MSC Software

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Design Rules Discussion for Improving Multi-axle Vehicle Stability

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Introduction

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- Modeling Process
- Whole Vehicle Model
- Suspension Kinematics Analysis
- Dynamic Analysis and Discussion
- Conclusions
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Background

- Multi-axle vehicles require more stability for safety purposes
- Need more time and money for prototype experiments
- Uses of wide and large tires, non-linear springs, multi-axle driving and steering are common
- Simplified whole vehicle model can not predict the real handling and stability character
- Need more sophisticated models and analysis to ensure the quality and efficiency of design

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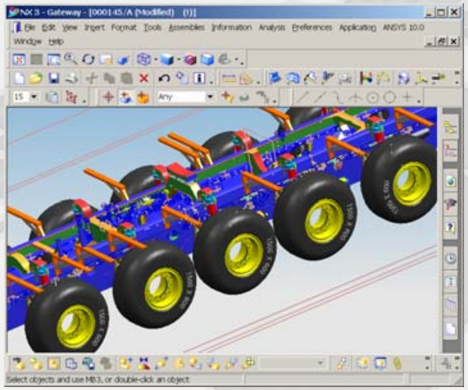
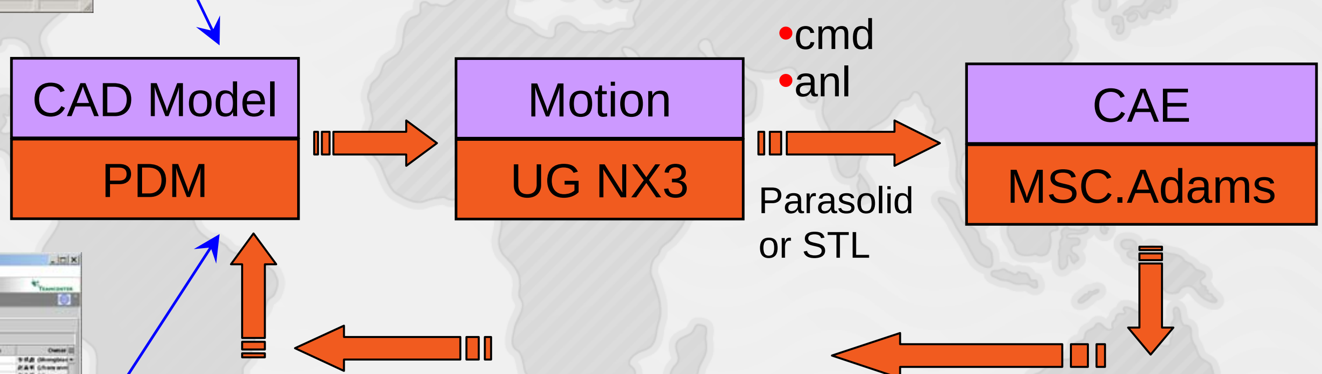
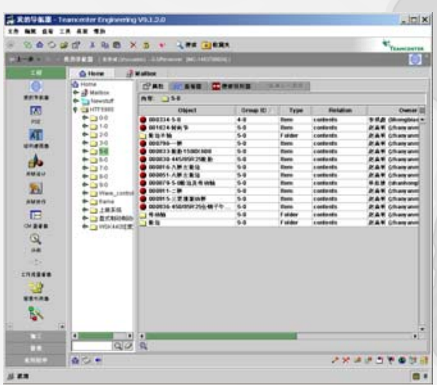
Modeling Process

- CAE models have more detailed information
- All data from CAD and CAE can be managed by PDM system



