Viscous Damping in Legged Locomotion

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Motivation

Animal observations and muscle models suggest that **damping** is **beneficial** for legged locomotion [1-3]. Legged robots implement *virtual damping*, while **mechanical damping is often overlooked, despite its potential advantages**. It remains unclear which type of damping (viscous, Coulomb friction, etc.) is preferable.

Virtual damping	Mechanical damping
High frequency force control	Act instantaneously, less control
Strong actuators	Share load of actuators

Research Goal

Our goal is to study the **effectiveness of mechanical damping** on the leg-system **total energy dissipation** within one drop cycle.


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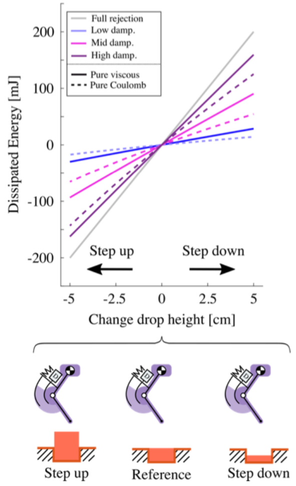
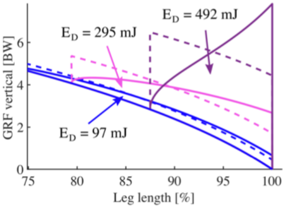
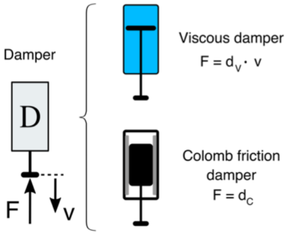
Key Messages

1. **Viscous damping** is generally *superior to Coulomb friction damping*, and *a* **trade-off** exists between *energy efficiency* and *fast rejection of ground perturbation*.
2. Adjustable mechanical dampers exhibit **complex mechanic response** *when embedded into real legged systems.*
3. **Future work**: investigating **neuromuscular damping strategies** in an *actuated hopper* with an **adjustable mechanical damper**.

Simulation







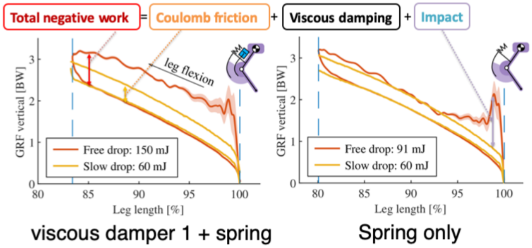
Model: 2-segment leg with a *damper and a spring in parallel.* No active motor: *touch-down to lift-off analysis.*
Analysis: rejection of ground perturbation *(change in system total energy)* through *viscous and Coulomb friction damping.*

Results: *viscous damping generally outperforms Coulomb friction damping*, with higher damping rates producing faster rejection at the cost of lower energy efficiency. Viscous and Coulomb friction damping produce *distinct work-loops*.

Hardware Experiment

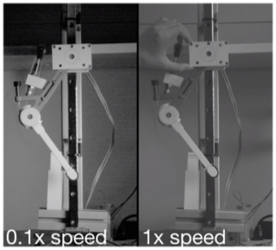
right click below and open in a new tab 😃

Work loop components



viscous damper 1 + spring

Spring only



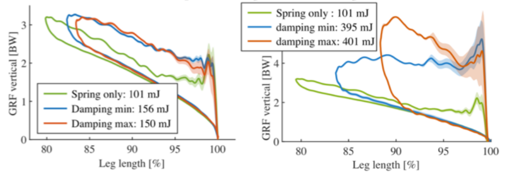
Free drop

(manual) Slow drop

"Free drop" and "slow drop" to separate dissipated energy components:

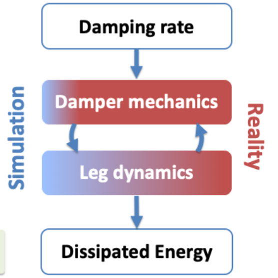
Viscous damper 1 (1214H): **150mJ = 60mJ + 60mJ (40%) + 30mJ**
Viscous damper 2 (1210M): **401mJ = 60mJ + 311mJ(77%) + 30mJ**

Damper adjustability



viscous damper 1

viscous damper 2



Adjustability is **desired**, but *complex* to implement.

References

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