Optimising components in the rail support system for dynamic vibration absorption and pass-by noise reduction

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2023-02-21 ICRI workshop on Noise and Vibration

Applied Acoustics / CHARMEC
Chalmers University of Technology
Gothenburg, Sweden

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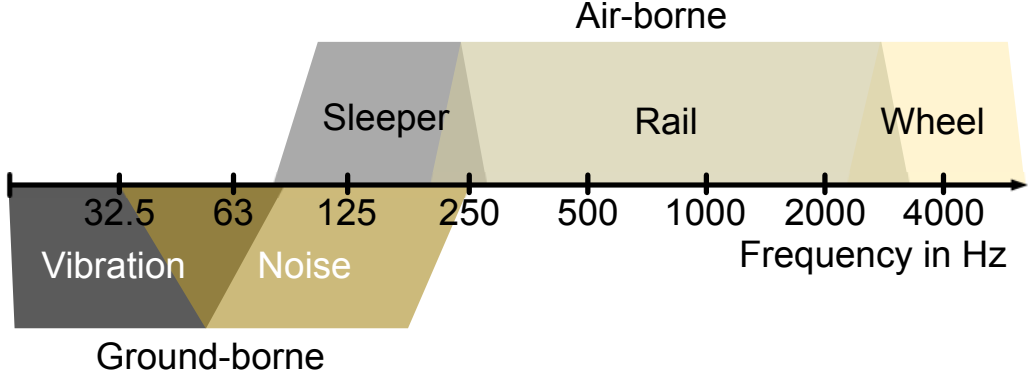
Background

- Rail pad stiffness is main lever for reducing noise from the rail
- Slab tracks typically have low rail pad stiffness
- Increasing rail pad stiffness increases load on supporting structure and ground-borne vibrations
- Conflict of interest: air-borne noise vs. ground-borne vibrations



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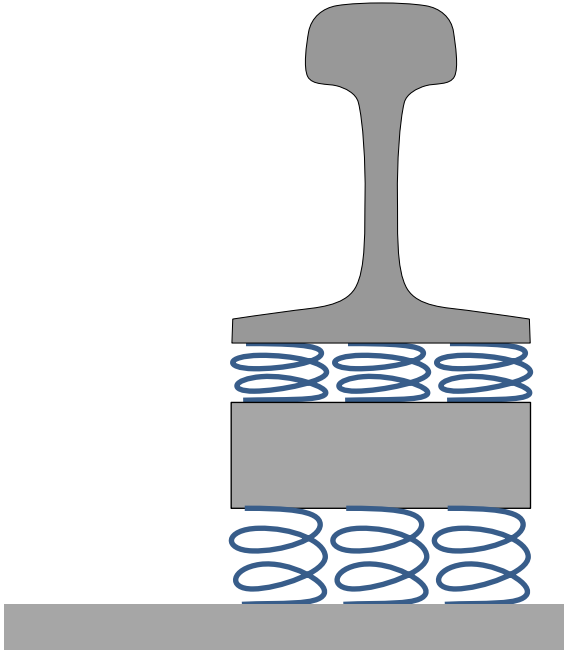
Background

- Two-stage elastic support acts like a dynamic filter



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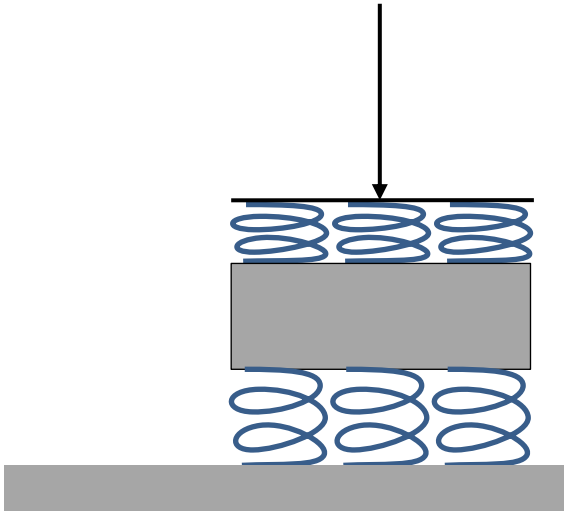

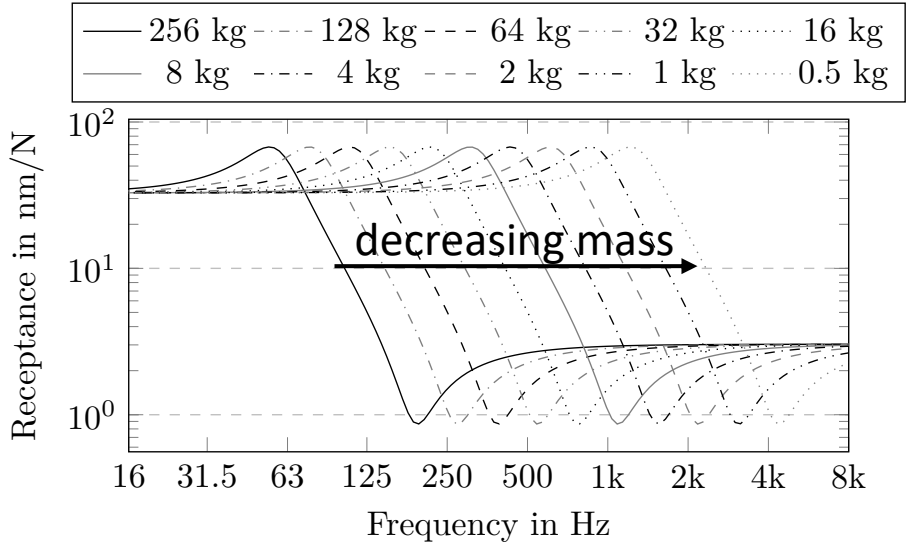

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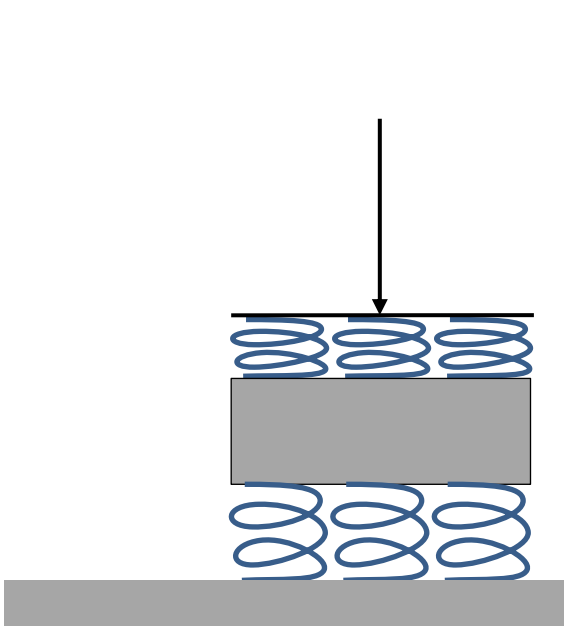

