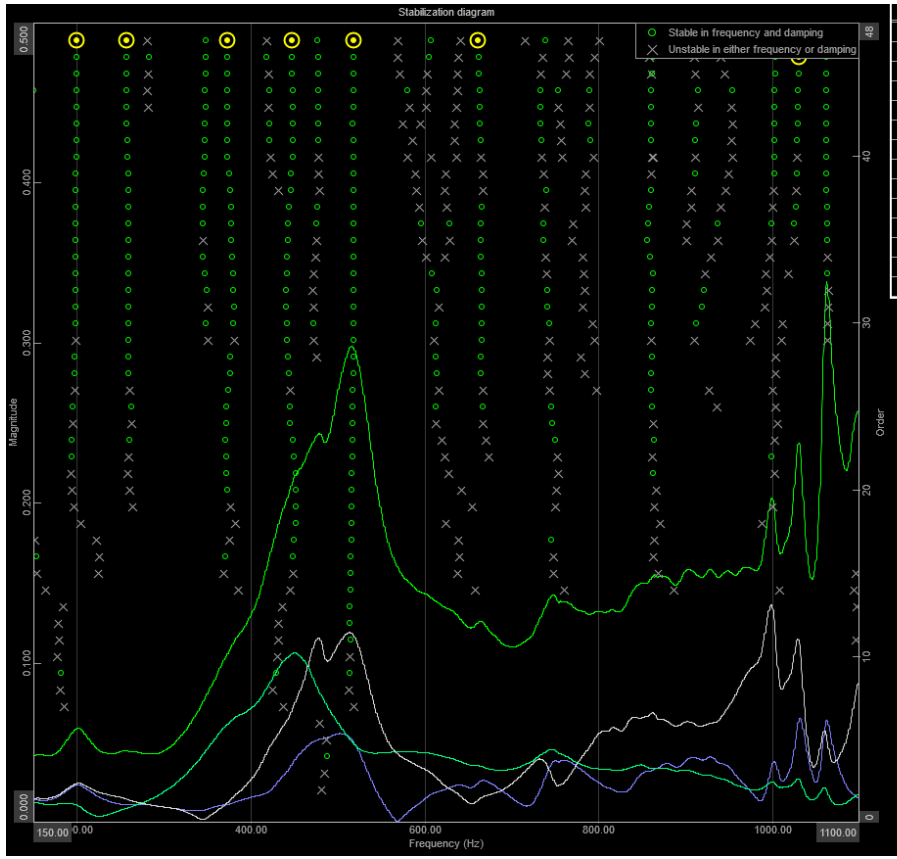
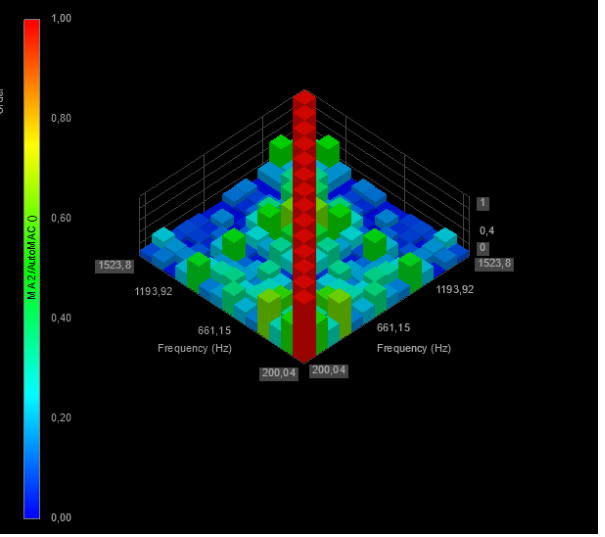
Methodology | Modal Analysis

Excitation Number	1	2	3	4	5	6
Tightening torque (N·m)	220	165	110	80	0	*0 / 0*
Damage severity (%)	0	25	50	64	100	*100*





