Improve vehicle handling by deploying a target setting process for body rigidity

Wednesday November 14, 2018
Vehicle handling news
Manufacturers put significant effort in design of vehicle body & chassis

Technical Analysis: The All-New 2017 BMW 5-Series (G30)

youwheel.com
“… big step forward in some areas (for example more lightweight / advanced materials in the body construction …”

businessinsider.com
“you could think of the Odyssey as the BMW of minivans…”
“The minivan is large and weighs over 4000 pounds, but it’s easy to maneuver, with responsive steering, …”
Vehicle handling news
Manufacturers put significant effort in design of vehicle body & chassis

businessinsider.com / wardsauto.com
“… built on VW’s highly praised MQB platform, which also underpins the Audi A3 and Volkswagen Passat…”
“VW is spending $7 billion on developing its new MEB platform…”

autoexpress.co.uk
“… the Passat is very easy to drive, with precise and ultra-accurate steering, …”
“Because there’s less weight, it turns more confidently into bends and has more agility than previous models.”
### Typical OEM needs & current trends

#### Challenges

<table>
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<th><strong>Body light-weight design while keeping performance</strong></th>
<th><strong>Body target-setting for handling performance</strong></th>
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<td>‘Design the right stiffness in the right place’</td>
<td>‘Identify &amp; improve body weak-points’</td>
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<td>‘Multi-attribute target setting’</td>
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<th><strong>Optimal chassis performance for handling and comfort</strong></th>
<th><strong>Chassis on-center / low lateral acceleration performance</strong></th>
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<td>‘Performance deterioration at low AY?’</td>
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‘Does the body limit optimal suspension performance?’

‘Performance deterioration at low AY?’
Body target setting for handling performance

Typical process flow at OEM

Requires

Body metrics

Full vehicle metrics

Typical OEM challenge: objective characterization

Requires

Subjective rating

Should involve full vehicle simulation – but CAE techniques have strong limitations considering body rigidity analysis and target setting.

Input into design process
Importance of body rigidity
Engineering implications

- Targets required

Mechanism body vs handling?

Subjective vs objective?

Reference data?

*Multi-attribute Optimization*

Body design needs to consider multiple attributes:

To define body targets, the relation of body rigidity vs handling performance needs to be understood

- Influence can **subjectively** be perceived
- Use established **Test technology**
- Use established **Simulation technology**

Need for a method that provides a better understanding of the relation body rigidity versus handling performance
Importance of body rigidity
Insights in the relation between body stiffness and driving dynamics performance

BodyFlex methodology, an approach that combines

- **Time domain**
  - Body load identification (strain-based)

- **Body Loads**

- **Influence body characteristics on load distribution & driving dynamics**

- **Body Model**
  - Test or CAE-based

- **Identify weak-spots by decomposing body deformation in mode contributions and Global / local**

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Ingenious for Life
Defining body rigidity targets for handling

Building blocks

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<th>Mechanism identification</th>
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SIEMENS
Ingenuity for life

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Siemens PLM Software
Defining body rigidity targets for handling

Building blocks

**Body**

- **Body characterization**

**Full vehicle**

- **Weak-point identification**
- **Mechanism identification**
- **Link towards subjective**
Body characterization
Static from dynamic

Local and global body static stiffness identification

Excitation global + local

Accurate modal model (ML-MM)

Static load case inputs

Stiffness results & contribution analysis

Torsion Stiffness: 20.200Nm/deg
Body characterization
Hard-point static stiffness

Benefits

- Benchmarking database creation
- Identify weak-points
- Input to body design – target setting
- Mode contributions, …

Possible on BOTH Body-in-White and Trimmed Body

Hard-point static stiffness

Front Suspension Lateral Stiffness

All front suspension to body connection points

Identify ‘gap’ with competition

Vehicle 1  Vehicle 2  Vehicle 3  Vehicle 4
Body characterization
Global body static stiffness

**Benefits**
- Freedom for any static input scenario
- No clamping: easy CAE correlation
- Decomposition in mode contributions
- Identify weak-points: front, rear, local, …?
- Input to body design – target setting
  
  Possible on BOTH Body-in-White and Trimmed Body

Static torsion stiffness: 20.200Nm/deg

Impossible on a test-bench
Volkswagen
Trimmed body static stiffness identification and CAE correlation

Objectively identifying trimmed body stiffness with static-from-dynamics

- Objective approach to identify trimmed body stiffness with static-from-dynamics
- Correlate CAE with trimmed body testing
- Enhance body target setting process
- Enable better balancing of multiple performance attributes

Example of correlation with CAE

Trimmed body CAE and TEST

- Global static stiffness and contribution analysis to get insights in the static performances
- Identification of static stiffness distribution of the body to allow benchmarking and weak-point identification

