



Modeling and Factor Analysis of Hydraulic Power Steering Systems for Rotational Steering Vibration by Using MSC.ADAMS

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This presentation presents a study on the rotational vibration sensitivity of automotive hydraulic power steering systems by using MSC.ADAMS. The results are used to predict the effect of specification change and provide countermeasure ideas for reducing the level of steering rotational vibration.

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- *Introduction*
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Introduction



Steering vibration is a major NVH issue that affects overall NVH comfort in passenger cars.

Two types of fundamental steering vibrations:

- Vertical/lateral translational vibration
- Rotational vibration ← **Focus of this study**

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Introduction

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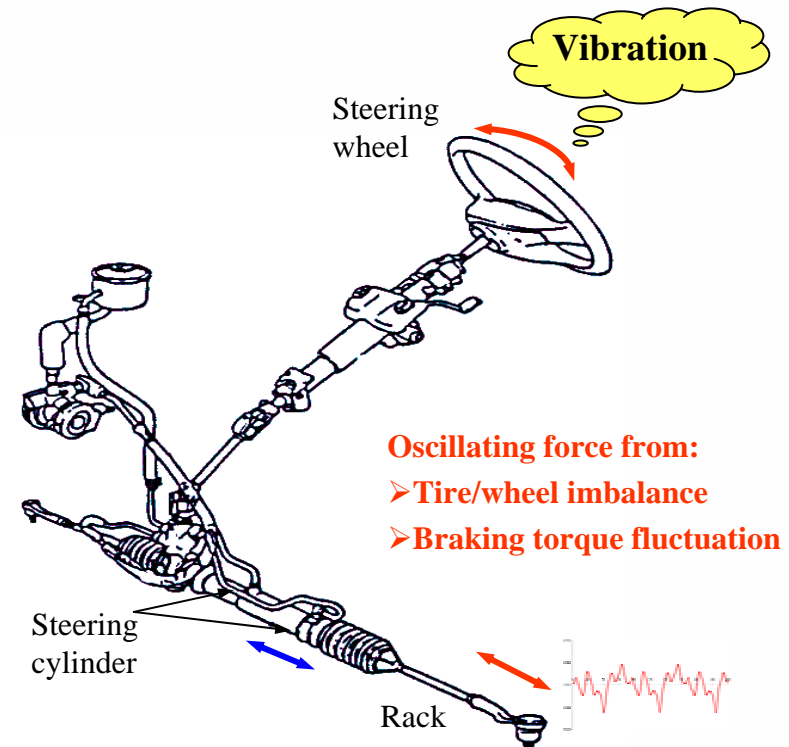
Rotational steering vibration:

mainly caused by excitation force acting on the steering rack due to:

- tire/wheel imbalance
→ “Steering shimmy”
- braking torque fluctuation
→ “Brake judder”

Normal frequency range: 15Hz – 20Hz

Steering system behaves exactly the same for both steering shimmy and brake judder





Introduction

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Purposes:

- ✓ Analyze the sensitivity of steering rotational vibrations to the excitation force acting on steering rack;
- ✓ Guide steering system tuning for reducing steering vibration;
- ✓ Achieve an important step toward full transmissibility analysis of vibration from road wheel to steering wheel.

Challenge:

- ✓ Non-linear dynamic coupling between the steering rack-pinion mechanism and the hydraulic sub-system.

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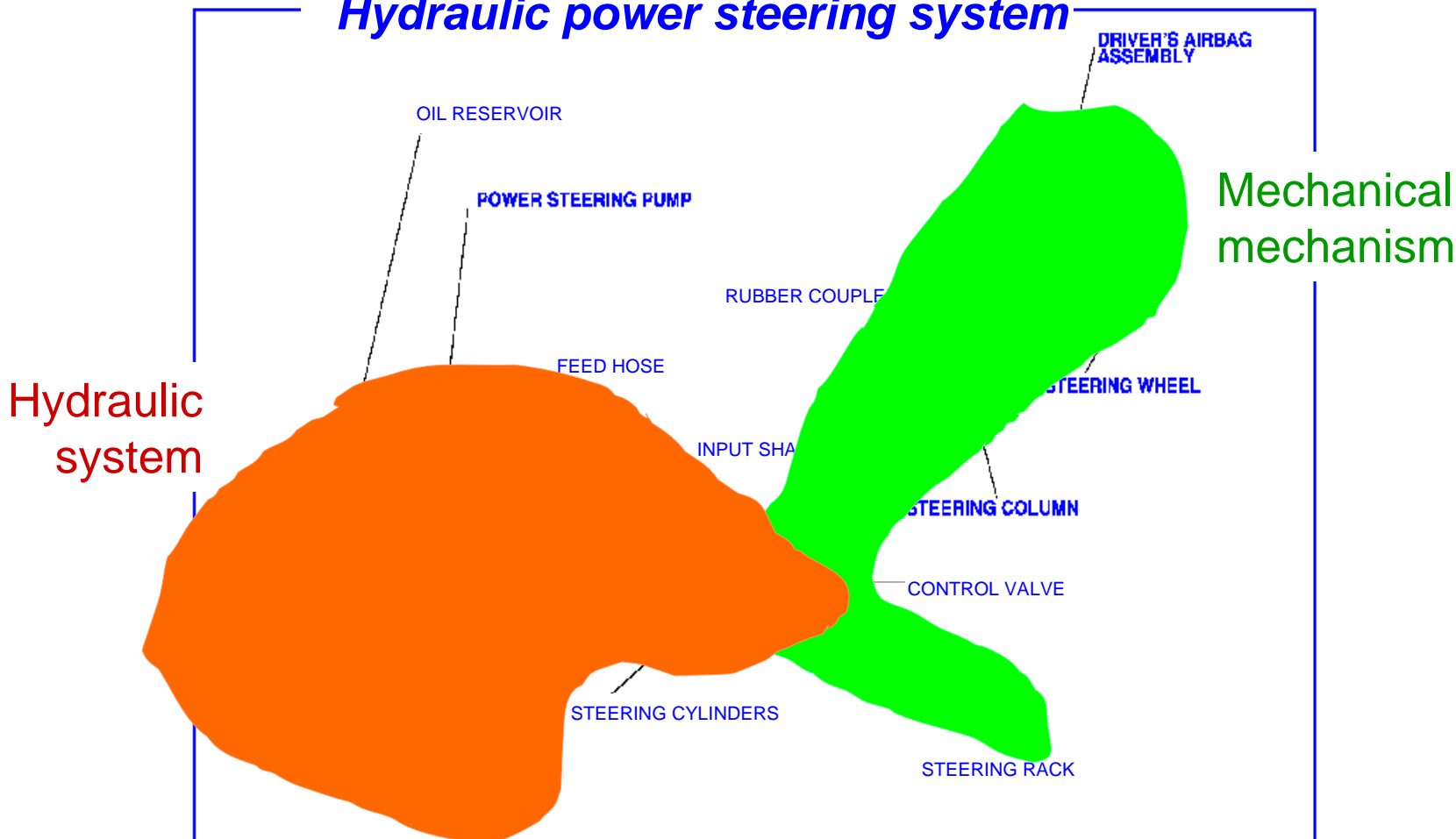