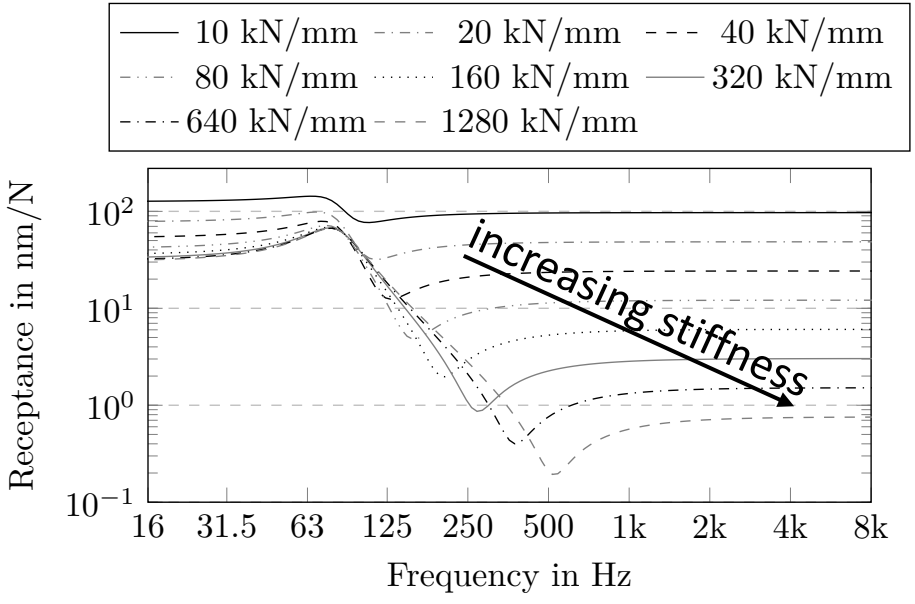

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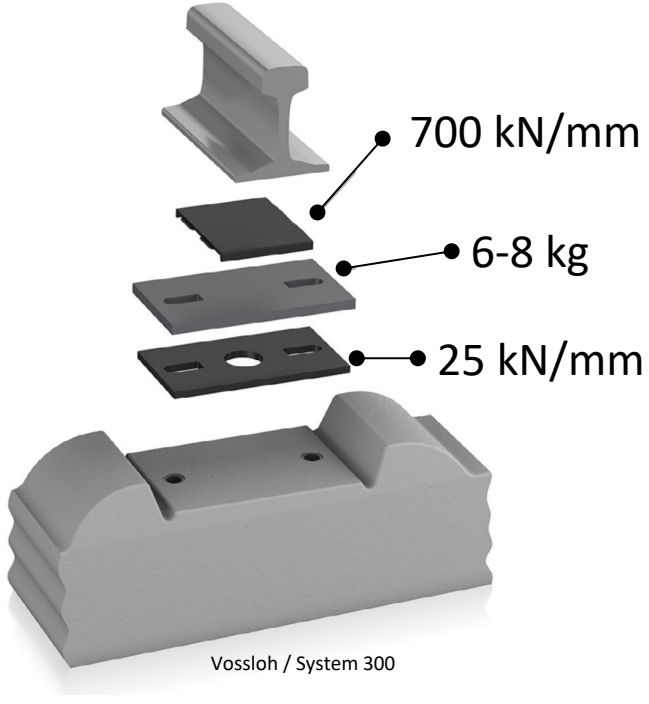
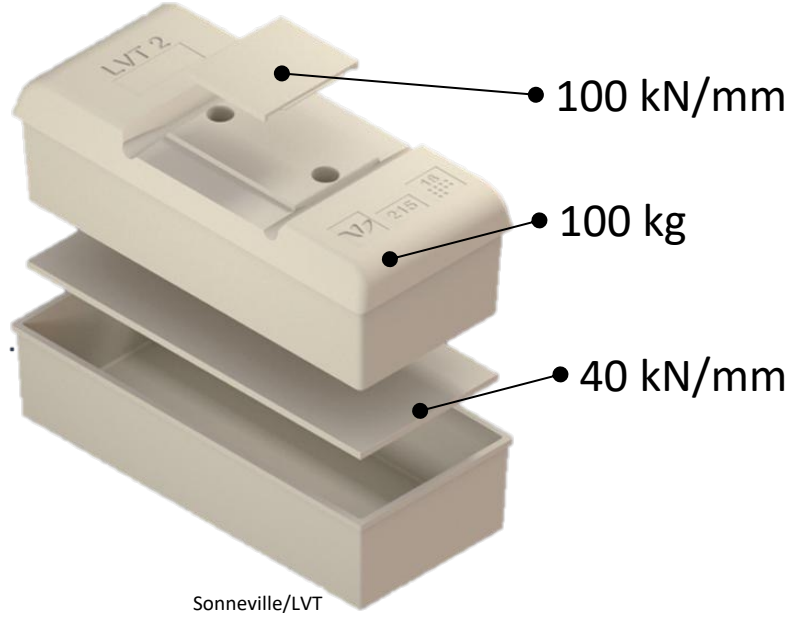


Vossloh / System 300



Sonneville/LVT

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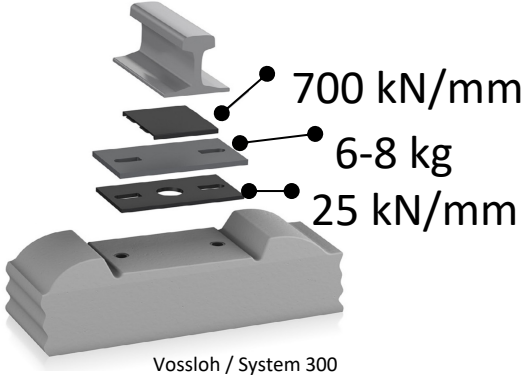
Background



Vossloh / System 300

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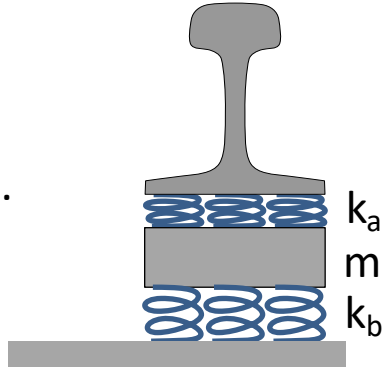

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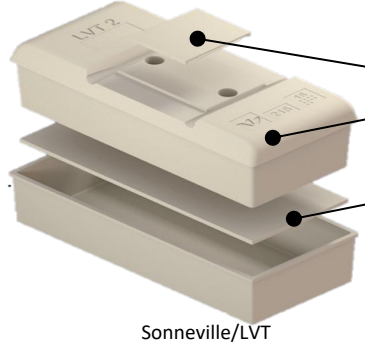
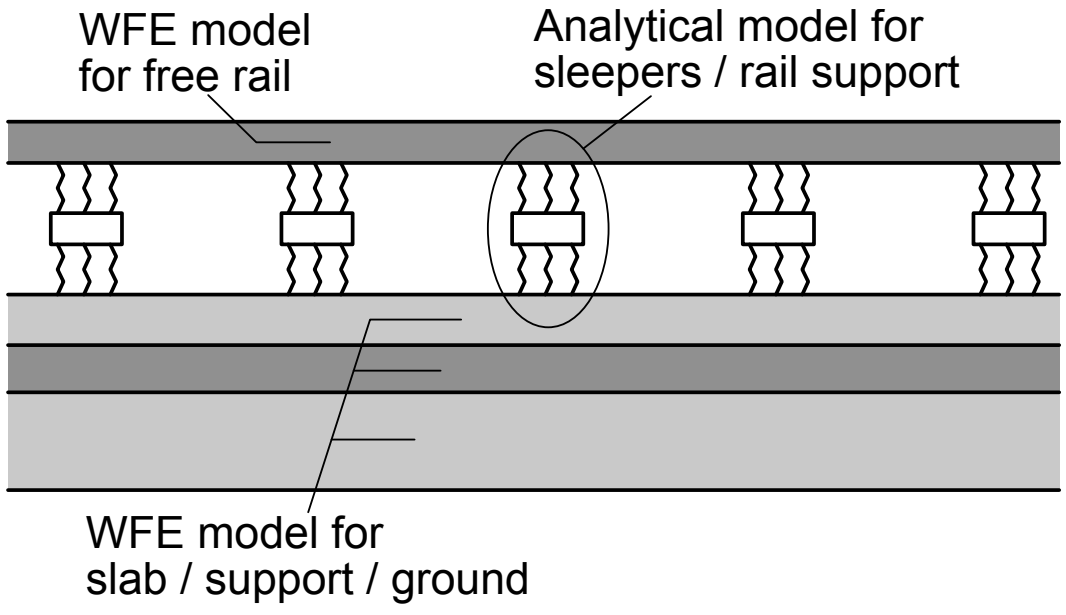