“The Simcenter Engineering correlation approach supports Volkswagen engineers to get even more insight into the best possible balance between structural stiffness driven vehicle attributes like NVH and Vehicle Dynamics on the one hand and cost and weight performance on the other”

Volkswagen, Presented at ISNVH 2018
Defining body rigidity targets for handling

Building blocks

**Body**

- **Body characterization**

**Full vehicle**

- **Weak-point identification**
- **Mechanism identification**
- **Link towards subjective**

**Body loads & body deformation**
Body rigidity and Vehicle dynamic performance

Simcenter Engineering Body flexibility methodology: advanced time-domain body load and deformation analysis

Body Loads

Body Model

Time-domain Body Deformation

\[ X(t) = \psi(t)q(t) \]

Which steps to take to enable body rigidity analysis for vehicle dynamic performance

1. Identify objective changes
2. Understand changed performance
3. Establish links to subjective
4. Identify mechanism body - handling

Classic handling data

Body Loads

Body deformation

Global vehicle data

Suspension to body loads

Stiffness & deformation

(minor result changes)

(relevant result changes)

(insight phenomena)
Full vehicle track testing with body load identification

Limitations of traditional handling parameters

- Classic instrumentation for vehicle performance
  For example: lateral acceleration, roll, slip, yaw-rate

These **global vehicle parameters**

- are defined at **center-of-gravity**
  (global vehicle behavior)
- result from **all loads** that work on the body structure
- can’t capture **subtle changes** as ‘a faster front response’
Full vehicle track testing with body load identification

Why usage of time-domain loads?

- Body loads are **contributors** to each global vehicle parameter
- Using these **body loads**
  - performance changes can be identified in a **far more detailed** way
- enable estimation of **time-domain body deformation**
- enable to **understand interaction** of body and handling performance

**Benefit:** Identify time-domain body loads, providing in-depth insight in changing vehicle performance and subjective ratings

**Local vehicle data:** typically **clear result changes**

**A lateral body load** (contributor to lateral acceleration) can clearly capture the effect – a much faster rear axle response
Full vehicle track testing with body load identification

Approach

1. Instrumentation & model-based load calibration for each suspension component
2. Full vehicle track measurements in base / modified condition
3. Values from track data analysis
   - Load estimation
   - Quantify & understand impact modification on vehicle performance
   - Data analysis to establish links towards subjective evaluations

**Benefit:** Identify time-domain body loads, providing in-depth insight in changing vehicle performance and subjective ratings
Body deformation analysis & Vehicle dynamic performance
Potential influences of body rigidity on vehicle dynamic performance

- ‘Slow reaction of rear suspension’
- ‘Understeer feeling. Weak yaw damping.’
- ‘Vehicle response not ‘natural’ or linear’
- …

Or: the Body is limiting the suspension (optimal) performance
Expanding to body deformation estimation

Approach

1. Use time-domain **body loads** (base / modified) identified for track-tests

2. Identification of a **body modal model** (Test or CAE)

3. **Body deformation calculation** through load application to body model
   • Visualization and decomposition of body deformation in the maneuver
   • **Weak-spot identification:** improvement potential for body structure
   • **Mechanism identification:** interaction body with vehicle performance

Benefits
1) Identify the mechanism between body rigidity – vehicle performance
2) In-depth analysis of body behavior – weak-spot identification
Defining body rigidity targets for handling

Building blocks

Body

- Body characterization

Full vehicle

- Weak-point identification
- Mechanism identification
- Link towards subjective

Body loads & body deformation
Body deformation analysis
Identification of weak-spots

Select visualization time-step during vehicle maneuver

Total hard-point deflection
Decompose point deformations

Global contribution
Local contribution

Detailed body analysis, identification of potential weak-spots
Identify which body characteristics are important in the transient or in the steady state

Dominating global flexibility contributions?
Which body property is important at steering input?
Dominating local flexibility contributions?

Body deformation analysis
Synchronous visualization:

- Handling parameters
- Loads
- Deformations
- Contributions of modes
Defining body rigidity targets for handling

Building blocks

- Body characterization
- Weak-point identification
- Mechanism identification
- Link towards subjective

Body loads & body deformation
Body deformation analysis
Weak-point analysis & Mechanism identification

**Challenge** Improving the vehicle dynamic performance through optimized body characteristics

**Solution** Body weak-spot analysis, body modification analysis → input to body target setting

Animate body deformation together with mode contributions, loads, handling parameters

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<th>Body deformation</th>
<th>Body loads</th>
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- Front lateral load
- Rear lateral load

Steering angle input

**Step steer maneuver @ 100kph**

Understand mechanism between body characteristic & vehicle performance

Time-domain loads

Body model

Body weak-point analysis with Siemens toolset
Honda
Importance of body rigidity in the transient stage of the maneuver

Contribution analysis

- Identify key body metrics for transient handling
- Link subjective evaluations to objective data
- Insights in mechanisms between body and suspension in the transient stage

Handling parameters and load distribution

- Analyze vehicle in base and modified body configuration
- Influence of reinforcements on handling parameters and body load distribution

Modification impact on rear axle response

Gain insights into the relation of body flexibility versus vehicle handling using an combined test and simulation approach.