Mode (Id)	Damped frequencies (Hz)	Damping ratios (%)	MCF (%)
1	200,04	9,061	42,63
2	257,35	8,260	86,85
3	373,02	10,076	73,09
4	447,58	7,700	57,66
5	518,36	5,139	47,63
6	661,15	3,181	96,67
7	1002,49	0,843	56,27
8	1030,56	0,551	39,58
9	1062,21	0,560	26,22
10	1117,99	1,511	15,70
11	1193,92	0,929	86,57
12	1378,85	1,665	23,31
13	1420,26	0,652	49,37
14	1523,80	0,918	64,59



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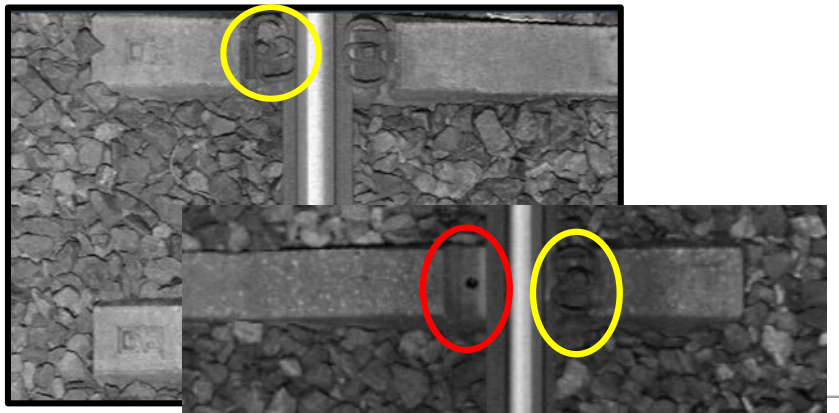
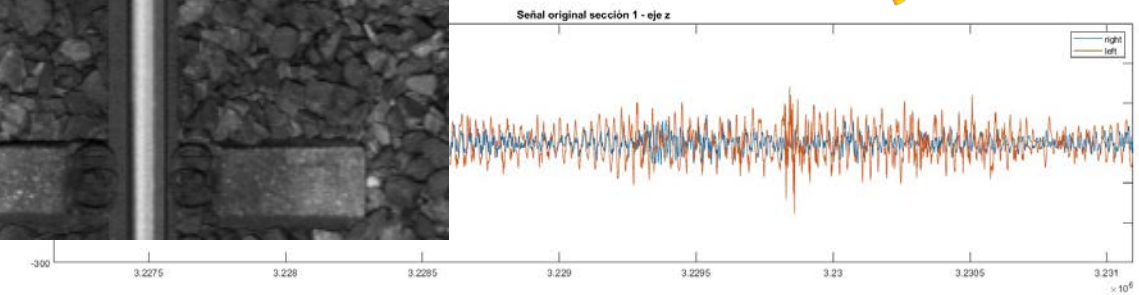
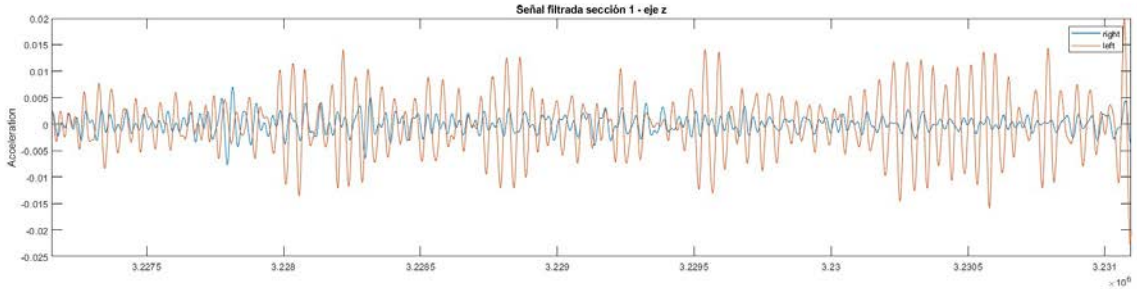
Methodology | Real ABA signals

Leonardo inspection vehicle (STRUKTON)