Sonneville/LVT

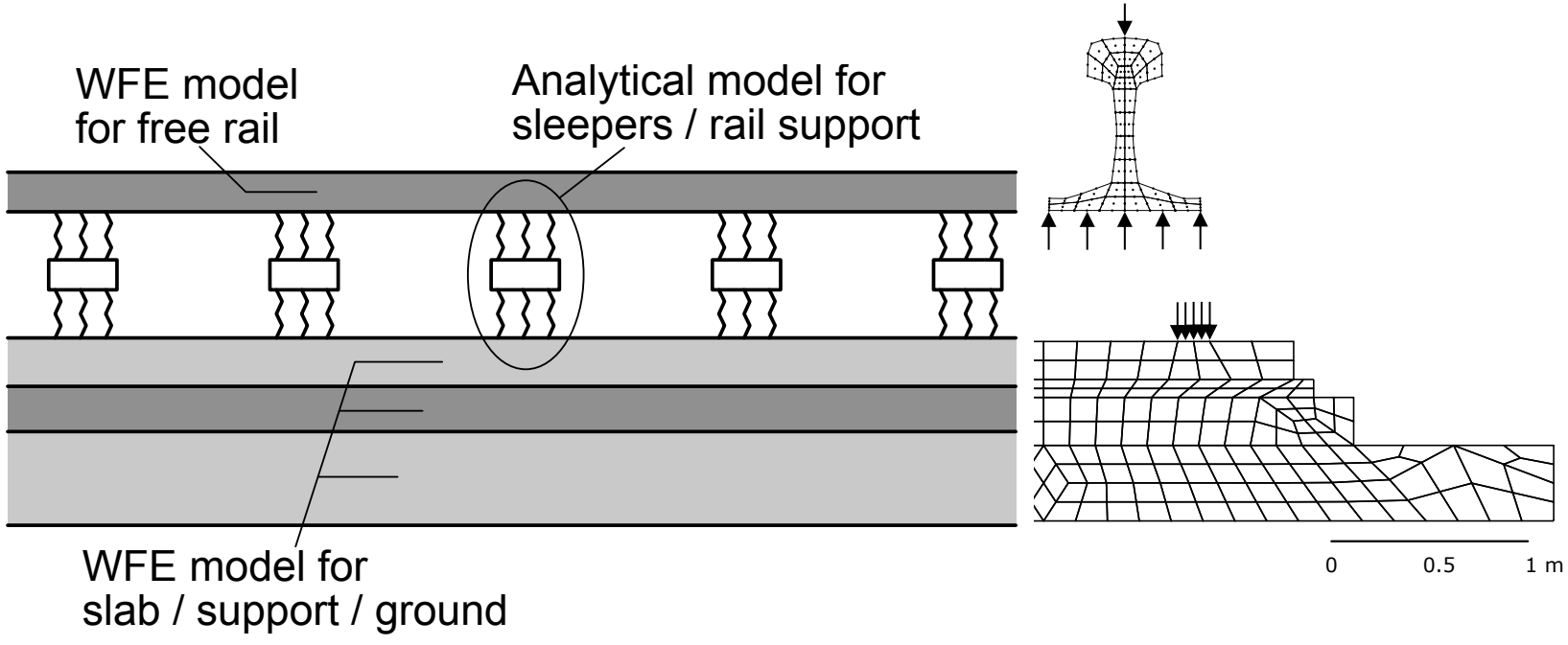
Vertical stiffness above the mass k_a (kN/mm)	25, 50, 100, 200, 400, 800
Weight of the mass m (kg)	8, 16, 32, 64, 128
Vertical stiffness below the mass k_b (kN/mm)	20, 40

Rolling contact force, support forces, radiated sound?

Dynamic model



Dynamic model



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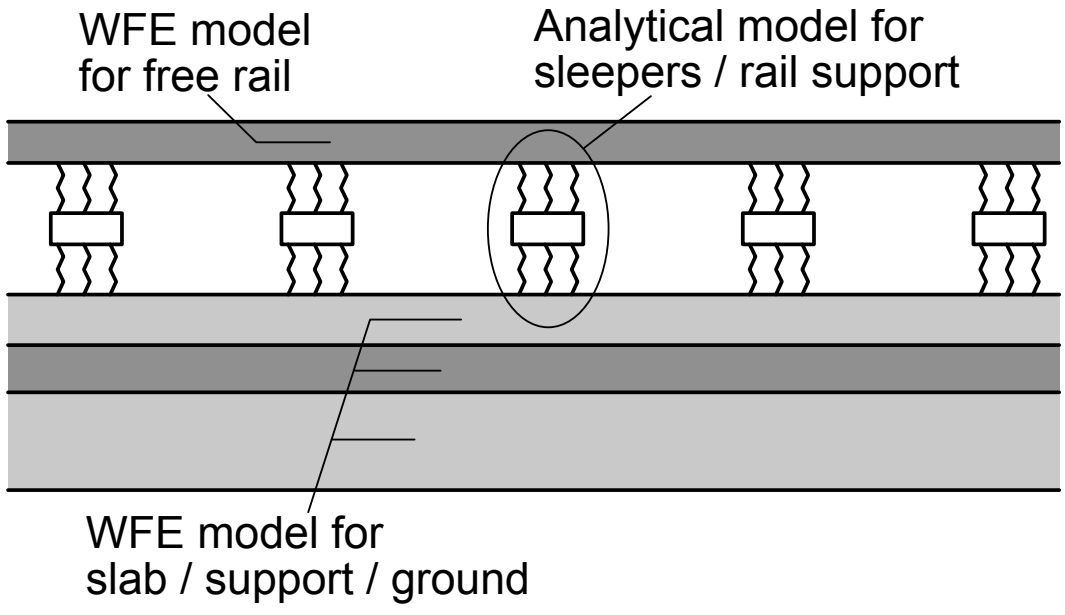
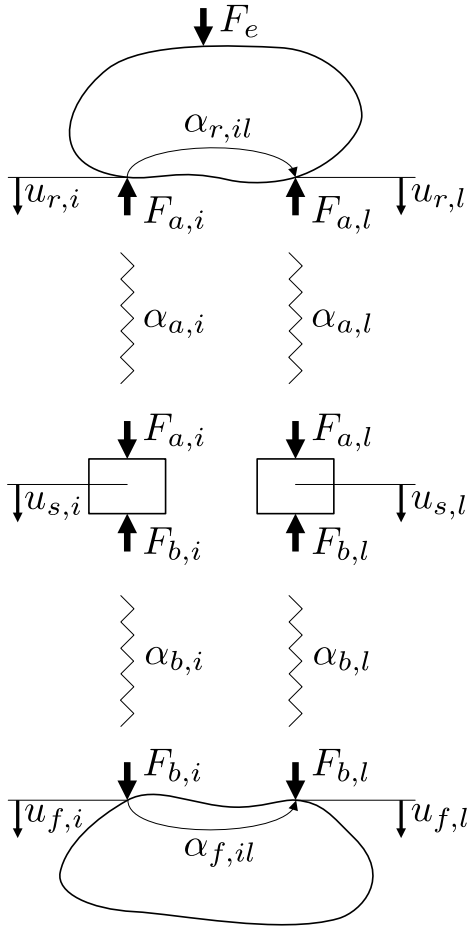
Dynamic model





