Ground Clearance Analysis of Passenger Cars using HyperWorks/MotionView

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Dynamic Clearance Analysis:
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Overview

Ground Clearance

- Introduction
- Load Cases
- Measurement Procedure
- Multi Body Simulation
- Dynamic Clearance Analysis
- Videos
- Outlook
Introduction
Aspects of Ground Clearance

Building Fuel Saving Cars

• Reduction of trim height (distance between wheel center and chassis)
• Packaging: Optimal usage of the space under the car
• Additional underbody panels to improve aerodynamic behaviour

Goal:
Optimize the design of the underbody in a way that ground clearance criteria are still fulfilled!
Introduction

Ground Clearance Criteria

Regular Maneuvers

• No ground contact shall occur.

Heavier Maneuvers

• Damage of car has to be obviated.

Misuse Maneuvers

• All components must remain attached and functional without permanent deformation

• Especially Brake, fuel and drive shaft components shall not be damaged
## Introduction

### Ground Clearance Criteria

<table>
<thead>
<tr>
<th>Acceptable Damage</th>
<th>Unacceptable Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>slight scratches / contact at underbody are acceptable</td>
<td>scratches on painted surface are unacceptable</td>
</tr>
<tr>
<td>scratches at crossmember are acceptable (screws protected and not damaged, no functional impact)</td>
<td>scratches on painted surface are unacceptable</td>
</tr>
<tr>
<td>extensive contact at underbody acceptable if damage is restricted to scratches</td>
<td>disassembling of airdam (component did not remain attached)</td>
</tr>
</tbody>
</table>
Load Cases
Overview

• Curb test
• Ramp parking garage
• 13° / 16° US ramp
• Speed humps
• US 7” curbstone

Several driving maneuvers per obstacle
Load Cases
Curb Test

• 12 cm height
• Walking speed (4-5 km/h)
Load Cases
Ramp Parking Garage

• Forward and rearward driving
• Parking lot speed (10 km/h)
• Edges rounded
Load Cases
13°/16° US Ramp

• 13° ramp: Walking speed (4-5 km/h)
• 16° ramp: Creep speed (1-2 km/h, heavy contact & damage to soft components expected)
Load Cases
Speed Humps

- Walking speed (4-5 km/h)

<table>
<thead>
<tr>
<th>Dimensions Speed Humps</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length L (cm)</td>
<td>35</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>Height H (cm)</td>
<td>9,5</td>
<td>9,0</td>
<td>8,5</td>
</tr>
</tbody>
</table>
Load Cases
US 7” curbstone

• 18 cm height
• Walking speed (4-5 km/h)
• Forward and rearward driving
• Drive until the tire contacts the curbstone, or the vehicle stops
Measurement Procedure

- Seven bars of plasticine on the underbody
- Grinding of “ground lines” in the plasticine by driving over the obstacles
- Heightened trim height
- Digitalization of the ground lines with point taker for further constructional evaluation
Multi Body Simulation
Simulation vs. Measurement

Disadvantages of measurement procedure
• Laborious to prepare cars
• Usually evaluation of all load cases at once

Advantages of simulation
• Evaluations of ground clearance long before first prototypes
• Saving of real test runs (saving of time and money)
• Verification of more variants
• Fast parameter studies to analyze influence of speed, steering angle, ...

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Multi Body Simulation
Tasks of Simulation

• Calculate the minimal distance of every point of the underbody to the ground to explore maximal construction space

• Detect points of collisions

• Prediction of the dimension of the damage not possible
Multi Body Simulation
New MotionView Master Model

• New MotionView model for entire vehicle load cases (ride & handling)
• One master model for all carlines
• Allows usage for engineers without knowledge of MotionView and multi body simulation techniques
• Modular architecture: ViMC (Virtual Modeling Components) encapsulated routines for chassis components with interfaces to different tools for common modeling

Reliable
Shareable
Flexible
Extensible
Multi Body Simulation
Simulation Techniques

• Linkage of FTire to MotionView (complex tire model, also regarding deflection)

• Dynamical simulation of entire vehicle

• Velocity controller

• Calculation of the motion of the bodies
  • Trajectory of body to determine translational motions
  • Tensor of directional cosinuses for rotational motions
Multi Body Simulation
Parcours 1

• 3 curbs (driving pattern a, b, c, curbs slightly sloped & rounded)

• 3 speed Humps

• Walking speed (4-5 km/h)
Multi Body Simulation
Parcours 2

13° Ramp
• Walking speed (4-5 km/h)
• 5 different angles (0, +/-30°, +/-60°)
• Forward and rearward driving
Multi Body Simulation
Parcours 3

16° Ramp
• Creep speed (1-2 km/h)
• 5 different angles (0, +/-30°, +/-60°)
• Forward and rearward driving
Multi Body Simulation
Parcours 3

Ramp Parking Garage
- Parking lot speed (10 km/h)
- Forwards up and rearwards down
- Velocity Controller
Dynamic Clearance Analysis
Ground Clearance Analysis based on Simulation Results

• Input: Motions calculated by MBS simulation (Trajectories and rotation tensors)

• Usage of CAD models of chassis & underbody

• Calculation of ground clearance (minimal distances of chassis & underbody to ground)

• Fast and easy identification of critical points and critical maneuvers

• Creation of video sequences for presentation purposes
Dynamic Clearance Analysis
Ground Clearance at different load conditions

- GVM
- 2/3 GVM
- Curb

^6.2mm

^14.3mm
Video 1
Video 2
Outlook

- Steering controller for steered maneuvers
- Sensitivity studies for the load case parameters like speed and steering angle in order to find out if load cases are redundant. Objective is to have a small set of optimized load cases that cover all customer relevant aspects of ground clearance.
- Create a map of the underbody showing which areas are critical at which of the load cases. If modification of certain parts of the underbody is considered the corresponding relevant load cases are known.
Thank you for your attention!