Modelling Approach

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Hydraulic power steering system



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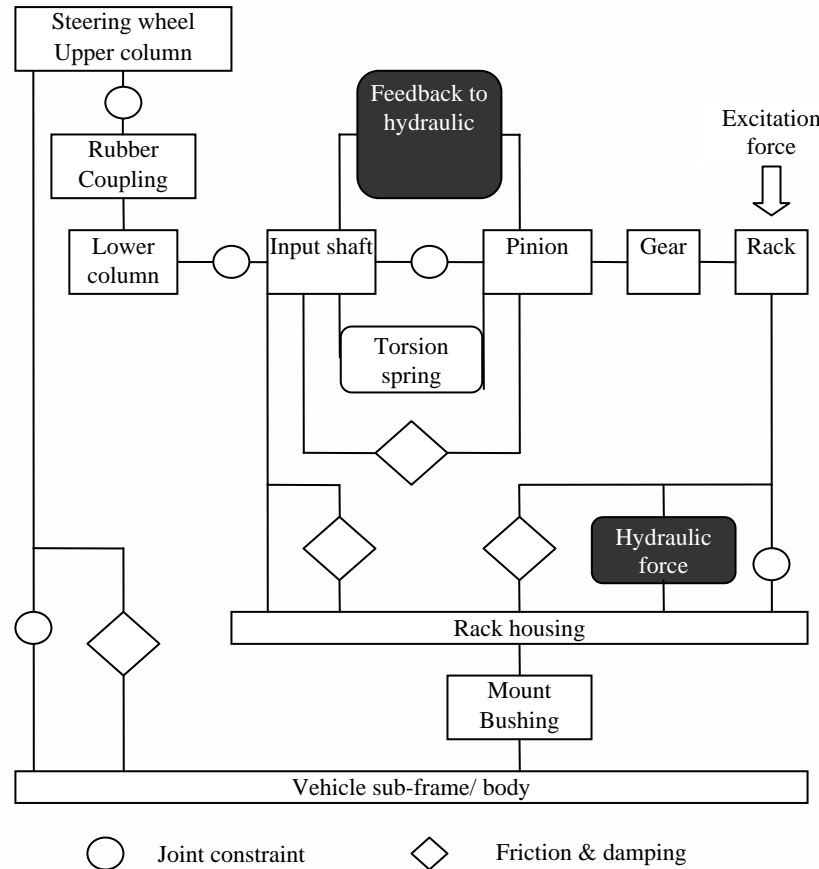
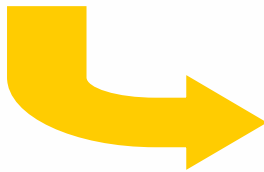
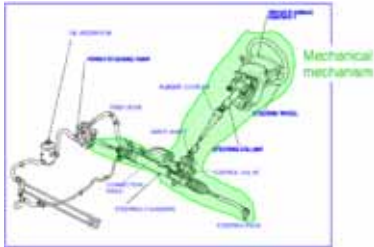


Modelling Approach

Mechanical rack-pinion mechanism

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- ✓ Rigid bodies model
- ✓ Non-linear elements:
 - friction
 - damping
 - backlash
- ✓ Coupling with hydraulic sub-system