UG NX3





Teamcenter Engineering

Collaborative process

Whole Vehicle Model

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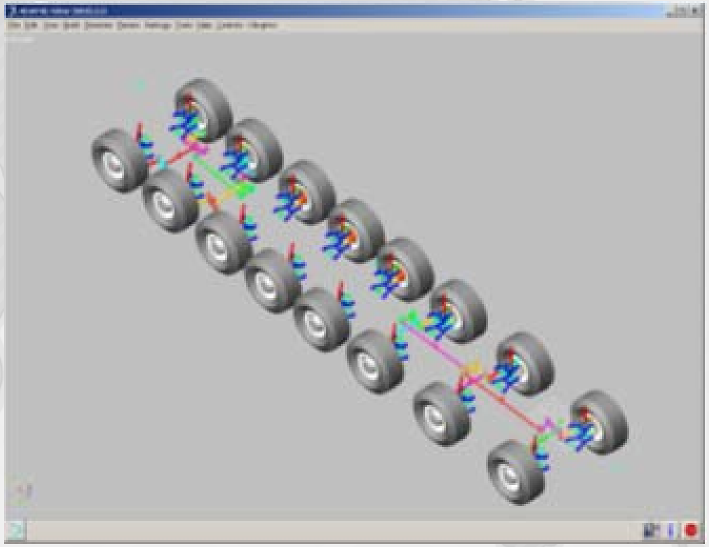
- 116 rigid part
- 36 degree of freedom
  - 16-Vertical movement of suspension
  - 16 – Wheel rotation
  - 3 – Body roll, yaw, pitch
  - 1 – Steer rod system
- UA tire
- SPLINE and AKISPL transfer the feedback angle of steering system



HTF eight-axle vehicle

Whole Vehicle Model

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Spring force

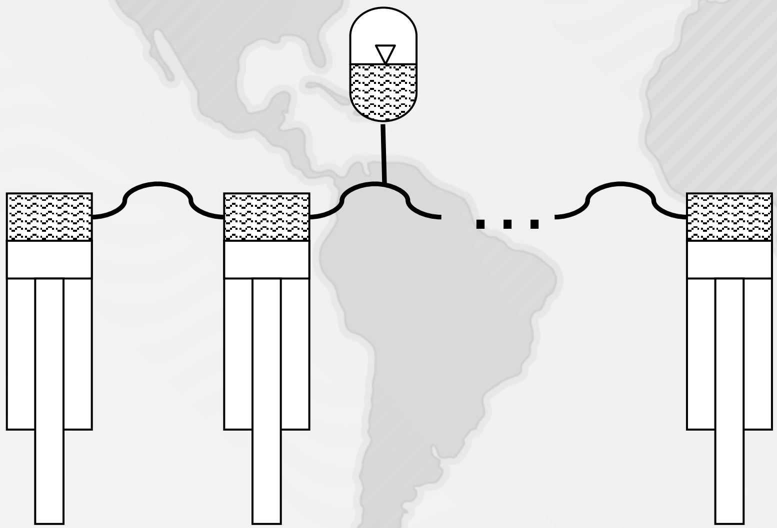
gas force + Damp force

SFORCE

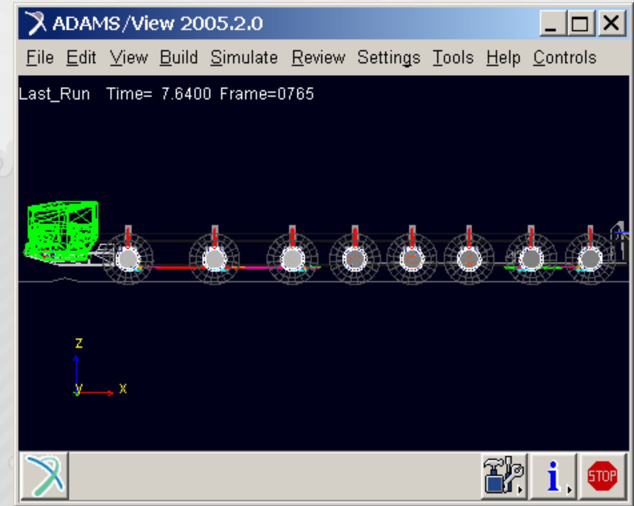
SPRING

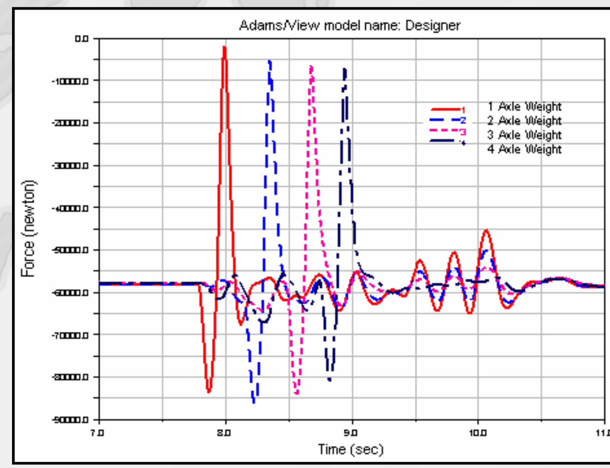
$$\frac{\sum_{i=1}^{n} F_i}{n} \cdot \left[L_0 \text{£¨} L_0 - \sum_{i=1}^{n} \Delta l_i \cdot \gamma \text{£©} \right]^{\alpha}$$

