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Brake Moan Simulation using Flexible Methods in Multibody Dynamics

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Plan of Presentation

1) Introduction
2) Modeling
3) Results
4) Conclusion

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Presentation Content

1) **Introduction**

2) Modeling

3) Results

4) Conclusion

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- General characteristics of brake moan
  - Low frequency noise phenomenon (<500 Hz)
  - Typically seen at very low vehicle speeds and brake pressures
  - Pad and disc stick momentarily and then release causing an excitation often transmitted to braking & suspension systems
  - Does not indicate a functional brake problem
  - Significant customer satisfaction issue resulting in costly warranty claims

Introduction

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- Specific moan case studied
  - Rear brake on SLA trailing arm suspension
  - Fundamental frequency = 320 Hz
  - Off-braking
  - Most evident during extreme turning of loaded vehicle
  - Very low vehicle velocity (< 5 km/h)
  - Sensitive to bending characteristics of trailing arm (tie blade)

Introduction

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- Several experimental measurements carried out to understand and describe the phenomenon (e.g. ODS, Modal Analysis etc.) on brake and tie-blade
- For deeper understanding of above phenomenon and as preventive action on forthcoming platforms, a virtual prototyping effort was launched

Introduction

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- Project Goals
  - Create a multibody dynamic model of brake system
    - Rigid-body foundation brake components
    - Flexible representation of tie blade
  - Simulate moan phenomenon
  - Use model to test and design potential countermeasures
  - Model to serve as template for moan studies on future brake systems

Modeling

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Modeling

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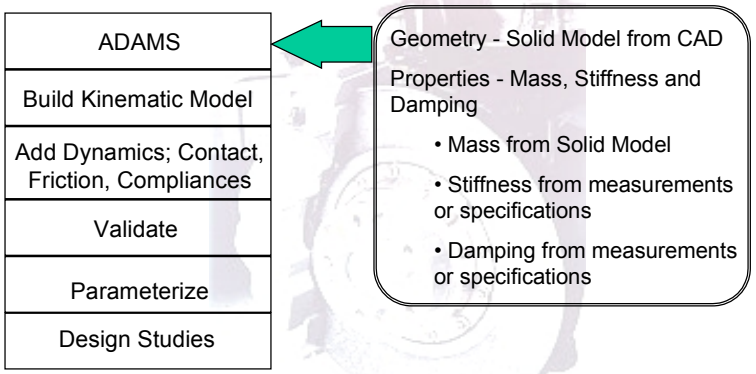
- Modeling Approach



Modeling

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- Model Components
  - Foundation Brake
    - Rotor
    - Pads
    - Caliper
    - Piston
    - Anchor plate
    - Guide pins
  - Suspension
    - Tie blades
    - Control arms
    - Springs
    - Shocks
    - Anti-roll bar

Modeling

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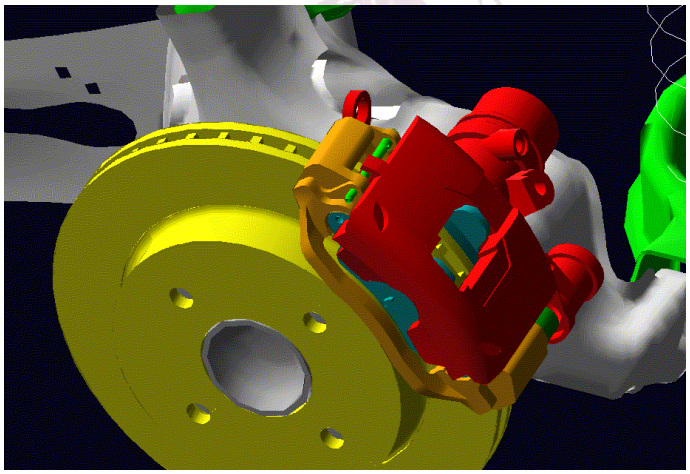
Foundation disc brake: modeled as
multi rigid-body system



