Design of an Active Suspension System for Passenger Vehicles

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System Overview

- **Goal:** Improve the comfort and performance of the vehicle
  - Reduce the effect of the road on the vehicle chassis
  - Introduce active suspension systems on cheaper vehicles

- **How this is accomplished**
  - Sensors
  - Variable dampers
  - Hydraulic servomechanisms
  - Computer control unit
Initial Design Tasks

- Fundamental Objective
  - Maximize the performance and comfort of the vehicle

Maximize performance and comfort

- Maximize Handling
  - Acceleration
  - Braking
  - Steady
  - Cornering

- Compensate for the effects of the road

- Maximize Ergonomics
  - Highway
  - City
  - Country
  - Off-Road
Design Alternatives

- Types of vehicle suspension systems
  - Leaf suspension
  - Spring + damper suspension

- Types of active suspension system
  - Active
    - Variable damper and hydraulic servos
  - Semi-Active
    - Variable damper only
Design Overview

- Car Location
- Wheelbase
- Weight Distribution
- Axle Length
- Car Speed
- Car Direction

Maximize Performance and Comfort

- Maximum Roll
- Maximum Pitch
- Suspension Displacement
- Price
- Transient Response Time

- Range for Dampening Coefficient
- Spring Coefficient
- Algorithm
Energy-Based Model

- Decisions made to simplify the problem
  - Consider only one road surface
  - Model only front independent suspension
  - Model only one type of suspension geometry

- Components to Model
  - Suspension geometry
  - Vehicle frame
  - Suspension test rig
Energy-Based Model
Energy-Based Model
Energy-Based Model
Energy-Based Model

Basic Suspension Results

Semi-Active Suspension Results
Uncertainty Modeling

- **Design Variables**
  - Spring Constant
  - Feedback Gain
  - Suspension Arm Length
  - Suspension Arm Angle

- **Uncertain Variables**
  - Frame Mass
  - Frame Length
  - Road Conditions
Uncertainty Modeling
Monte Carlo and LHS Simulations

**Monte Carlo**  
Mean: 3.913 m/s  
Std. Dev.: 0.616

**LHS**  
Mean: 4.082 m/s  
Std. Dev.: 0.581

350 runs & 200 runs
Preference Modeling

- Two attributes considered
  - Cost (€)
  - Performance (in terms of average frame velocity)
Optimization
Conclusion

- **Problems**
  - Dymola and ModelCenter learning curve
  - Experience with Feedback Control
  - Comprehension of Uncertainty and Preference Modeling

- **Design Revisited**
  - Transient time as an attribute
  - Allocate more time (and resources) to run simulations

- **Improvements**
  - Model different suspension geometries
  - Impact of different roads
  - 4-wheel system (pitch and roll of vehicle)