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Dynamic model

$$u_{r,i} = \alpha_{r,ie} F_e - \sum_{l=1}^{N} \alpha_{r,il} F_{a,l}$$

$$u_{f,i} = \sum_{l=1}^{N} \alpha_{f,il} F_{b,l}$$

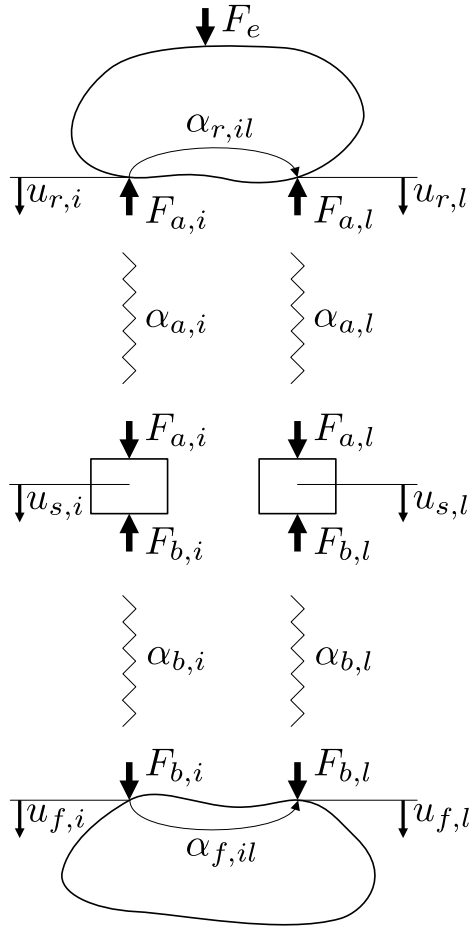
$$u_{r,i} - u_{s,i} = \alpha_{a,i} F_{a,i}$$

$$u_{s,i} - u_{f,i} = \alpha_{b,i} F_{b,i}$$

$$u_{s,i} = \frac{F_{a,i} - F_{b,i}}{-\omega^2 m}$$

$$\alpha_{s,i} = \frac{1}{-\omega^2 m_i}$$

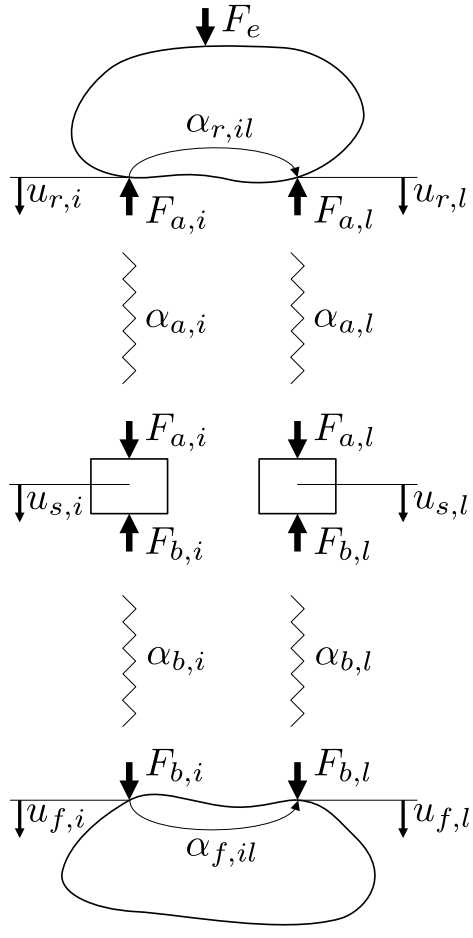
$$\begin{bmatrix} \alpha_r + \alpha_a + \alpha_s & -\alpha_s \\ -\alpha_s & \alpha_f + \alpha_b + \alpha_s \end{bmatrix} \begin{bmatrix} \mathbf{F_a} \\ \mathbf{F_b} \end{bmatrix} = \begin{bmatrix} \alpha_{r,e} F_e \\ \mathbf{0} \end{bmatrix}$$



Dynamic model

- infinitely long rail and slab / support
- finite number of discrete rail seats
- individual stiffnesses and mass at each rail seat

- Calculate rail, sleeper and slab surface vibration



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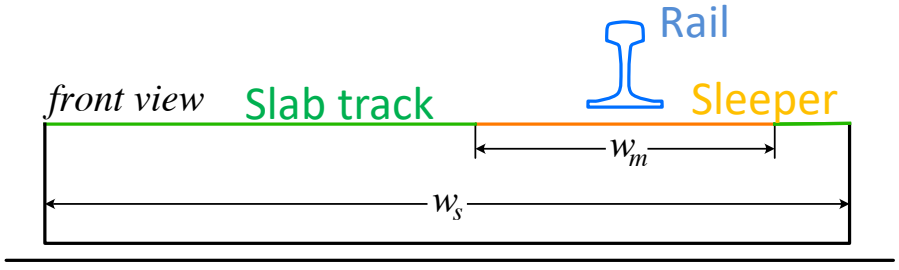
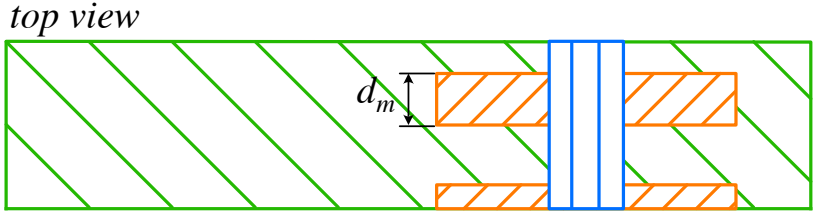
Radiation model

Wavenumber domain BE (2.5D BE)





8 kg

16 kg

32 kg

64 kg

128 kg

15 x 10 cm

22.5 x 40 cm

30 x 70 cm

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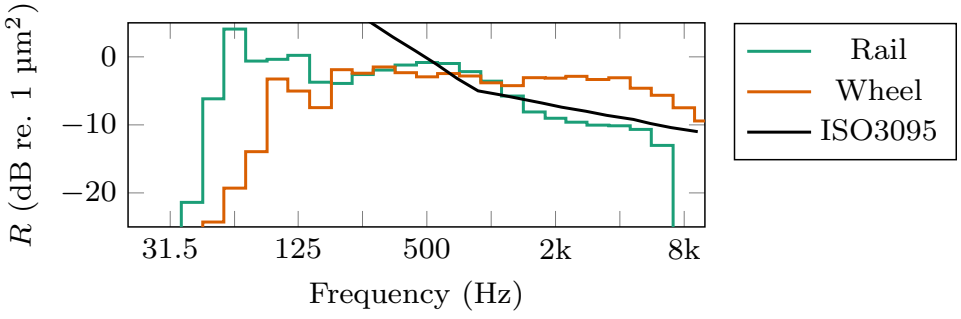
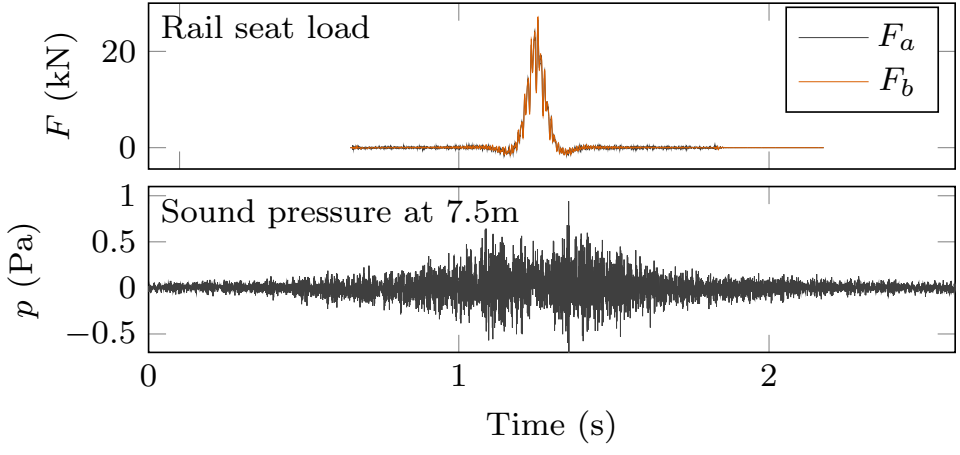
Pass-by simulation

- Roughness from measured wheel and rail

- Time-domain calculation of
  - Contact forces F_c
  - Forces F_a and F_b
  - Sound power