Modeling

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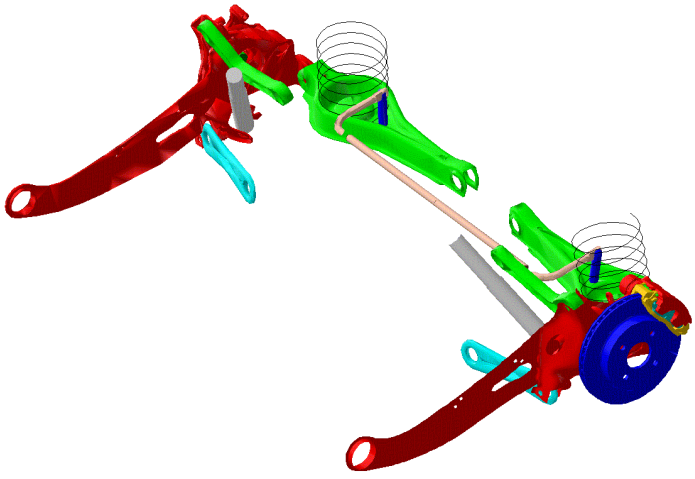
Suspension components –
all rigid bodies, except tie blade (flexible)



Modeling

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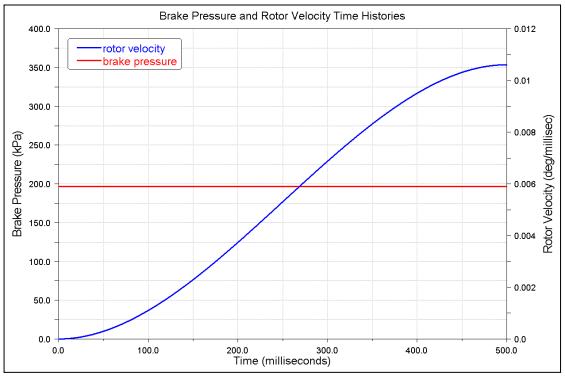
- Model Inputs
  - Rotor Velocity: 0-10.6 deg/s (vehicle 0.2 km/h) in 0.5 sec
  - Brake Pressure: constant 197kPa (approx. 2bar)



Modeling

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- Modeling assumptions
  - All rigid bodies except tie blade
  - Only foundation brake modeled, no hydraulics
  - No thermal effects
  - No full-vehicle simulation; motion applied directly to rotor

Modeling

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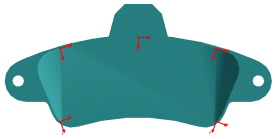
- Specific model elements
  - Pad-to-Rotor contact
    - 5 contact points per pad



    - Each includes normal and tangential (friction) components
      - Normal force: controlled by ADAMS IMPACT function
      - Frictional force: $F_{fri} = \mu(v) \cdot F_N$
        - » $\mu_{static} = 0.5$
        - » $\mu_{dynamic} = 0.37$

Modeling

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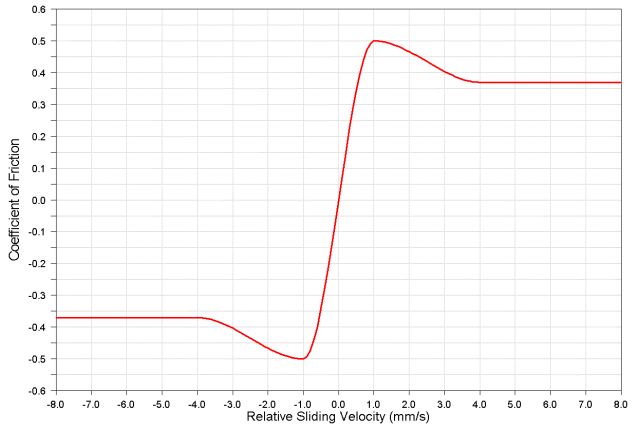
- Specific model elements
  - Pad-to-Rotor contact

Coefficient of Friction vs. Relative Pad-to-Rotor Velocity



Modeling

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- Specific model elements
  - Flexible tie blade
    - Physically, moan known to be sensitive to bending characteristics of tie blade
    - Unable to replicate moan with rigidly modeled tie blade
    - Import modal data from FE model of tie blade to ADAMS model
    - Constrain FE tie blade in ADAMS and upon it mount rigid-body brake model