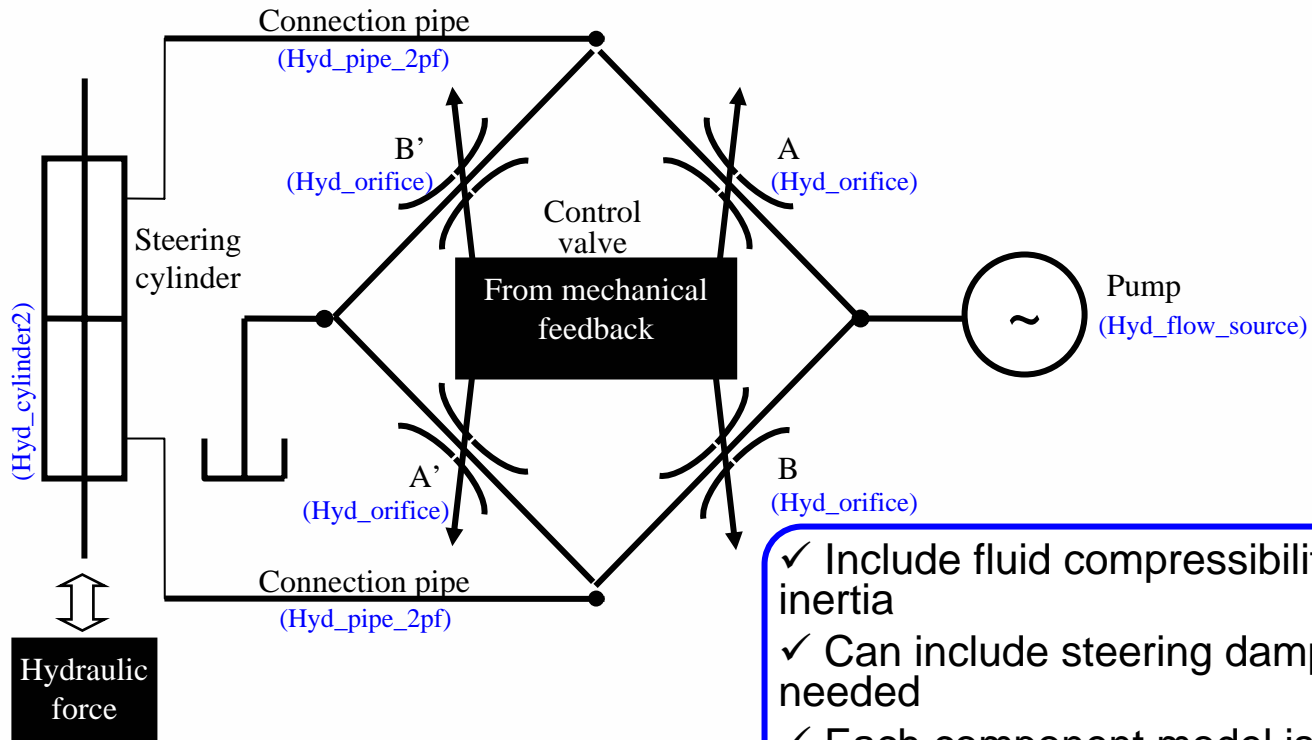
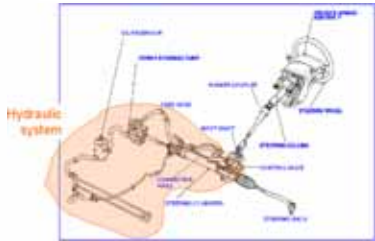


Modelling Approach

Hydraulic sub-system

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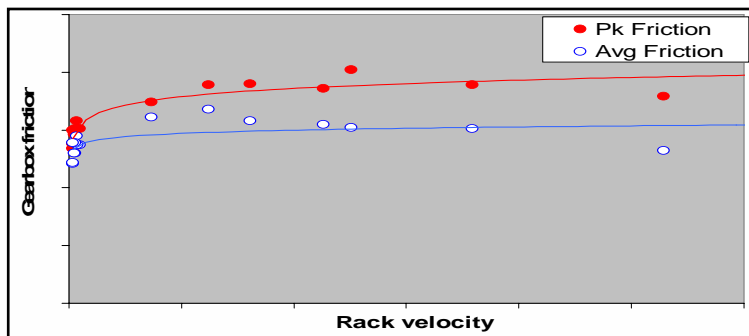
Modelling Approach

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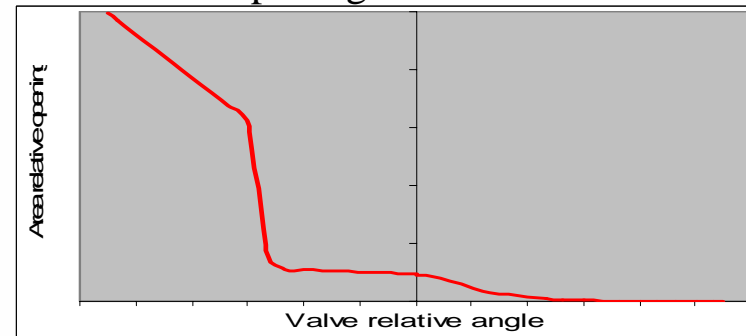
Gearbox friction

- ✓ Based on inverted sliding test
- ✓ Velocity-friction function was identified



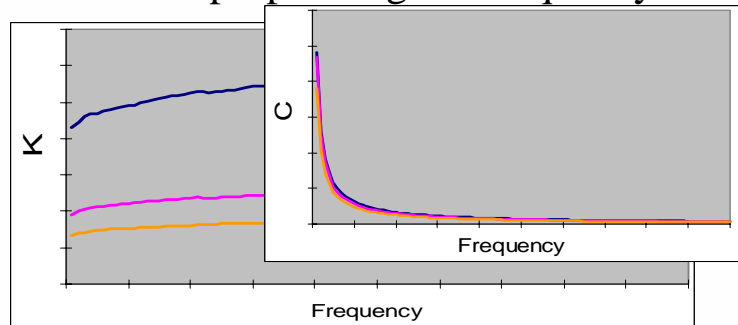
Control valve characteristics

- ✓ Based on gearbox torque-pressure test
- ✓ Relative opening function was identified



