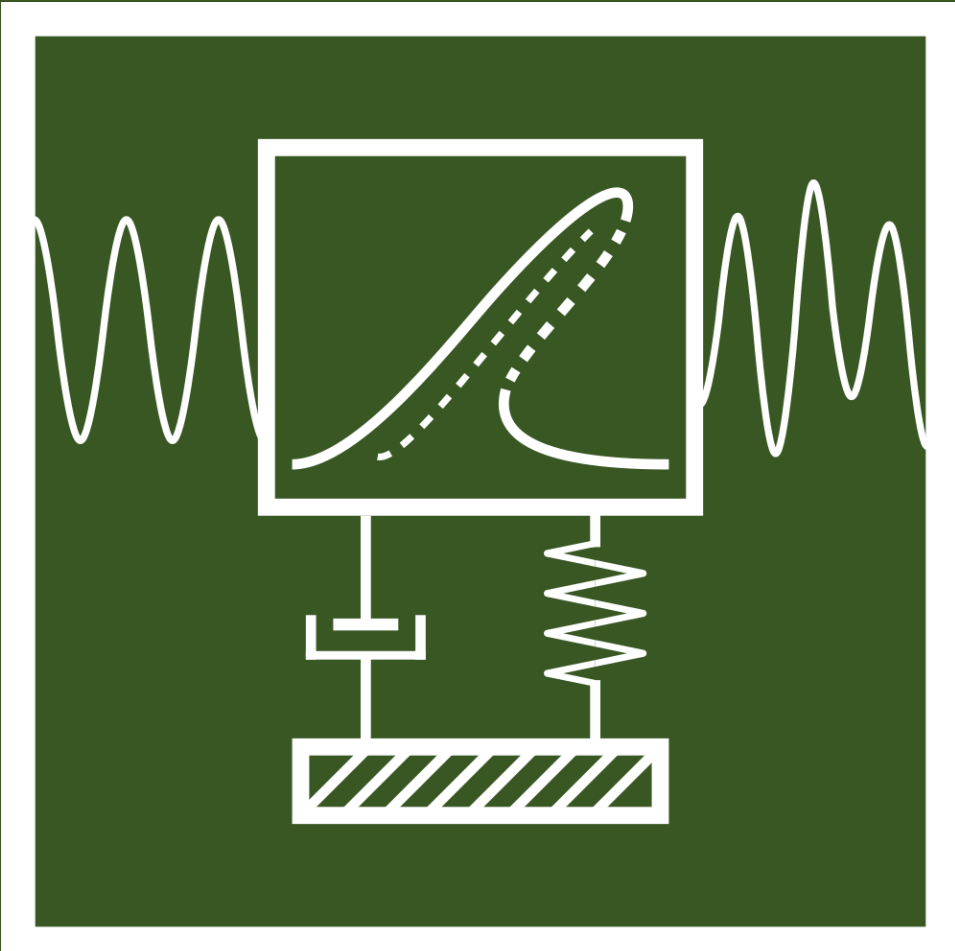


Speed and torque optimization of a crank-driven wheeled robot in non-impact and vibro-impact regimes

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A Abstract

We compare non-impact and compliant-impact locomotion under common torque constraints. The model retains exact crank-slider kinematics and moving-link inertia. At 0.20 N·m, the best speed found increases by 16.3%, while positive shaft work per distance rises by 8.1%.

01 Methods

Optimize $p = (m, k, c, r, f, g)$ for the greatest mean speed. Sobol sampling, differential evolution and local refinement retain settled period-one responses under load constraints. RMS torque budgets: 0.05–0.30 N·m. Peak torque ≤ 0.60 N·m. Contact force ≤ 100 N. Travel: $-0.09 \leq z \leq 0.04$ m.

02 Results

Selected designs at the 0.20 N·m RMS torque budget

Quantity	Non-impact	Vibro-impact
Mean speed (m/s)	0.4433	0.5157
RMS torque (N·m)	0.1985	0.1997
Peak torque (N·m)	0.354	0.357
Positive work/distance (J/m)	6.540	7.070

Selected impact design: $m = 1.194$ kg, $k = 841.8$ N/m, $c = 1.114$ N·s/m, $r = 15.04$ mm, $f = 5.233$ Hz, $g = 30.01$ mm. Contact occupies 12.74% of one revolution.