Modeling

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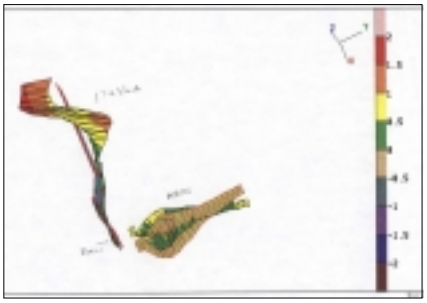
Tie Blade FE Model



Tie Blade ODS Vehicle Measurements

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- Model output considerations
  - Time domain moan signal
  - Frequency domain moan signal
  - Mode shape animation

Results

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- Model output characteristic of moan
  - Acceleration on caliper and along tie blade
  - Stick-slip pulses followed by sustained vibration
  - Fundamental frequency in 300Hz range
- Frequency comparison

Test Point	ADAMS Model Moan Frequency	Physical Test Data Moan Frequency
Point A: forward, high on tie blade	268 Hz	312 Hz
Point B: forward, low on tie blade		
Point C: middle, low on tie blade		
Point D: top of caliper, near guide pin		

Results

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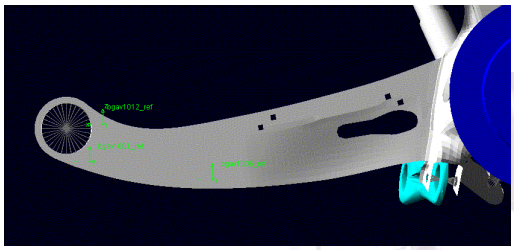
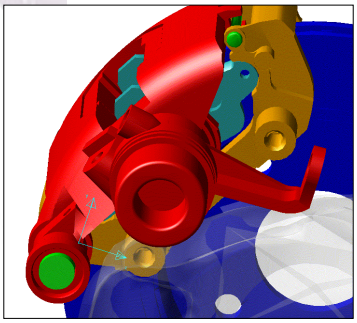


Measurement Points:Tie Blade



Measurement Point:Caliper

Results

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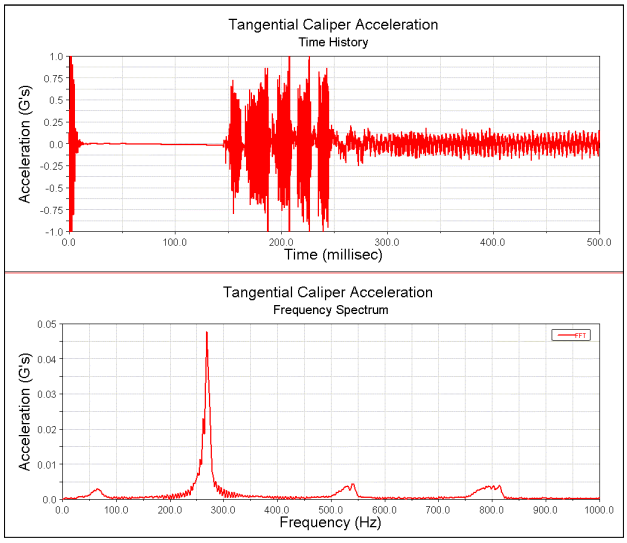
Moan Profile: model results



Results

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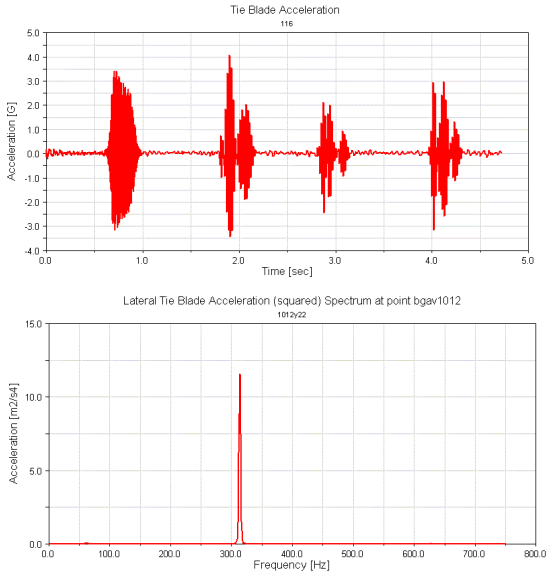
Moan Profile: experimental test data