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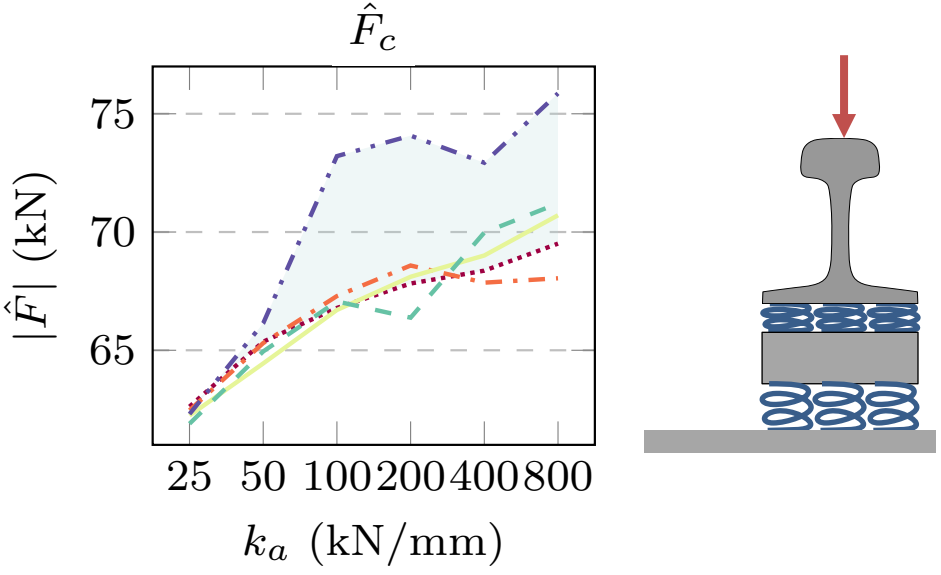
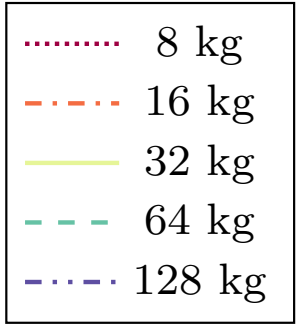
Pass-by simulation

Peak forces during pass-by





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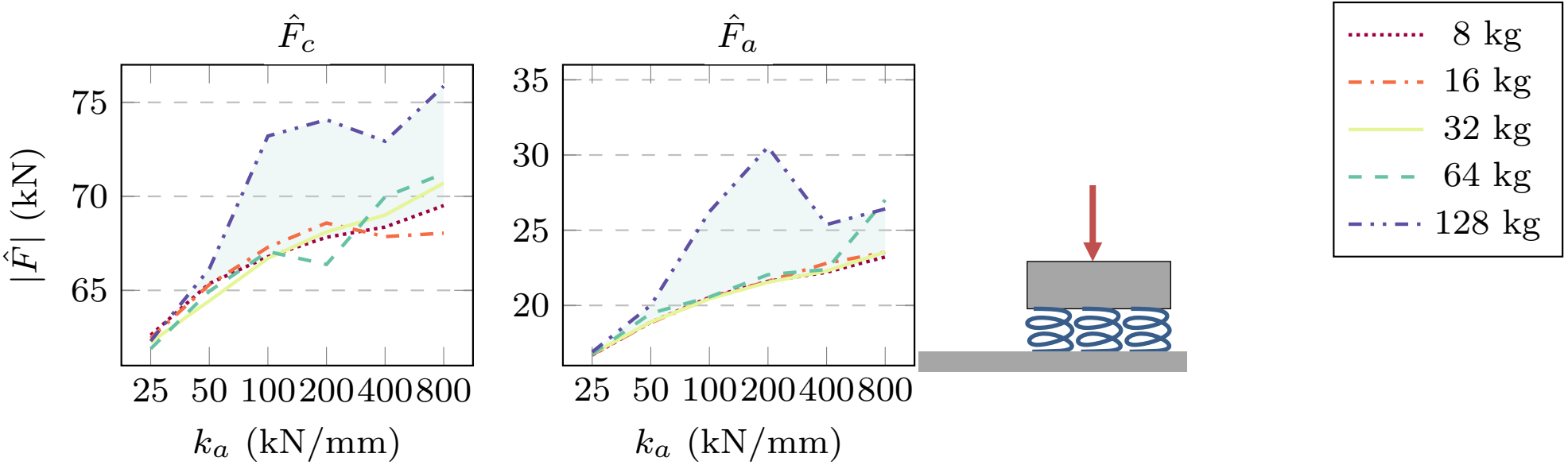

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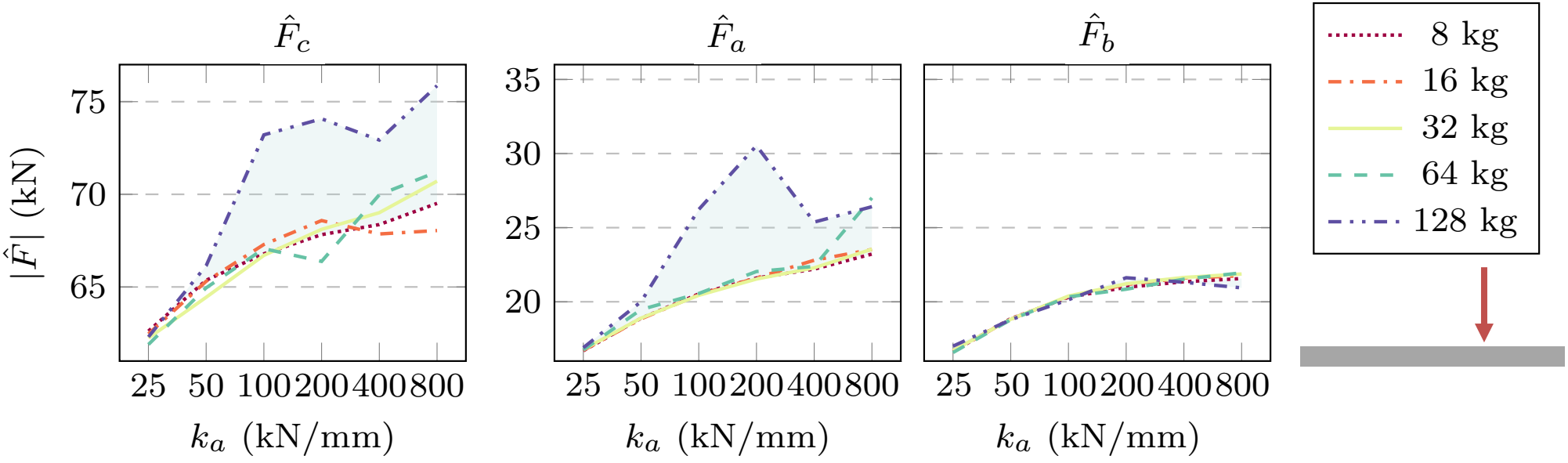

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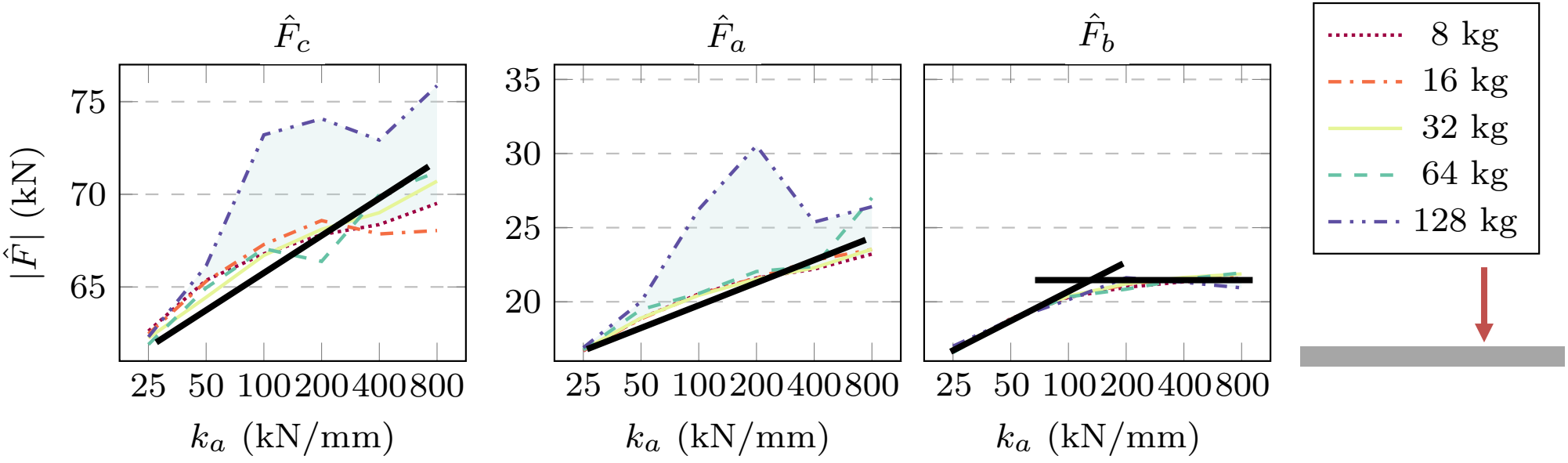