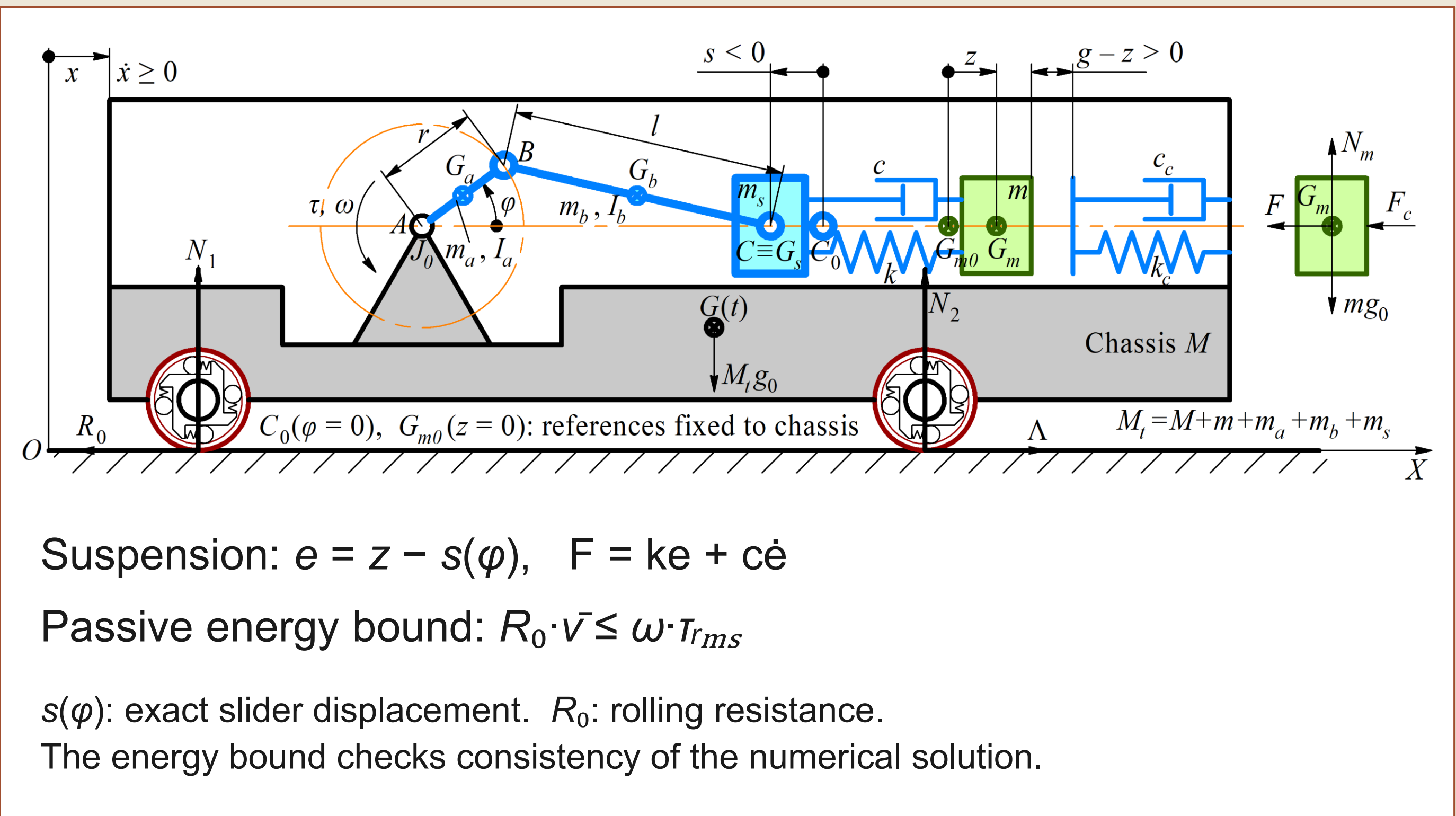


Fig. 1. Robot model and mass free-body diagram. Architecture: [1].

Numerical results for settled period-one branches under the stated contact, resistance and drive assumptions. The search approximates the attainable front. Global optimality remains unproved. Refinement from 4,000 to 8,000 steps/revolution changes mean speed by less than 0.0010%.

Contact and data availability

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Datasets are available from the corresponding author on reasonable request.



03 Discussion

Speed gains range from 41.7% at 0.05 N·m to 11.8% at 0.30 N·m. Equal torque budgets at different frequencies do not impose equal power limits. The impact design operates near the contact-force and travel limits. Parameter selections therefore require design margins.