0 stiffness



connected hydrogas spring system





Response of impulse input

Suspension Kinematics Analysis

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Design rules:

- Different inclination angle of front and rear steer axle to ensure that cornering moment is opposite to the steering moment
- Compositive moment of tire lateral force is opposite to the disturb moment

Optimization target:

Minimized $$J_E=\sqrt{\frac{w_1\cdot J_1+w_2\cdot J_2}{w_1+w_2}}$$

$$J_1=\int_0^{nf}\left(\frac{\theta(i)-\theta_0}{\hat{\theta}}\right)^2 dn \qquad J_2=\int_0^{nf}\left(\frac{l(i)-l_0}{\hat{l}}\right)^2 dn$$

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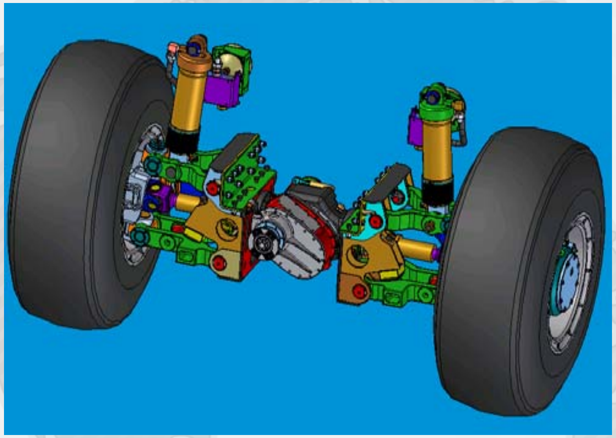
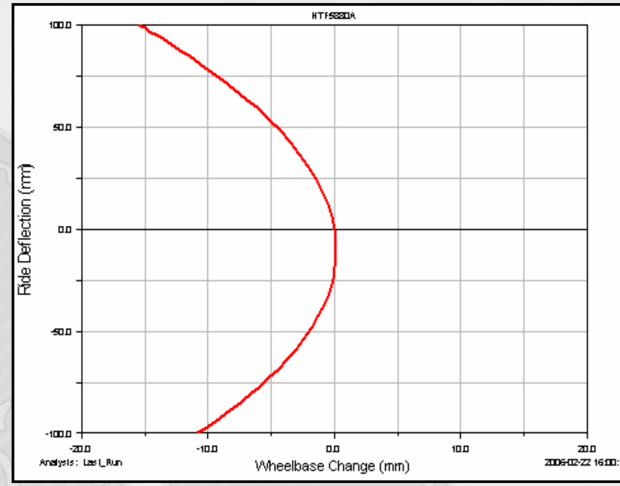
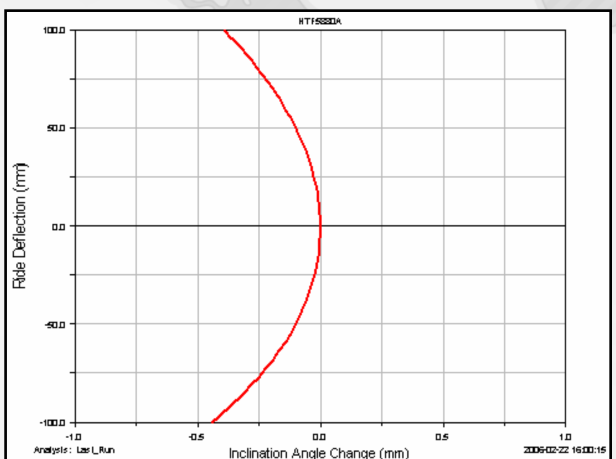
Suspension Kinematics Analysis