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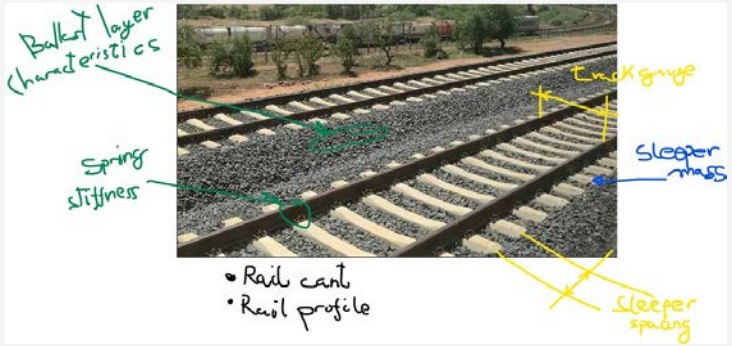
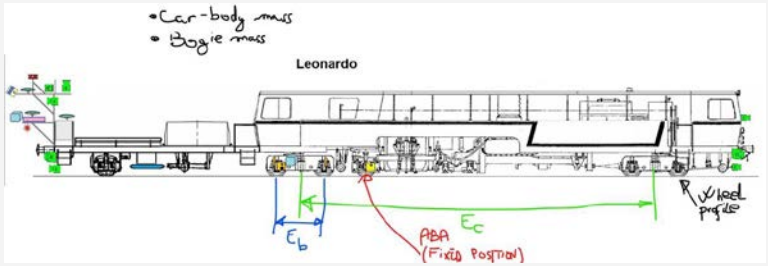
Methodology | Virtual acc. signals