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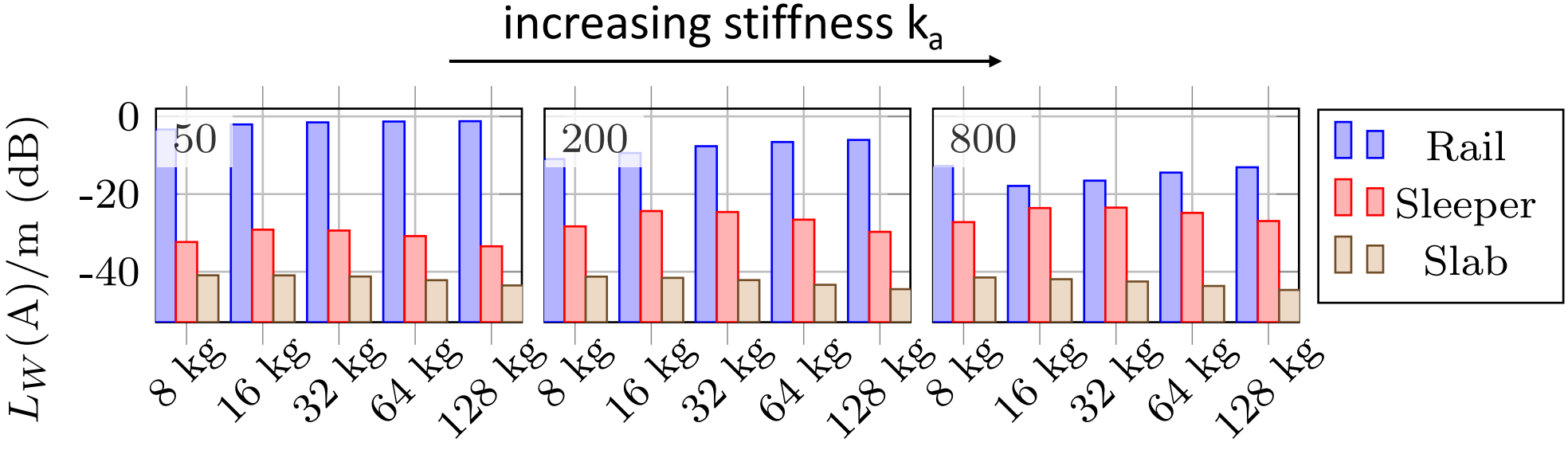
Pass-by simulation

Radiated sound power



Pass-by simulation

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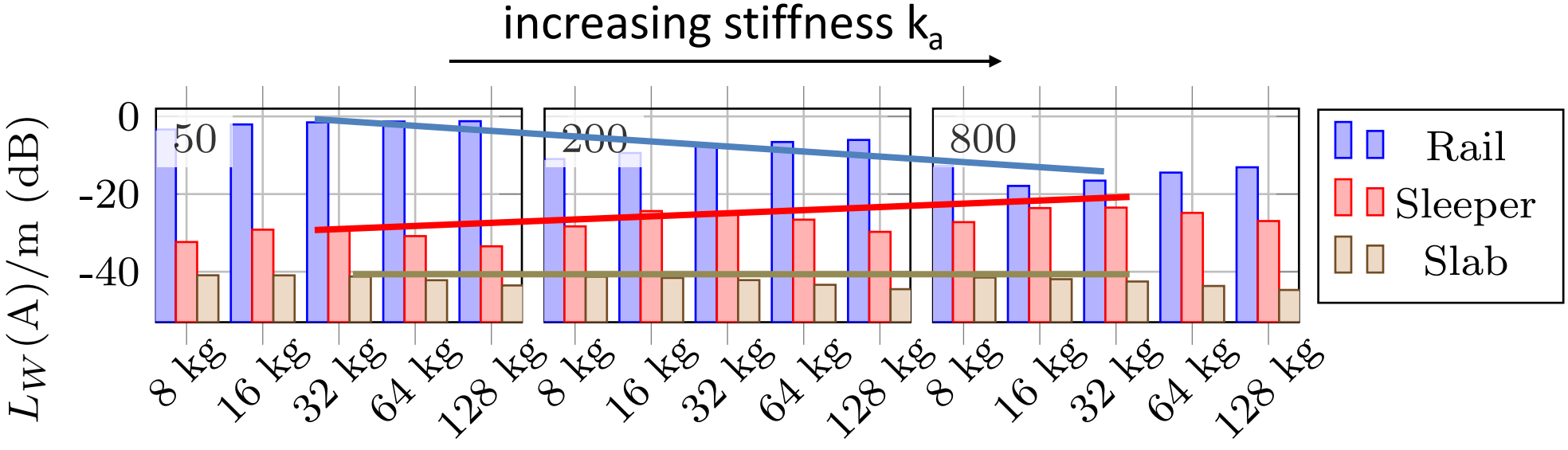

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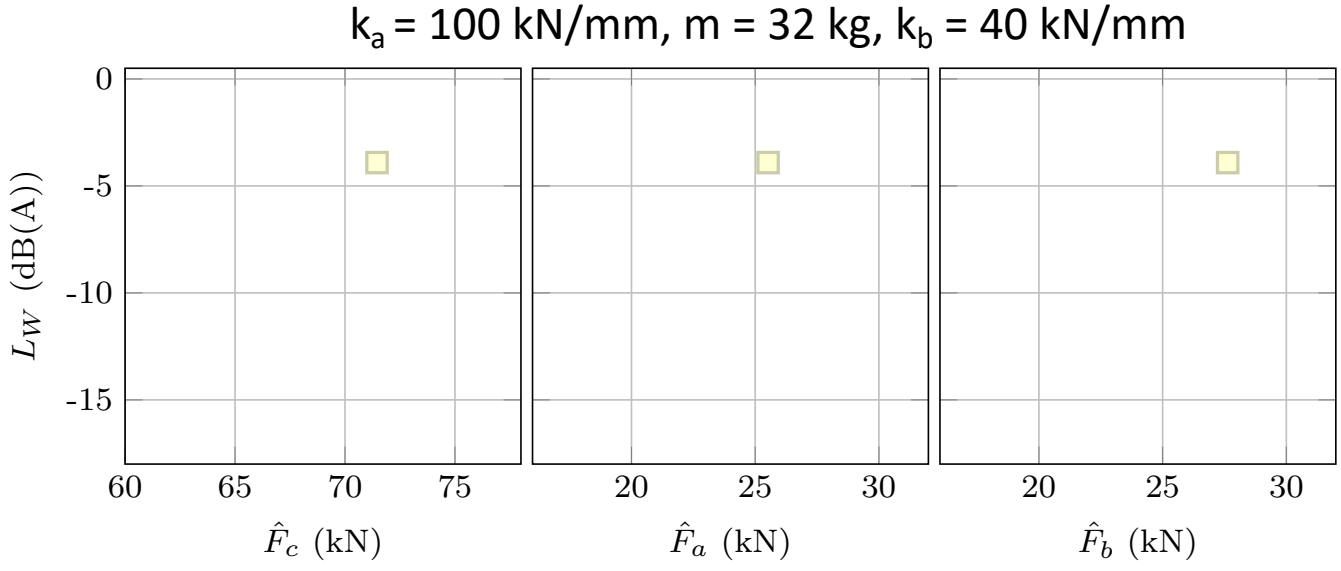
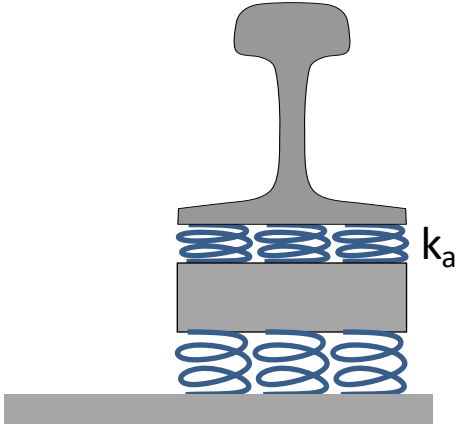
Pass-by simulation