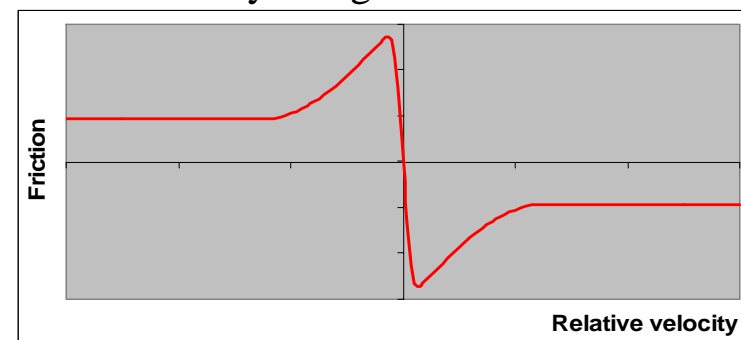
Rubber parts stiffness & damping

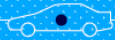
- ✓ Based on excitation measurement
- ✓ Data at proper range of frequency were used



Friction profile

- ✓ Customized for hydraulic rubber sealing
- ✓ Created by using "STEP" functions



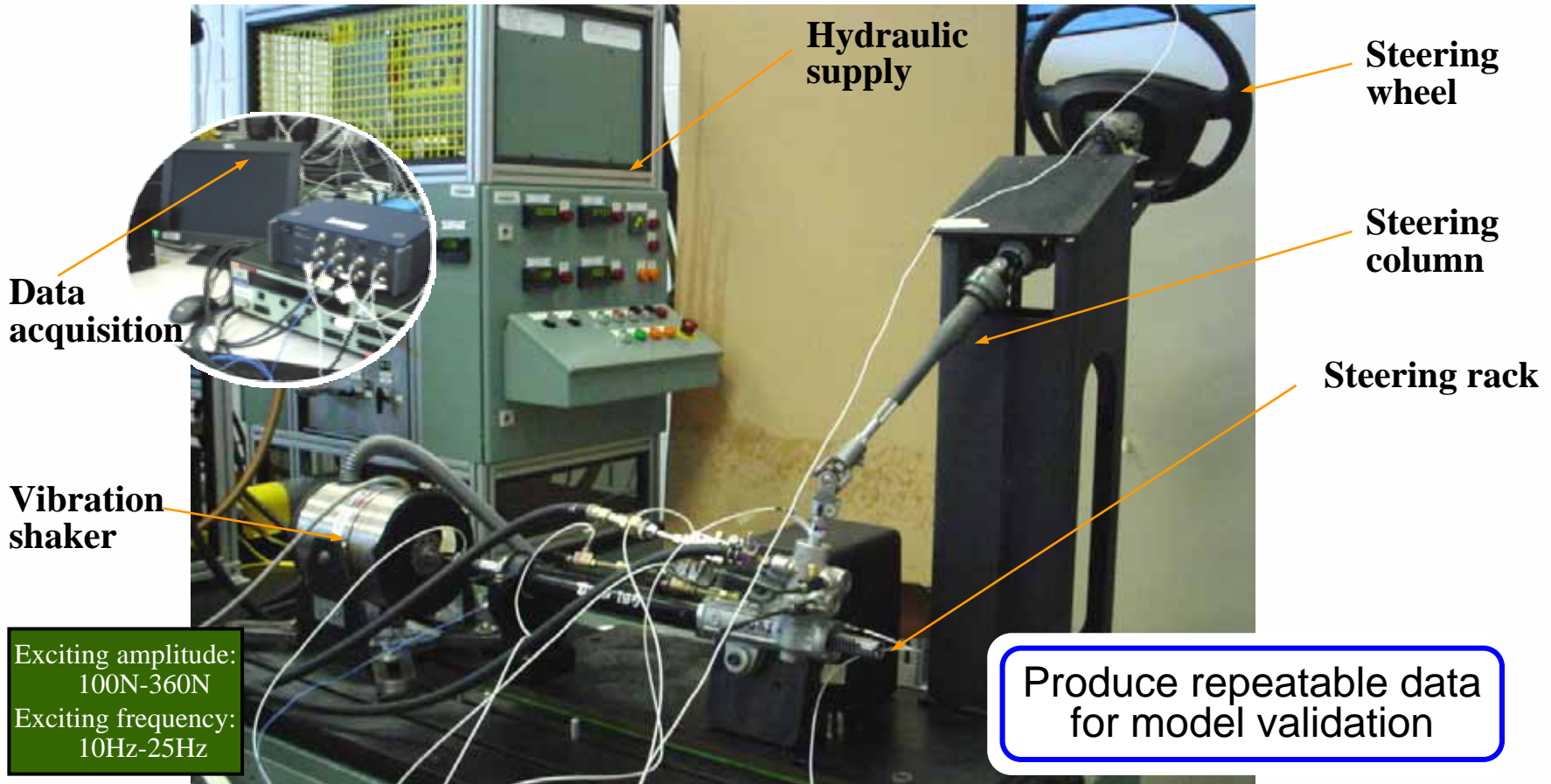


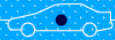
Model Validation

Bench test system