04 Conclusions

Impacts increase attainable speed within the studied domain. Select the regime to balance speed and energy demand [2]. Experimental identification, a controlled start-up and motor validation remain necessary before implementation.

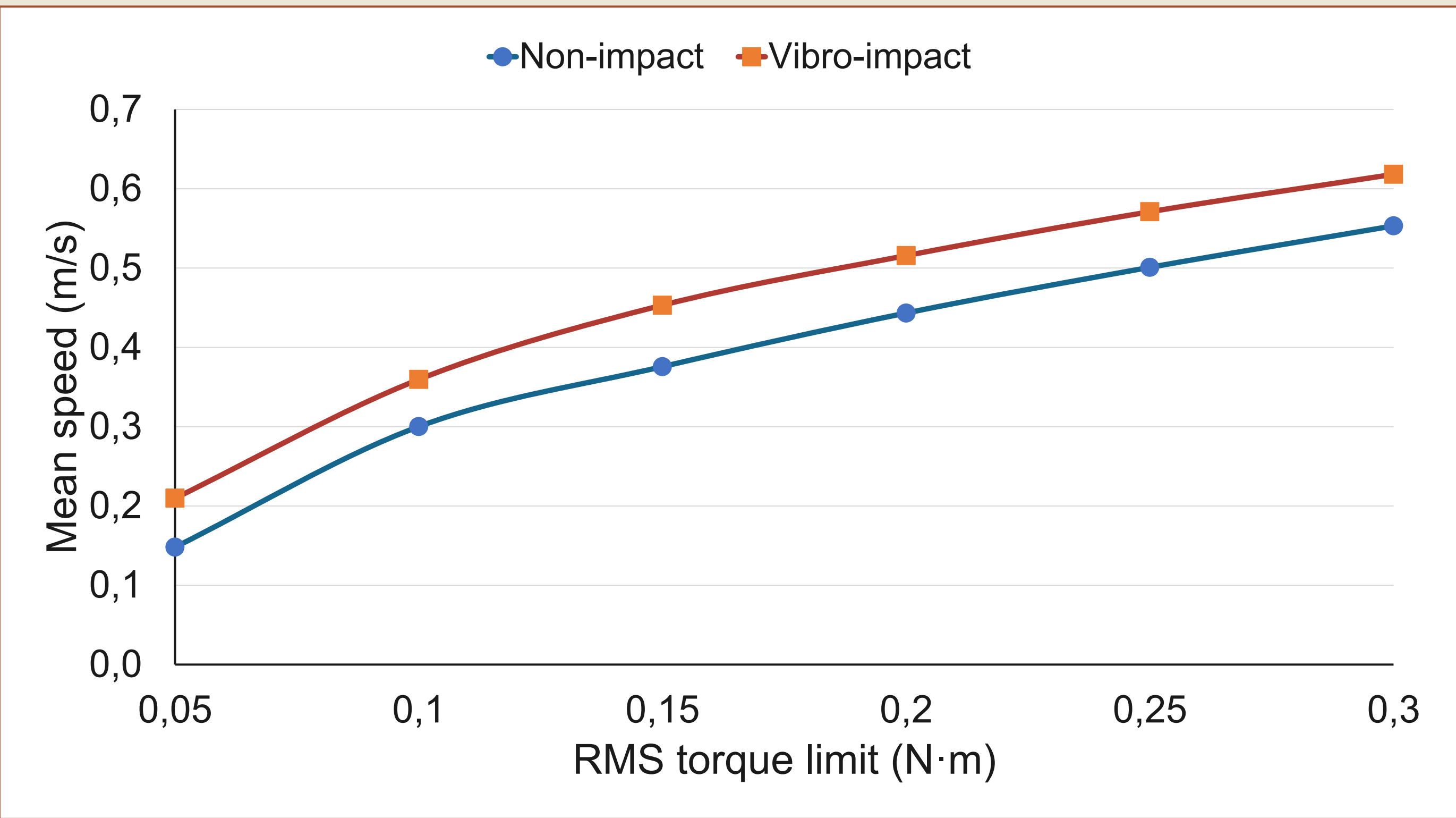


Fig. 2. Best feasible period-one solutions found. Lines connect budgets.

