Bachelor thesis

Dynamics and control of Hyperloop suspension system

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Robotics
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1. Introduction

Hyperloop is a new transportation system designed to be safe, energy efficient, and reliable. It will take passengers or cargo directly to the destination at speeds of up to 300 m/s. The vehicle accelerates gradually via electric propulsion through a low-pressure tube. It floats above the track using passive magnetic levitation and glides at airline speeds for long distances due to ultra-low aerodynamic drag. Hyperloop tube system will be built on pylons, embankments or tunneled below ground. It is fully autonomous and enclosed, eliminating pilot error and weather hazards.

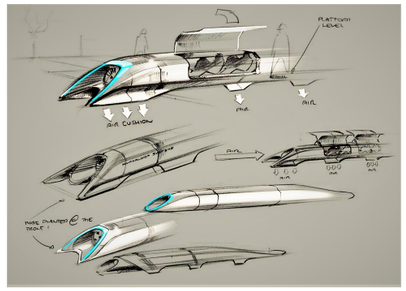


Figure: Hyperloop conceptual sketches

Goals of the thesis

The main goals of the thesis were: analysis of the dynamic performance of one-dimensional two-degree-of-freedom Hyperloop vehicle quarter-suspension model followed by control system design for quarter-suspension with the main objective to increase passengers ride comfort. Additionally, analysis of the dynamic performance of two-dimensional three-degree-of-freedom Hyperloop vehicle were performed.

2. Quarter-suspension model

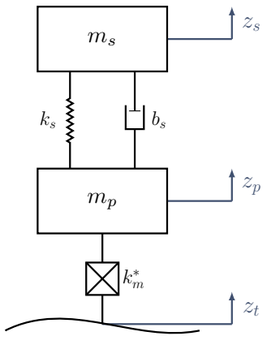


Figure: Quarter-suspension

- Two-degree-of-freedom linear quarter suspension model of low order has been selected for the analysis with primary and secondary suspension embraced.
- Only vertical motion of the vehicle is considered which is sufficient in terms of vehicle dynamics and ride comfort examination.
- Linear time-invariant system allow to use a variety of control design techniques.
- Model consists of two lumped masses m_p and m_s, one linear spring k_s, one viscous damper c_s, and one Halbach array which, can be replaced by a linear spring with stiffness k^*_m.

3. Results

In order to improve stability and increase ride comfort of passengers, an active control system in primary suspension together with semi-active control in secondary suspension were proposed and analysed. Results for 1-DOF suspension model and 2-DOF vehicle model are presented below.

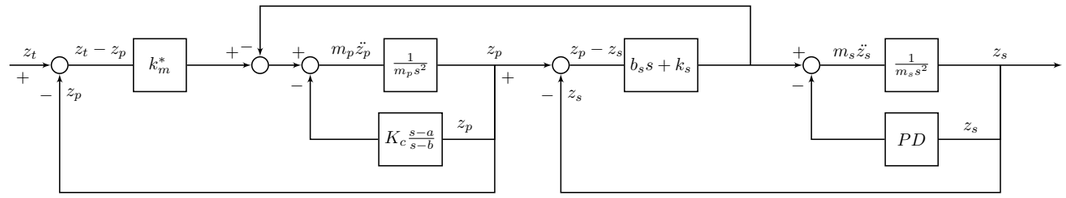


Figure: Block diagram of the suspension system with active control

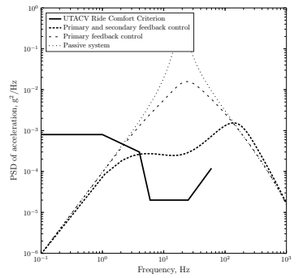
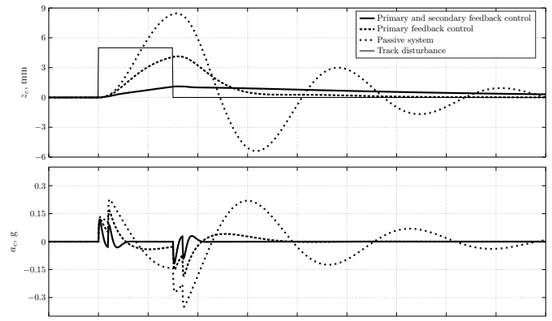


Figure: PSD of secondary suspension acceleration



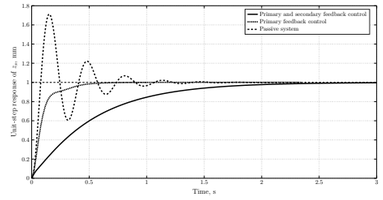


Figure: Transient response of secondary suspension with a unit-step input of track perturbation

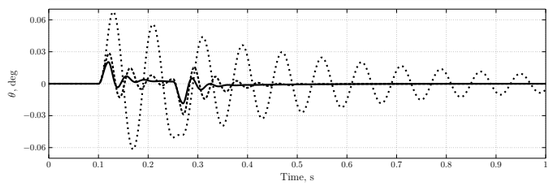


Figure: 2-DOF vehicle response to square-shaped bump track disturbance

4. Conclusions

- Electrodynamic suspension in Hyperloop vehicle provides its stability without support of any active control system. Nonetheless, dynamic response of the vehicle has highly oscillatory character which results in high vertical acceleration values implying poor quality of ride comfort.
- Implementation of the active element in primary suspension system clearly improves its performance reducing oscillations about equilibrium point and extensive overshoot of system response to a unit-step input, but nevertheless, ride comfort is slightly enhanced this way.
- Semi-active control of secondary suspension improves ride comfort considerably. However, regardless of selected control system configuration, UTACV criterion has never been satisfied in this study. Optimization of passive parameters might be a solution in this case. Advanced control techniques might be used in order to increase the system performance as well.

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