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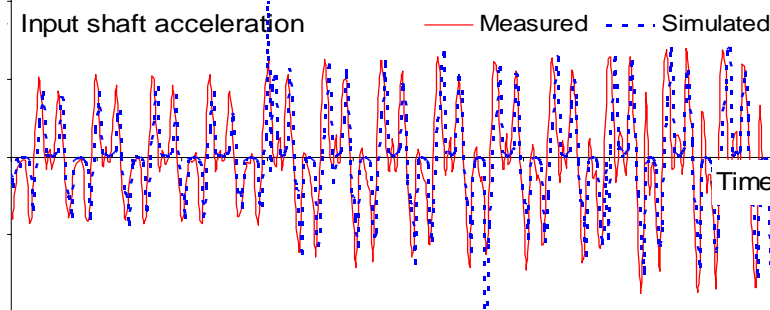
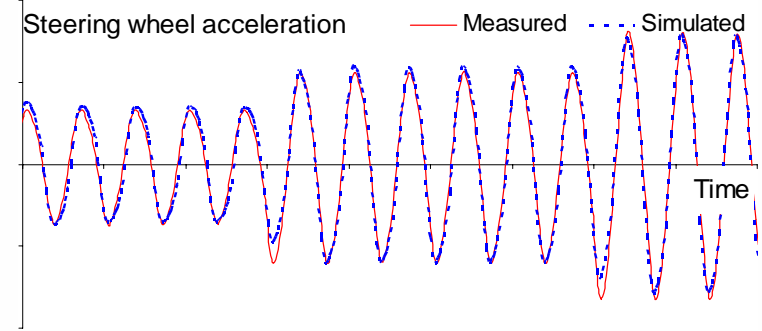
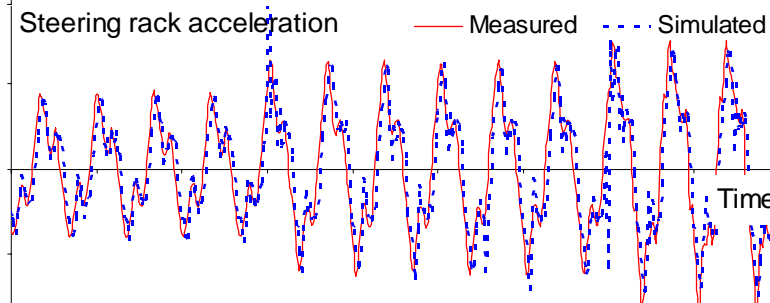
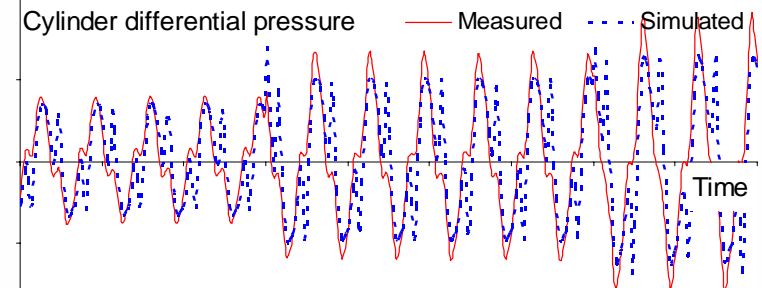
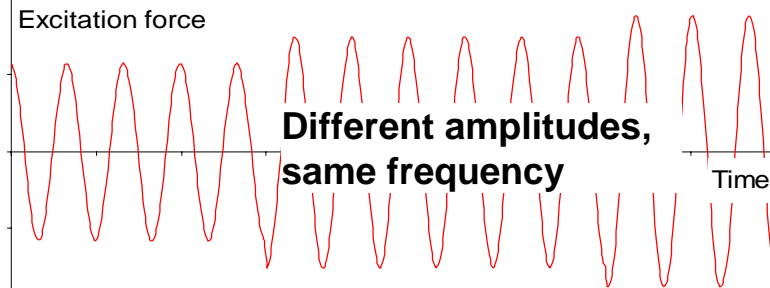


Model Validation

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Comparison of measured & simulated results – time domain



Excellent agreement between simulation and measurement, even for different exciting force levels