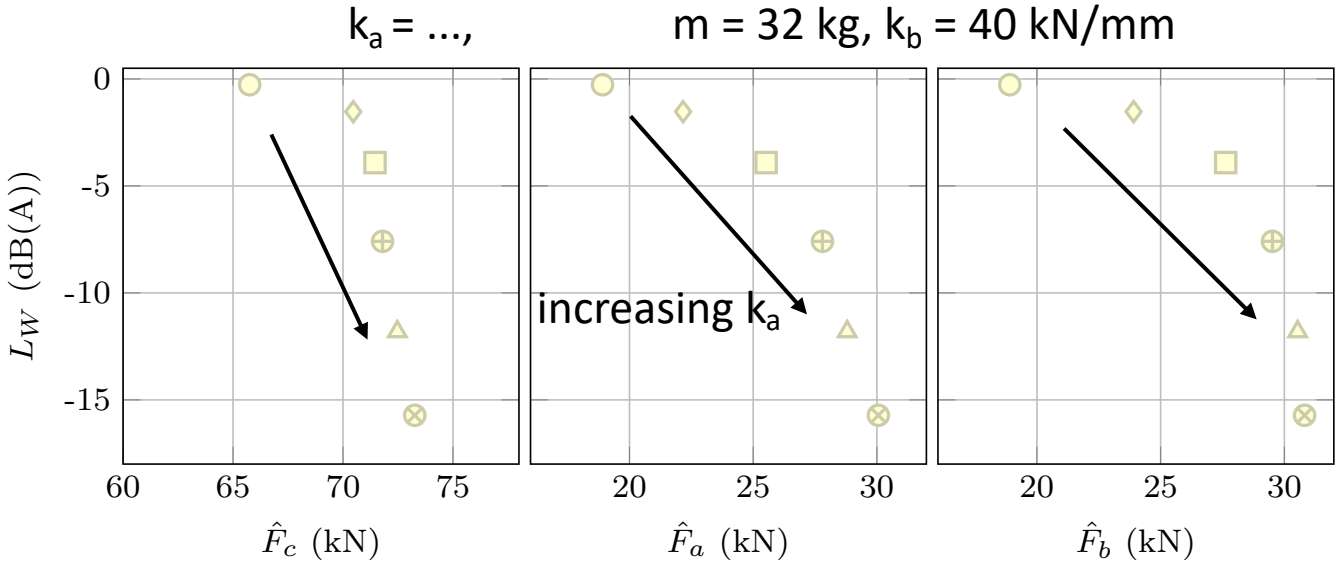
- Each track is represented by one data point



Pass-by simulation

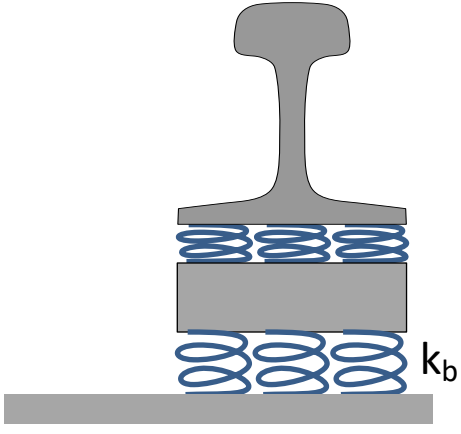
- Increasing k_a
- decreases L_W
- increases forces

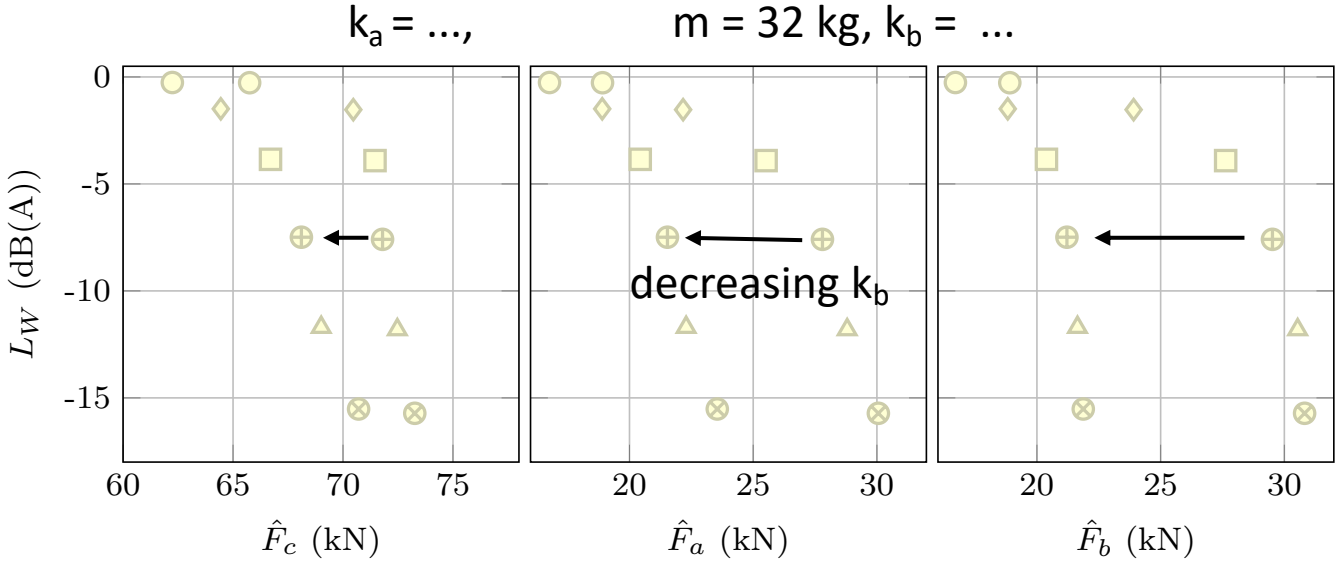




Pass-by simulation

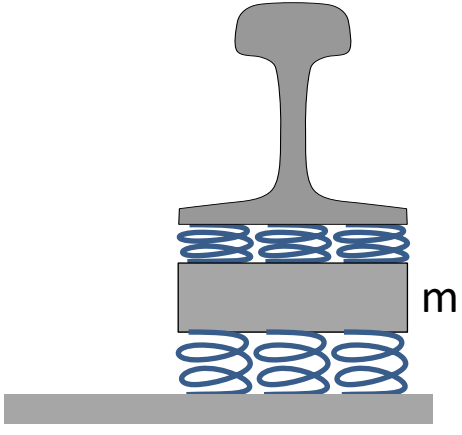
- Decreasing k_b
  - decreases the forces F_c, F_a, and F_b
  - small impact on L_W