Presented at Chassis.Tech 2015
Defining body rigidity targets for handling

Building blocks

**Body**
- Body characterization

**Full vehicle**
- Weak-point identification
- Mechanism identification

**Link towards subjective**

**Body loads & body deformation**
Body modification analysis
Relation to subjective perception

**Challenge** Identification how **subjective evaluations** are affected by car body stiffening

**Solution** Load & deformation analysis to identify the **mechanism** body – vehicle performance

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**Changing body characteristics → Impact on vehicle performance → Link towards subjective**

1. Two-ply cowl top (*Front Struts*)
2. Member stay front (*Subframe - Body Rear*)
3. Tunnel stay rear (*Twist Beam*)

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![Diagram showing changes in body characteristics and their impact on vehicle performance and subjective perception.](image-url)
Nissan Motor Company
Uncovering the complex interaction between body flexibility & handling

- Gained insight into the relationship between the subjective perception of an expert driver and the influence of body rigidity changes on the vehicle’s dynamic performance
- Developed a method that enables insightful decisions on body flexibility earlier in the vehicle development process

"I think Simcenter Engineering has three main differentiators. Firstly, they combine high-end testing with CAE. Secondly, they have a very vast experience with automotive OEMs. And finally, Simcenter Engineering has a very talented global team of experts."

Hitoshi Kyogoku, Vehicle Dynamics CAE Group manager

Understanding the relationship between body flexibility & vehicle handling

- Accurately identifying operational force distribution
- Targeted body design decisions for optimal vehicle handling in the future
- Identify the operational loads between body and suspension in time domain
- Visualize body deformation as well as the contribution of the individual body modes in time domain
**Body modification analysis**
Identify key body characteristics

**Challenge** Identification of **key body characteristics for target setting** for vehicle dynamic performance

**Solution**  **Body modification analysis** to identify which performance relates to which body property

A changed body property ‘alpha’ results in:
different stiffness & changed on-track deformation

Impact on lateral deflection in maneuver

This analysis of body characteristics allows
- Establish relation body – performance
- Establish links to subjective
- Improve body target setting process
  - focus on body characteristics that are key for performance

Objectively quantify the impact of body property ‘alpha’ on global parameters, transient load build-up and subjective perception

Does ‘alpha’ impact
- Initial responsiveness?
- Load build-up capability?
- Rear axle timing?
- Roll behavior?
On-center vehicle performance
Application case

Growing interest in on-center performance

Challenges: Vehicle performance change (deterioration) towards low Ay
- How to measure, quantify objectively?
- How to set targets?
- Non-linearity?

Siemens solutions
- **Objective characterization method**
  - On both body and suspension level
  - Even at low response levels
  - Using suspension loads
- **Simulation methods**
  - Capture complex suspension phenomena
How to establish a body target setting process & ensure precisely the desired driving characteristics?

By combining these methodologies
Body target setting for handling performance
Typical process flow at OEM

Requires

Body metrics

Requires

Full vehicle metrics

Typical OEM challenge: objective characterization

Requires

Subjective rating

Should involve full vehicle simulation – but CAE techniques have strong limitations considering body rigidity analysis and target setting.

Input into design process
Body target setting for handling performance
Combining Test/CAE

Body metrics

Weak-point analysis of body

Body benchmarking

Body design modifications

Full vehicle metrics

Simcenter Engineering solutions

Body characterization
- Benchmarking, weak-point, modifications

Full vehicle testing process
- Track testing or bench testing
- New, efficient & fast methods
- Metric definition

Support target setting process
- On body level, on full vehicle level

Efficient process required: OEM setup + extensions
Body rigidity and vehicle dynamic performance
Deploying a target setting process for body rigidity

Support input for body target setting
Benchmarking, Body modification analysis (body / full vehicle)

Identify how the body interacts with suspension performance
Input for body design based on mechanism understanding

Body weak-point identification using Test or CAE data
Static cases or Handling maneuver loading scenario

Link objective performances to subjective ratings
Body modification analysis on full vehicle level
Thank you! Want to know more?

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Watch videos

Contact the expert