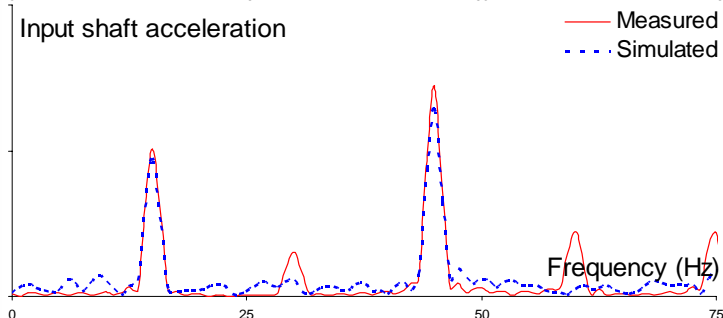
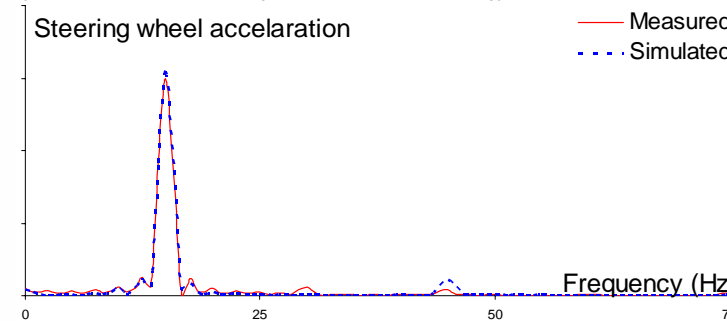
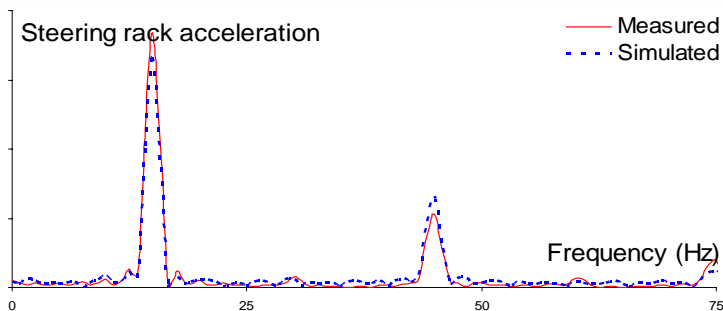
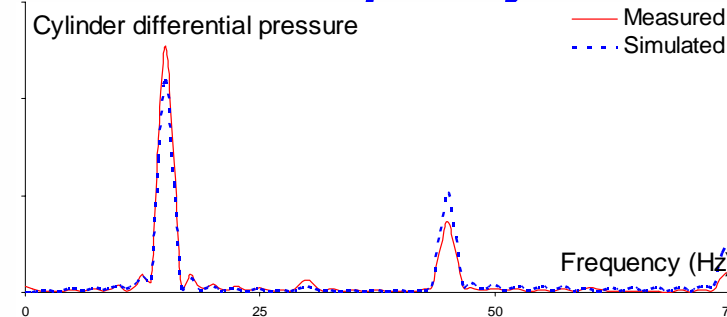
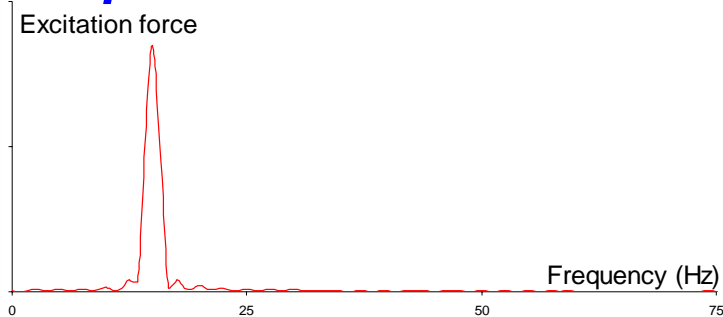


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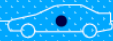
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Comparison of simulated & measured results – frequency domain



✓ Frequency domain data show an excellent agreement

✓ The model can predict the nonlinear vibration behavior very well

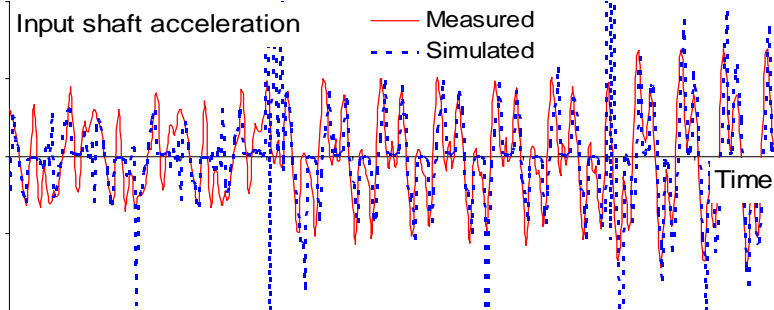
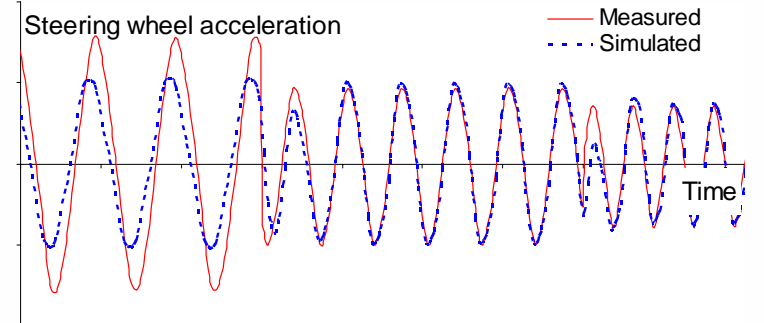
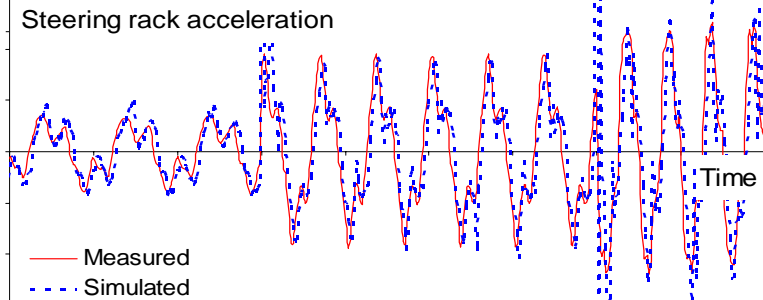
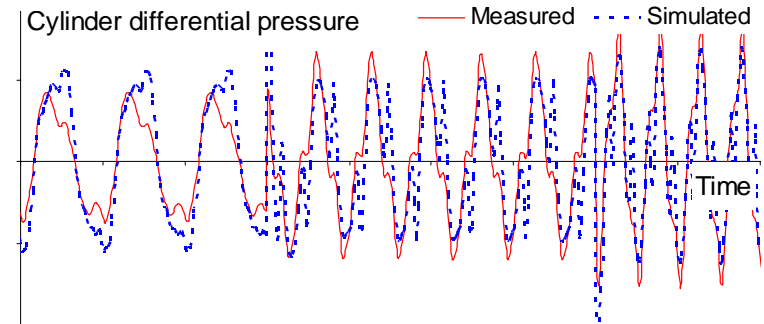
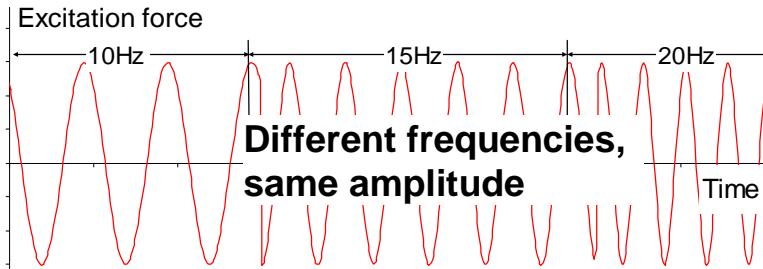