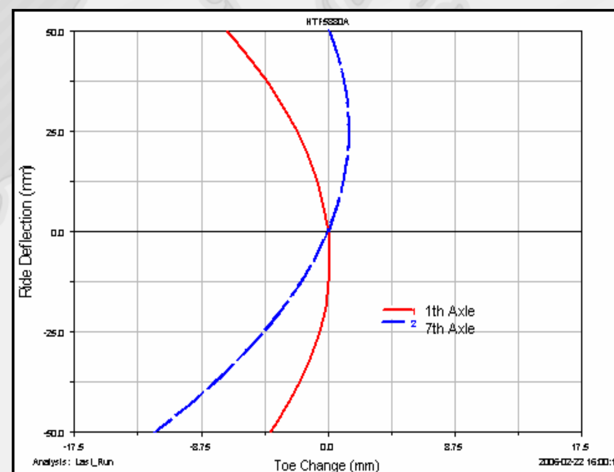
Double wishbone suspension



Wheelbase



Inclination angle



Toe

Dynamic Analysis and Discussion

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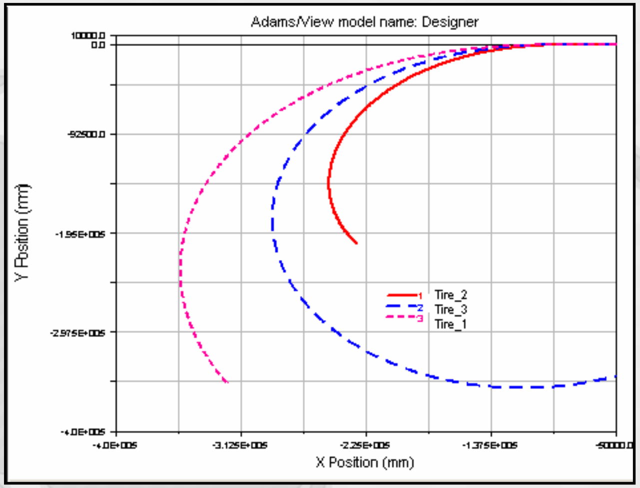
Design rules:

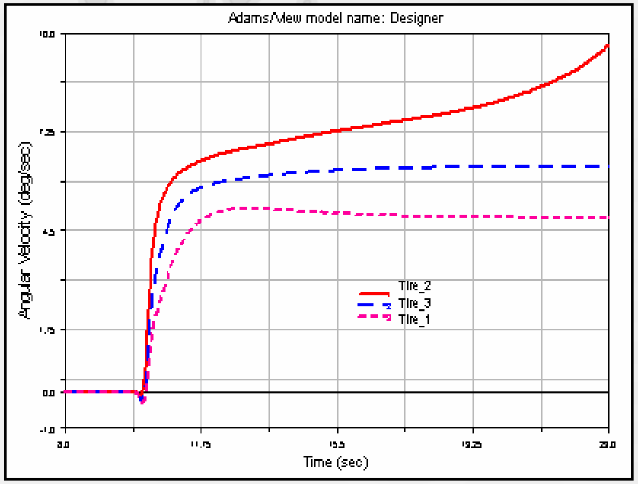
vehicle can obtain larger lateral acceleration using hard stiffness tire, but it is more likely to lose stability. Along with the decrease of tire stiffness, the lateral acceleration is also decreased.



Mass center track

Tire	Cornering stiff N/rad	Camber stiff N/rad
18.00-22.5(18PR) Tire_1	5.0E+4	1.25E+4
315/80R22.5 XZA Tire_2	2.0E+5	2.0E+4
Virtual Tire Tire_3	1.0E+5	0.8E+4