Track and vehicle data	Modelling	Results and processing

Track data

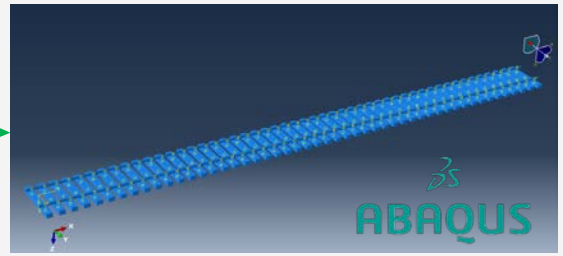


Vehicle data

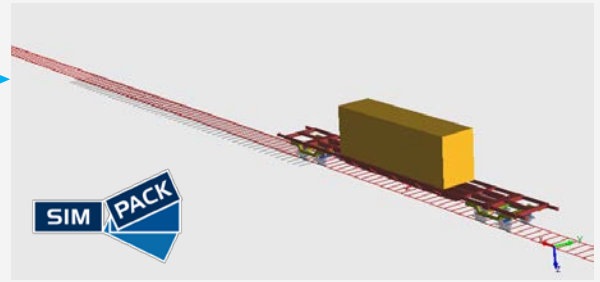


Input Data
Inertia
Mass
Stiffness
Damping

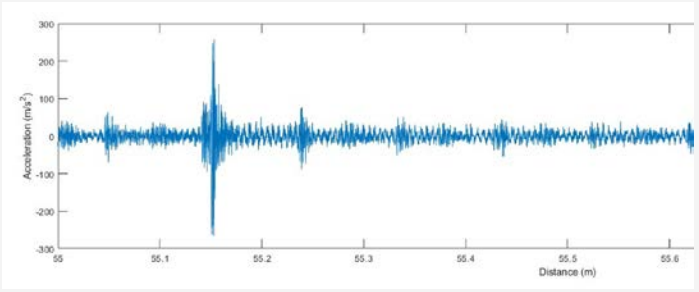
FEM



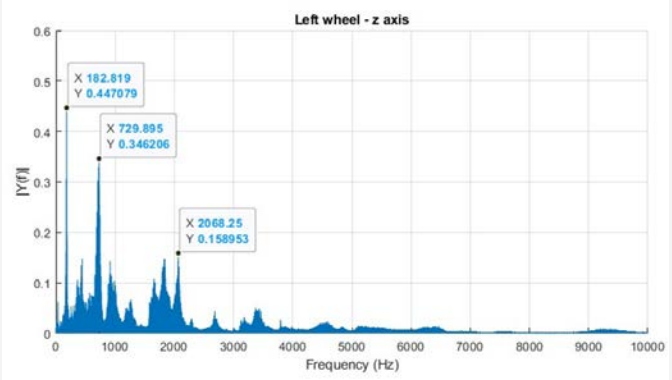
MBS



Results

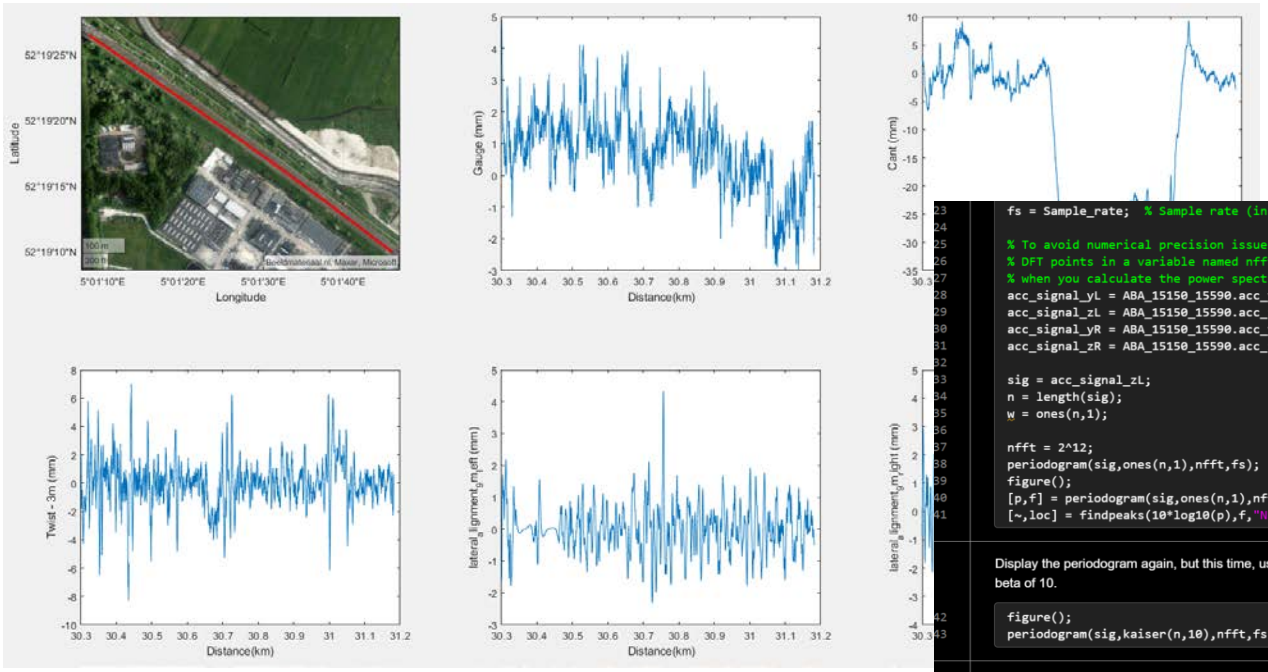


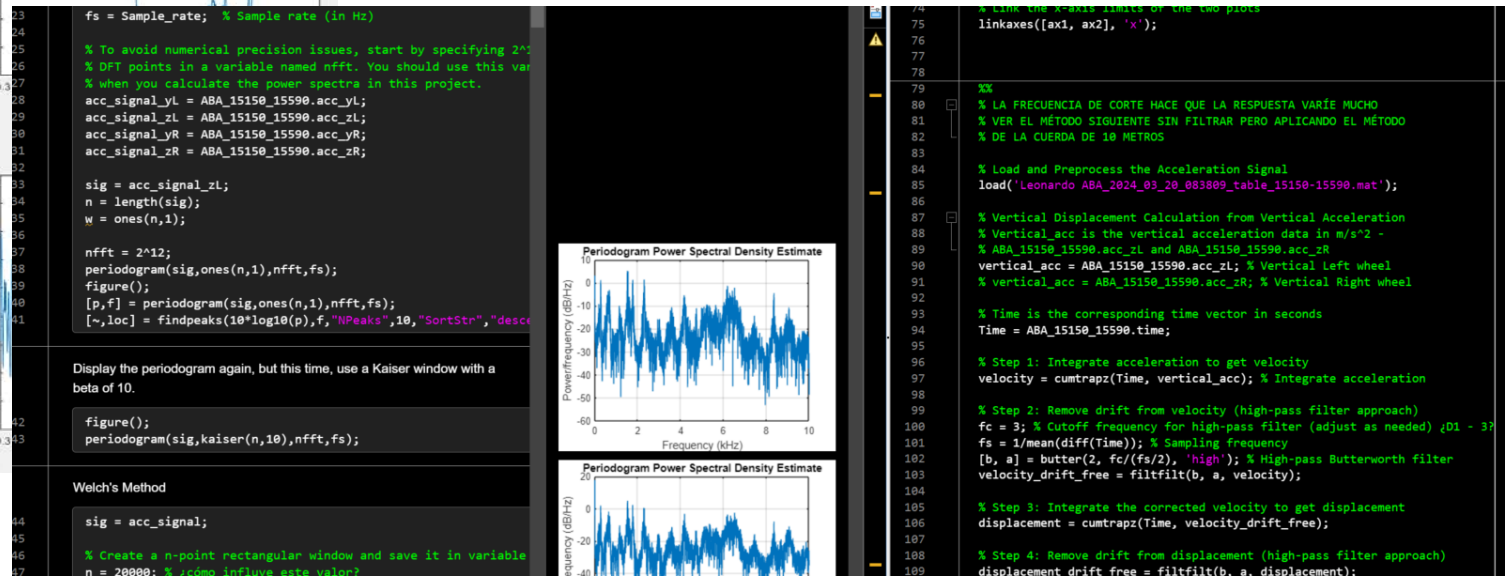
Processing



Methodology | Algorithms

- Acceleration signal filtering
- Analysis of the signal on the time domain and in the frequency domain: power spectral density (PSD), time-domain Bayesian approach, CNN trained using time-domain data, wavelet packet analysis, Power Spectrum Entropy





Conclusions and overview