Model Validation

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Comparison of measured & simulated results



Excellent agreement between simulation and measurement for exciting frequency range 10-20Hz

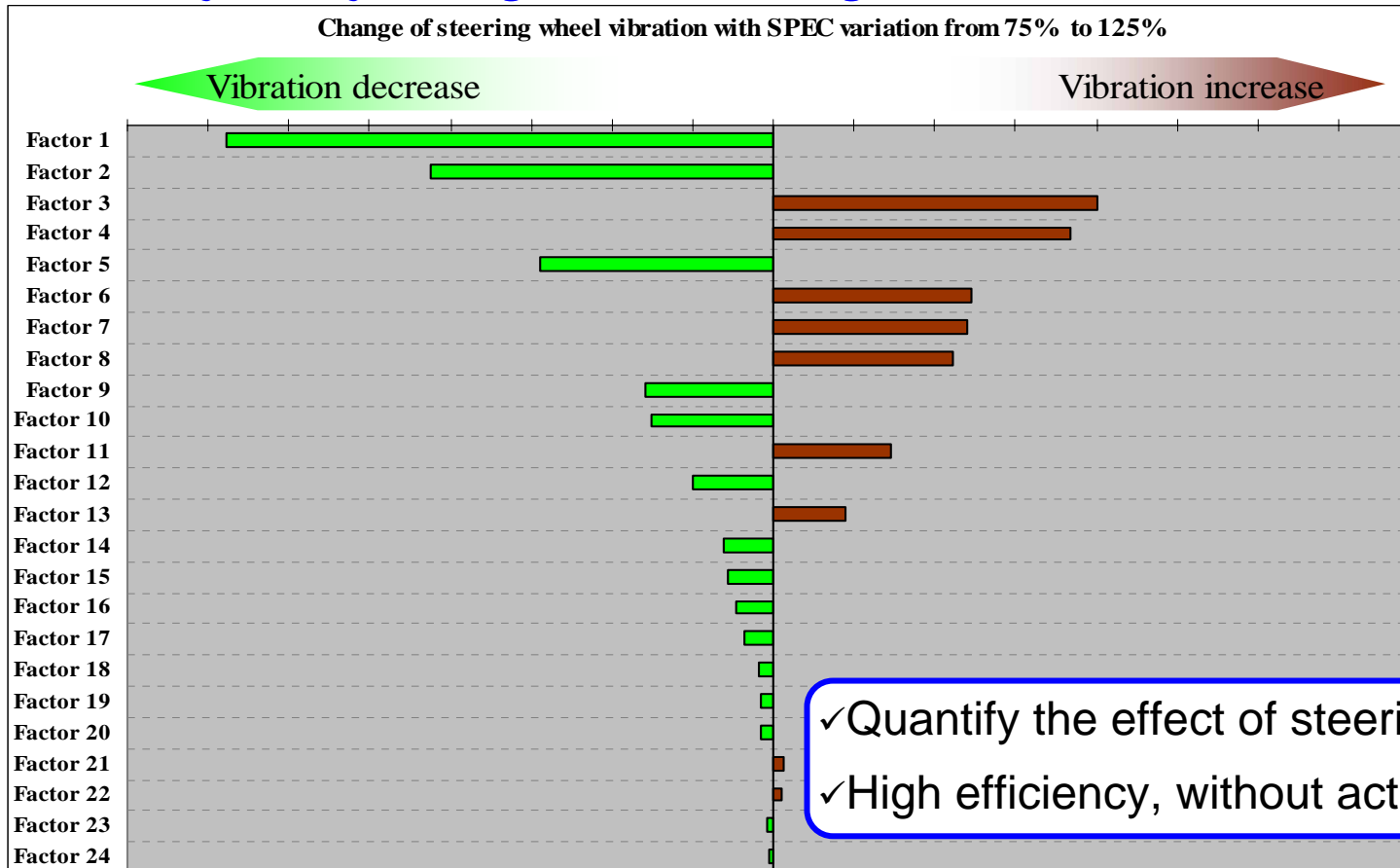


Application