Tire mechanical character



Yaw rate

Dynamic Analysis and Discussion

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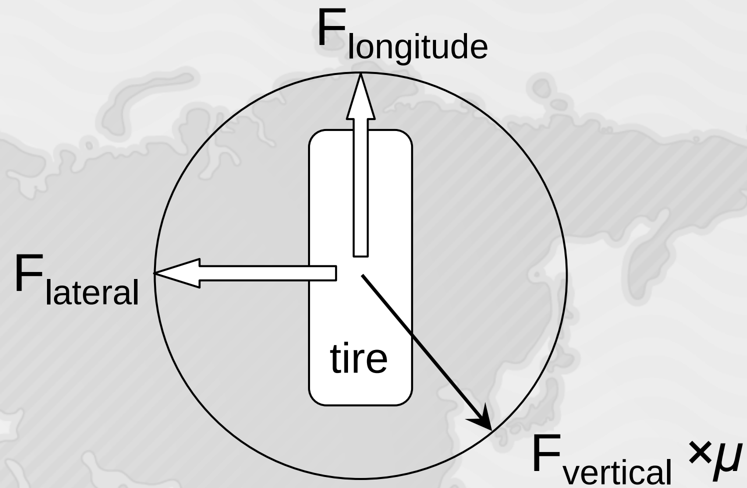
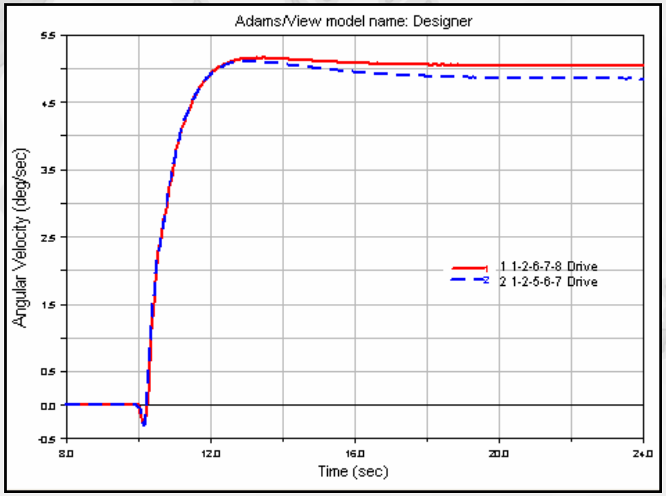
Design rules:

Varied driving configurations will result in different composite moments which act at different points. If the composite moment is opposite to the disturb moment, the vehicle will keep the stable status. Otherwise, the vehicle will lose its stability.



Friction circle theory



Yaw rate

Dynamic Analysis and Discussion

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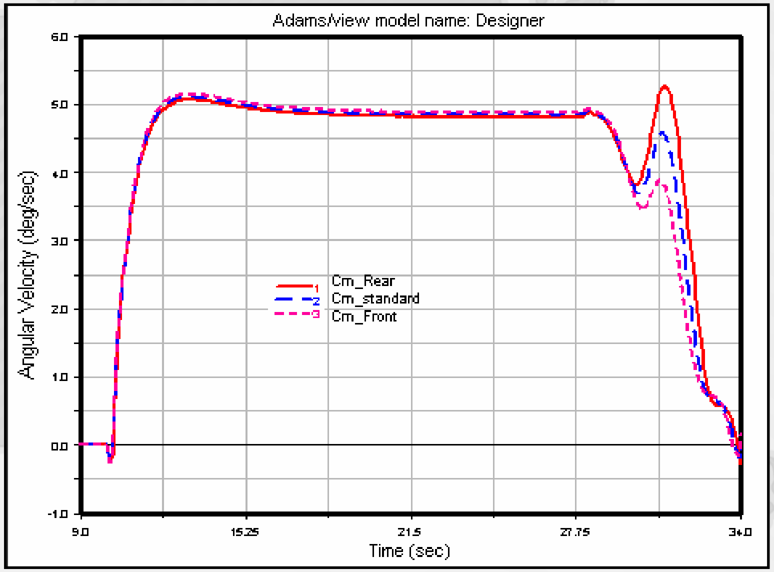
Design rules:

The longitude position of superstructure will effect multi-axle vehicle stability. Especially at the turning brake condition, improperly located superstructure mass center will result in instability.

Conditions:

- Velocity = 55 km/h
- 1th steer angle = 6 degree
- Brake time = 2 second



Yaw rate

Conclusions

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- Suspension parameters should be optimized according to the requirement of stability
- Appropriate tire mechanical character can balance the stability and handling
- Through our simulations based on MSC software, we were able to better understand the relationship between distributed driving axles and vehicle stability, thereby enabling us to develop safer vehicles.
- Improper mass center of superstructure will result bad stability

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Acknowledgements

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Questions?