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Lab 04: Active suspension optimization

[17/10/2025]

Abstract

This study optimizes an active suspension system using a quarter car model and Skyhook control strategy to minimize discomfort and road holding. By optimizing the equivalent stiffness and damping parameters using sorting and ϵ -constraint methods, the Pareto optimal set is identified and compared to a passive configuration. The results demonstrate that while the active system significantly improves road holding, it offers no substantial advantage over an optimized passive system when prioritizing discomfort minimization.

Contents

1. Introduction

The goal of this lab is to study the basic issues related to the design of an active suspension system; this has been carried out using the quarter car model combined with the skyhook control strategy. To make a valuable comparison between the passive and the active suspension, the optimized designs need to be considered.

1.1 Description of the problem

The geometry of the quarter car model has already been described in the previous lab, where a passive suspension was considered. In this case, the focus is going to be only on the features of the skyhook model used to model an active suspension. With reference to Figure 1, an actuator is introduced in parallel to the equivalent spring and damper element that model the suspension characteristics; this actuator generates a force that is proportional to the relative displacement between the sprung and unsprung mass and to the absolute speed of the sprung mass.

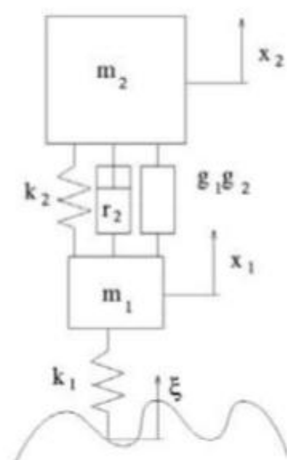

Figure 1

$$F_{actuator} = g_1(x_2 - x_1) + g_2\dot{x_2}$$

From the dimensional point of view

- g_1 is an additional stiffness
- g_2 is a damping that represents the active part of the suspension

An active suspension can dissipate energy (as a passive one) but it can also introduce energy into the system. In addition, the actual damping characteristics of the suspension can be changed dynamically.

Differently from the previous lab, in this case the goal is to optimize the equivalent stiffness and damping g_1, g_2 of the skyhook model, that defines the force provided by the actuator. Once again, the level of comfort is expressed by means of three indexes; for the sake of simplicity, the passive suspension parameters k_2, r_2 have been assumed to be zero and only two out of the three indexes have been used as objective functions to be minimized (Discomfort and Road Holding). Clearly, under all the assumptions introduced, the expression of the indexes changes from the ones considered in the case of a passive suspension.

The expressions of the objective functions considered are:

- Discomfort:

$$\sigma_{\ddot{x}_2} = A \cdot \sqrt{\frac{k_1 g_1}{m_2 g_2}}$$

- Road Holding:

$$\sigma_{F_z} = A \cdot \sqrt{\frac{g_1 k_1 (m_1 + m_2)^2}{g_2 m_2} - \frac{k_1^2 (2m_1 + m_2)}{g_2} + \frac{k_1^3 m_2}{g_1 g_2} + \frac{g_2 k_1^2 m_1}{g_1 m_2}}$$

2. Pareto optimal set

To compute the pareto optimal set two methods presented in the previous assignment are used:

- Sorting method: based on the definition of pareto optimal set
- ε – Constraints method (interior point algorithm)

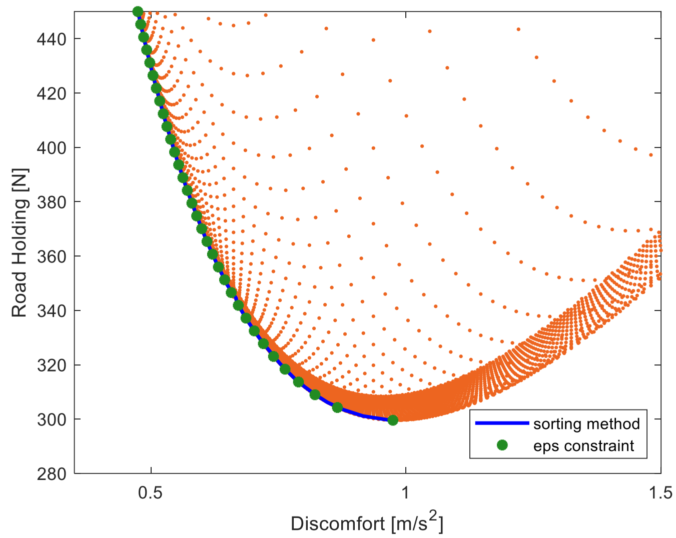

Figure 2

As shown in Figure 2:

- both sorting method and ε – constraints method is able to correctly identify the pareto optimal set for the two objective functions analyzed

3. Passive and active systems comparison

The results obtained for the active suspension system are compared to the one obtained for the passive suspension system in the previous assignment.

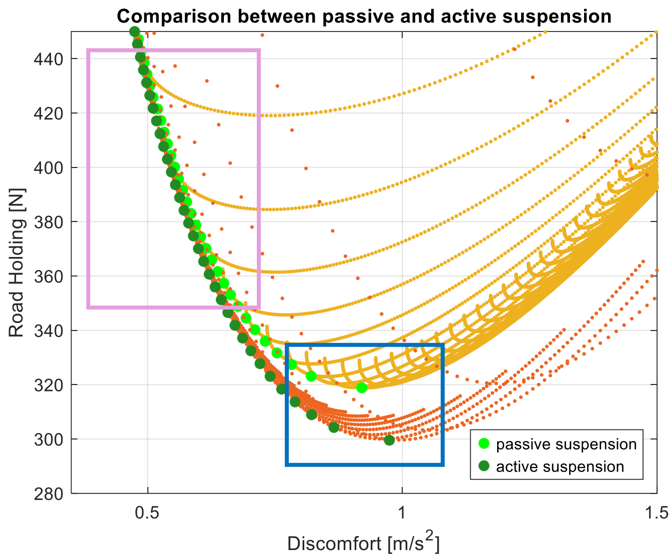

Figure 3

In Figure 3 is possible to see:

- If the goal is to minimize the road holding (blue rectangle region):
    - Active suspension is the best solution because:
        - For a fixed value of discomfort, the road holding obtained with an active suspension is approximately 6% lower.
        - For a fixed value of road holding the discomfort obtained with an active suspension is 21% lower.
- If the goal is to minimize the discomfort (purple rectangle):
    - Adopting a passive or active suspension provides the same result
    - Considering that the first one is a much cheaper solution; this is the best option

4. Conclusion

The objective of this laboratory was the optimization of an active suspension system with respect to road holding and discomfort. The analysis was carried out using the quarter car model combined with the skyhook control strategy.

Differently from the passive suspension system, the variables to be minimized were the equivalent stiffness and damping parameters of the skyhook model.

In summary, the implementation of an active suspension system using a skyhook control logic offers a significant performance improvement in Road Holding. However, it provides no substantial advantage over the optimized passive system for Discomfort minimization. If both functions must be minimized, a compromise must be reached between performance and cost, in order to choose the most suitable system.