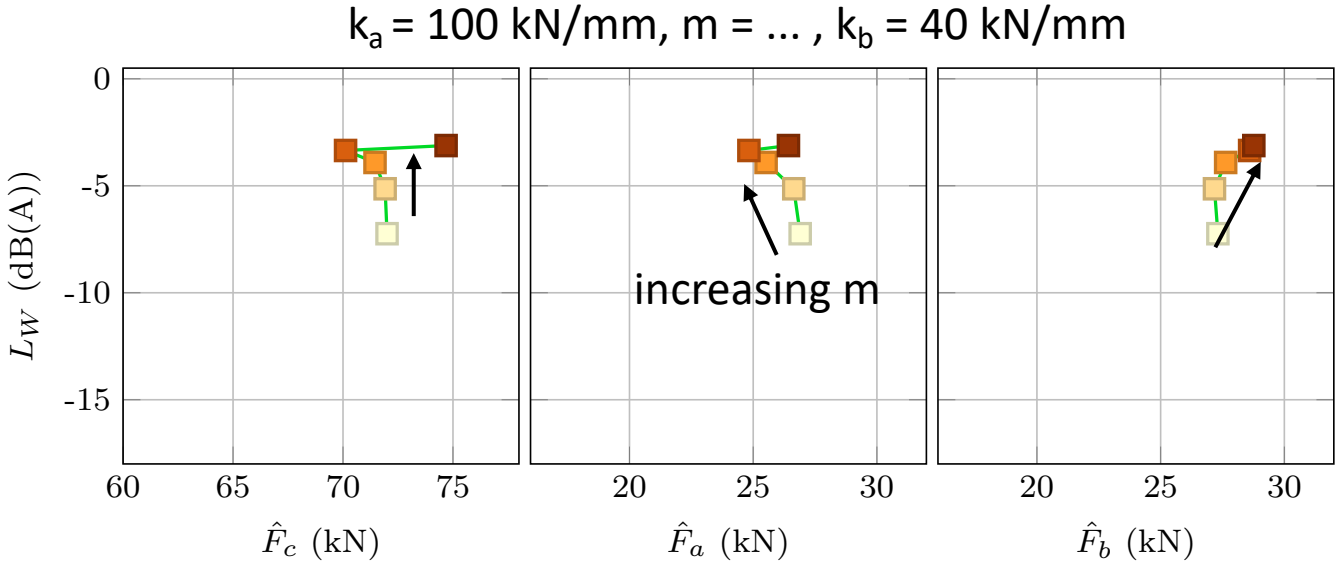




Pass-by simulation

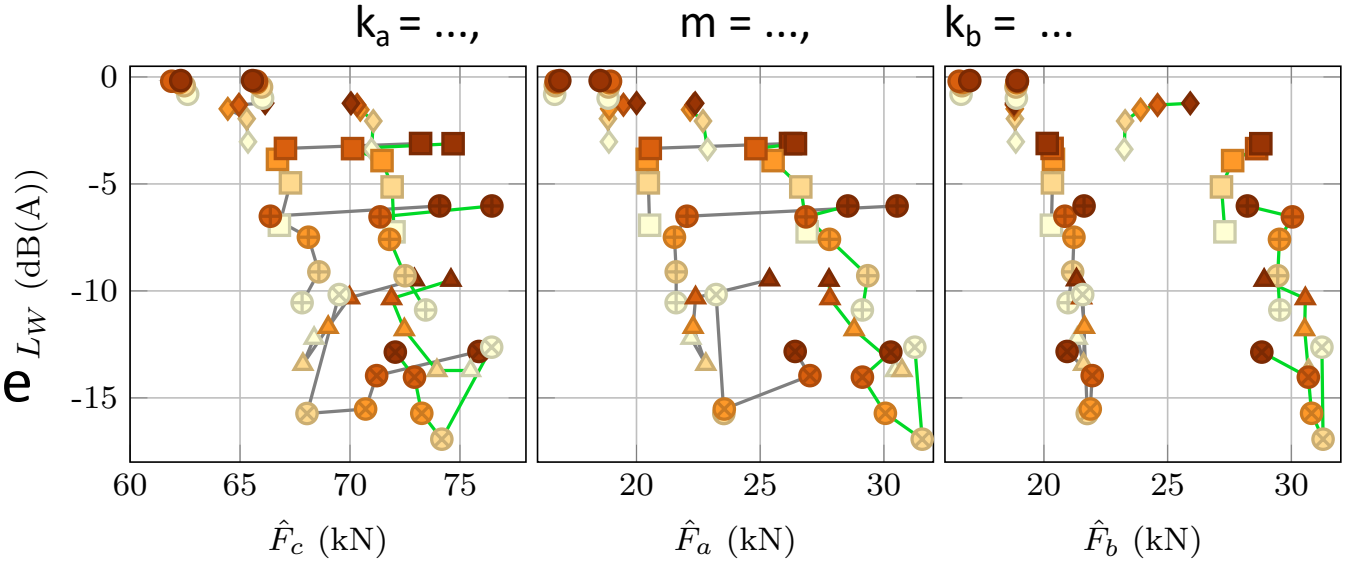
- Varying m
- Effect depends on excitation and track resonance frequencies





Pass-by simulation

- Trade-off between F_c/F_a and L_W
- Decreasing k_b and increasing k_a has potential for track noise mitigation while not changing F_b



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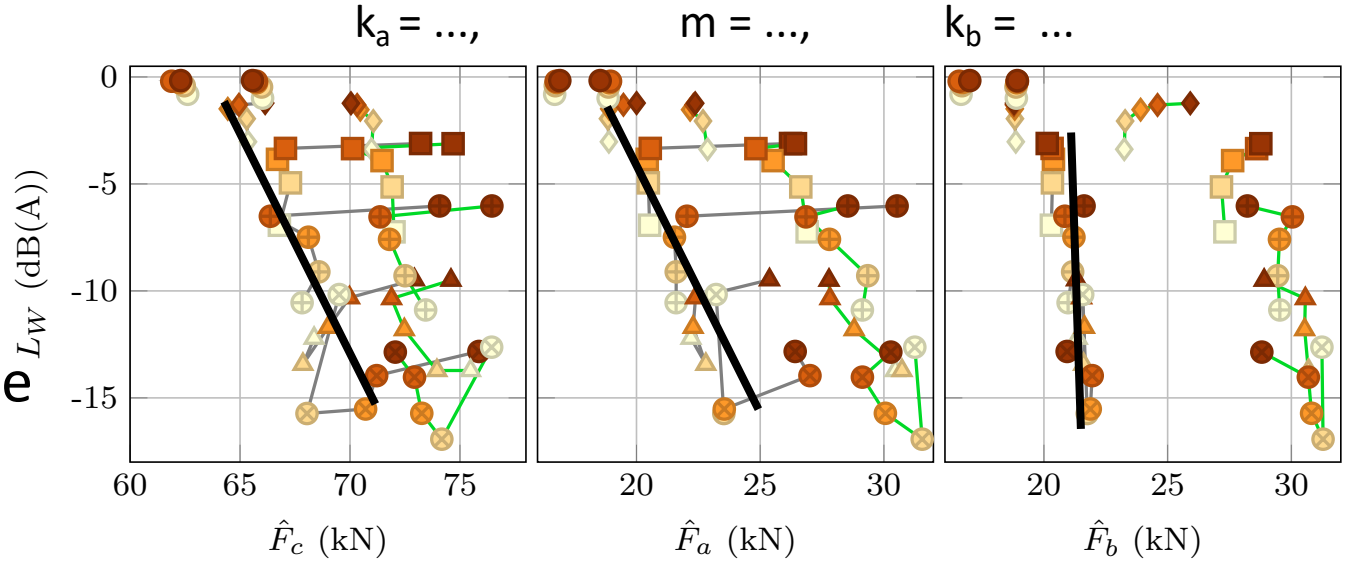

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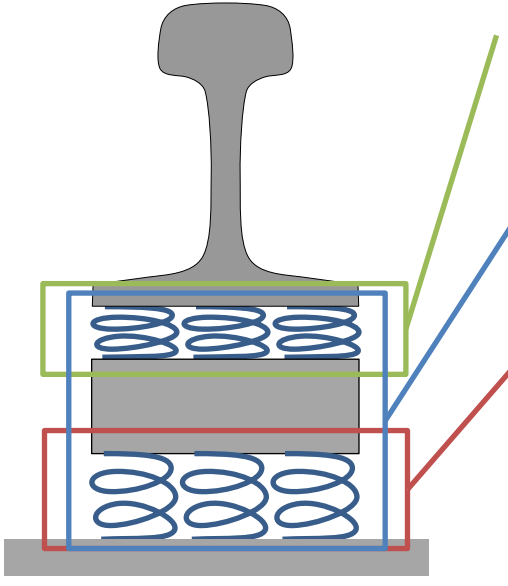
Conclusion

- Developed model for two-stage elastic support on slab track
- Time-domain calculation of rolling contact forces, track load, and sound field



major effect on sound power

affect rolling contact forces and track loads

minor effect on sound power

- Potential noise reduction without changing peak force on slab
- Effect on sound radiation from the wheel?

Acknowledgements

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