Results

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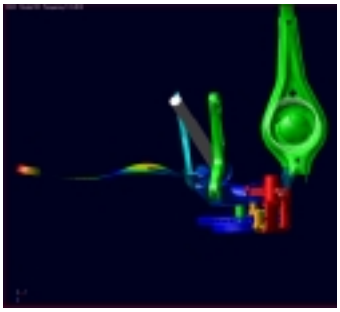
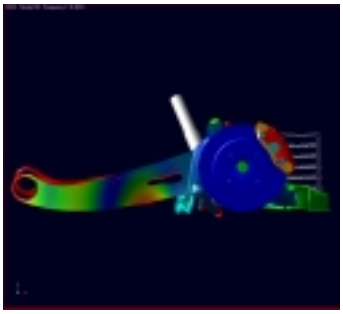
- Mode shape animation
  - Tie blade bending mode natural frequency (free-free) = 262Hz
  - Simulated system natural frequency = 268 Hz





Results

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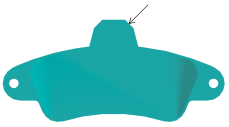
- Model response to moan countermeasures
  - Removal of anti-rattle clip
    - experimental: reduced moan occurrence
    - model: no moan



  - Swaged tie blade
    - experimental: reduced moan occurrence
    - model: no moan

Results

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- Model response to input variations
  - Brake pressure increase
    - experimental: no moan
    - model: no moan
  - Rotor velocity increase
    - experimental: no moan
    - model: no moan

Results

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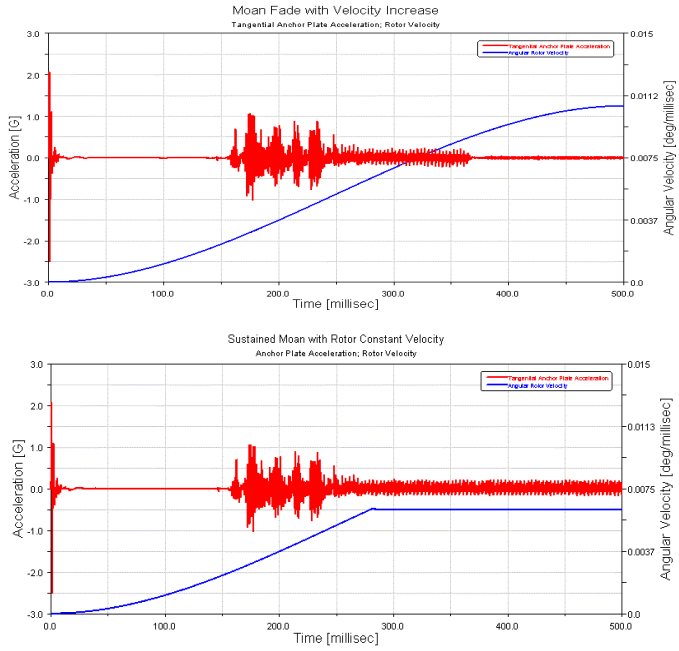

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- Model reasonably replicated the moan signal
- Successful comprehensive model validation
  - Response to known countermeasures
  - Response to input variations
- Flexible Multi-body dynamics approach allows for faster simulation time versus FE-only method
  - Use flexible bodies only where needed
  - Baseline model runs in ~1.5 hours on Pentium II NT workstation

Conclusion

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- Model usable for additional exploration
  - Parametric sensitivity studies
  - Guide to physical experimentation
  - Address future warranty issues
- Template for future brake system modeling
- Combined finite element and multibody dynamic simulation models are essential to successful brake vibration simulation