- ✓ After the modal test, a comparison between the vibrational response of the rail at different torque conditions of the fasteners is being done
- ✓ The track model is being created in FEM environment and will be imported into the multibody software
- ✓ The detection algorithms will be developed and tuned using real and synthetic ABA data

- X At this stage, the track model is a simplification, which can be made more detailed or complex once the method has been validated
- X Once the model is validated, the synthetic data could be used to train machine learning models.

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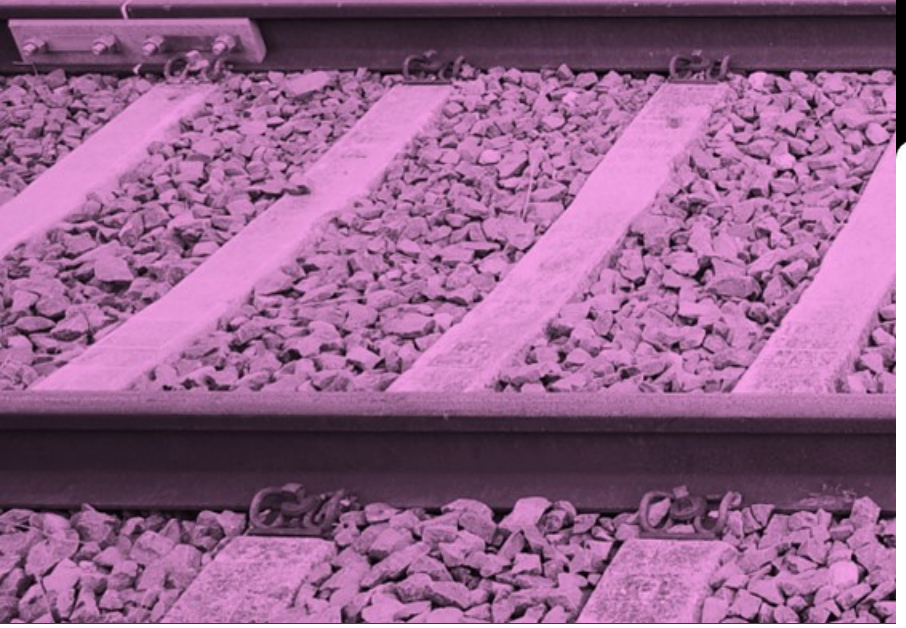

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