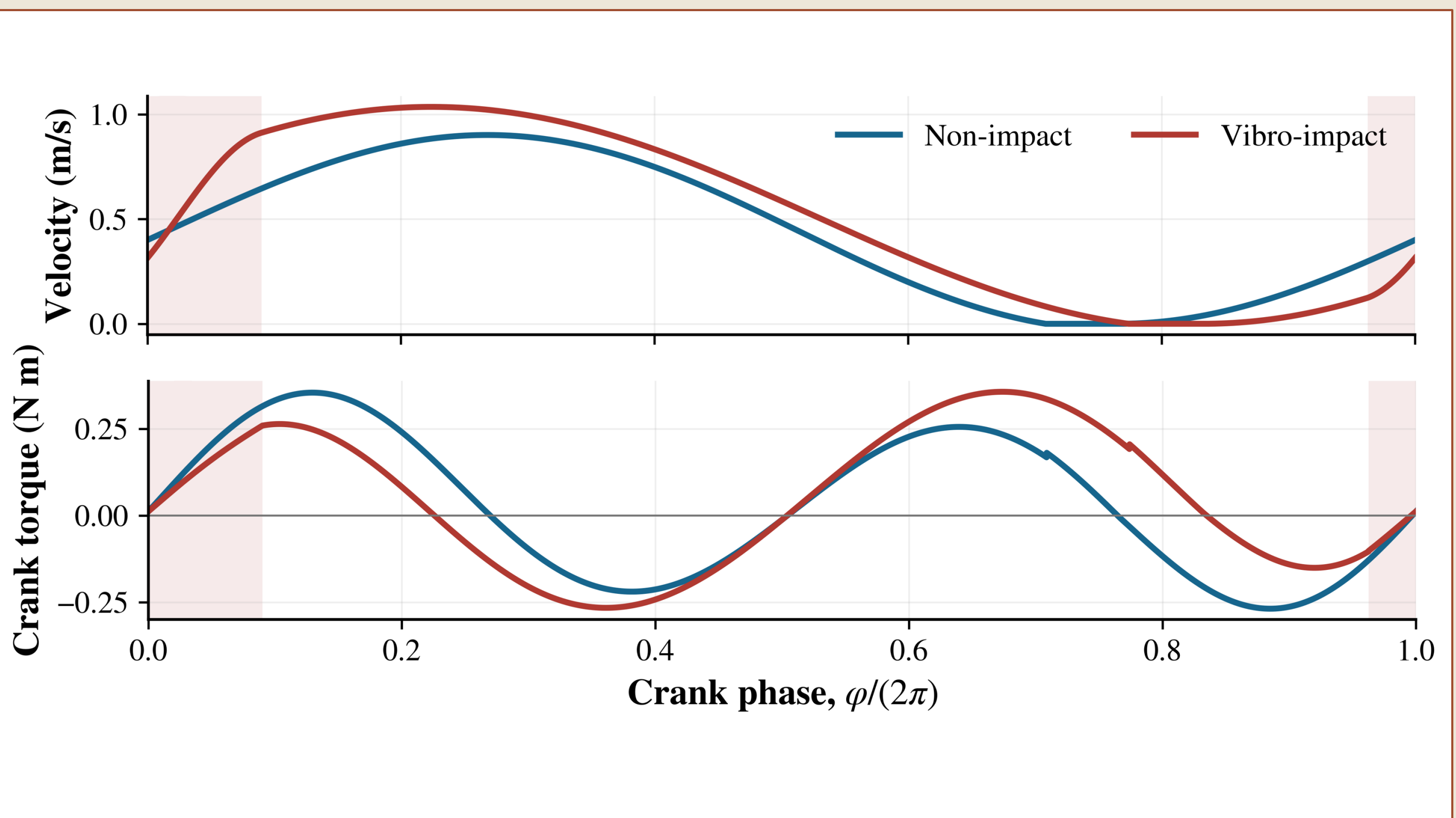


Fig. 3. Settled responses at 0.20 N·m. Shading marks impact contact.

Selected references

- [1] V. Korendiy et al., "Mathematical model and motion analysis of a wheeled vibro-impact locomotion system," *Vibroengineering Procedia*, 41, 77–83, 2022. <https://doi.org/10.21595/vp.2022.22422>
- [2] J. Xue, S. Zhang and J. Xu, "Coordinated optimization of locomotion velocity and energy consumption in vibration-driven system," *Meccanica*, 58, 371–385, 2023. <https://doi.org/10.1007/s11012-022-01488-7>