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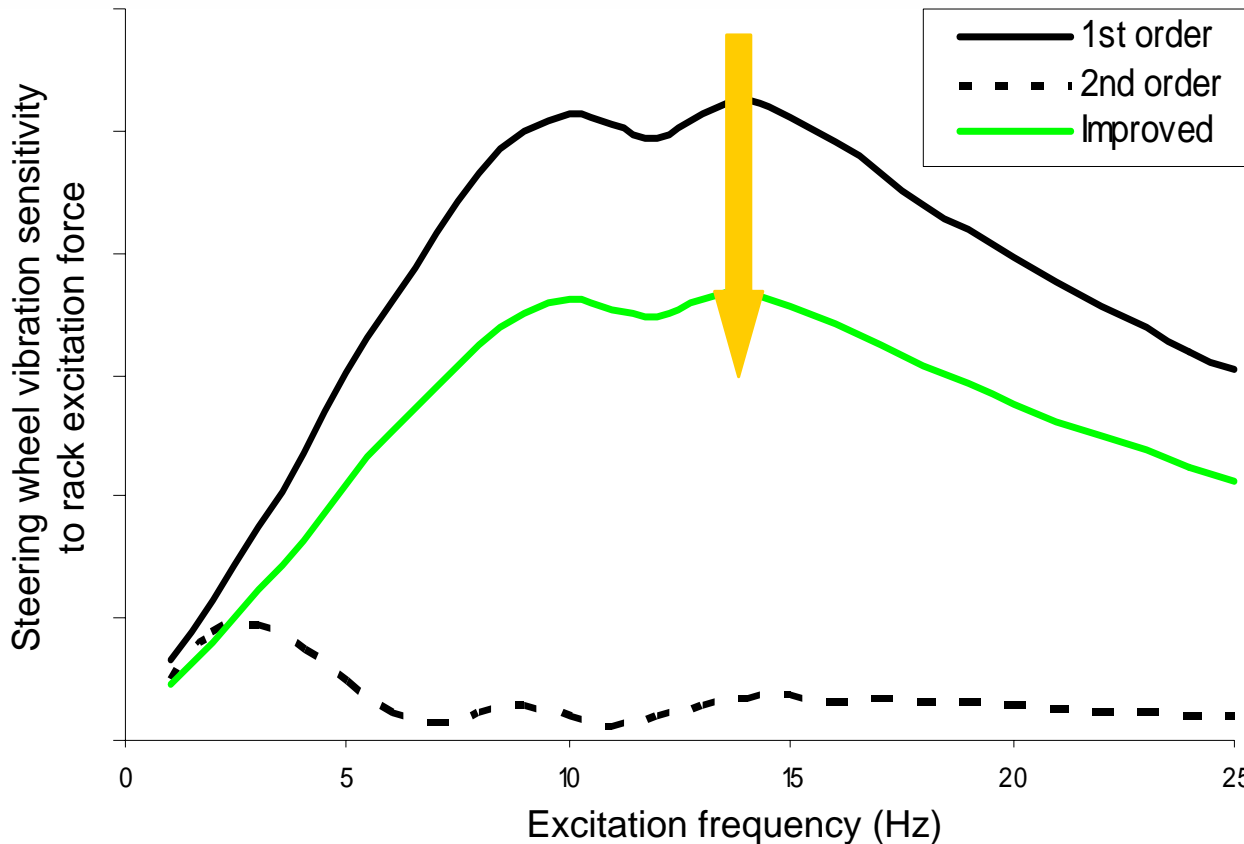
Factor analysis by using ADAMS/Insight



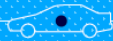


Application

Sensitivity analysis



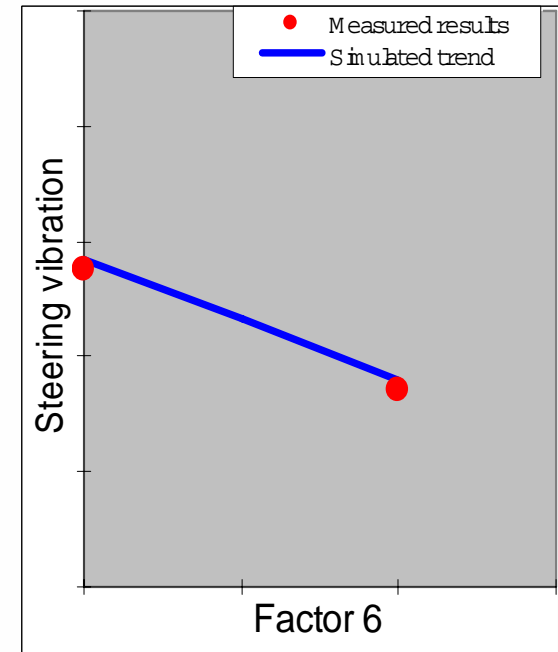
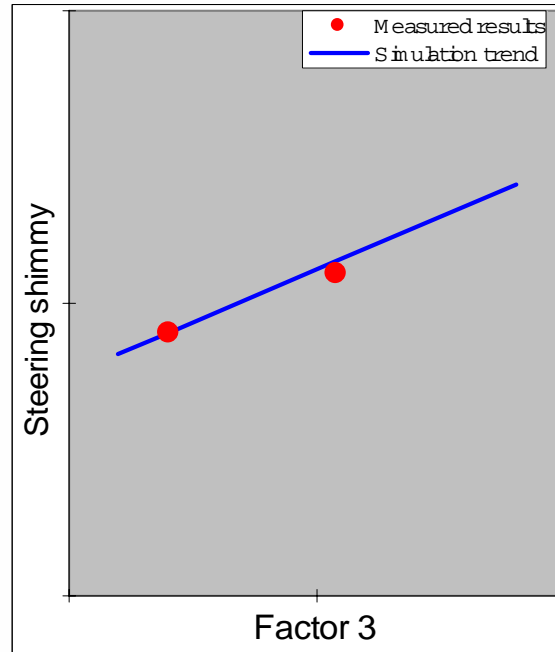
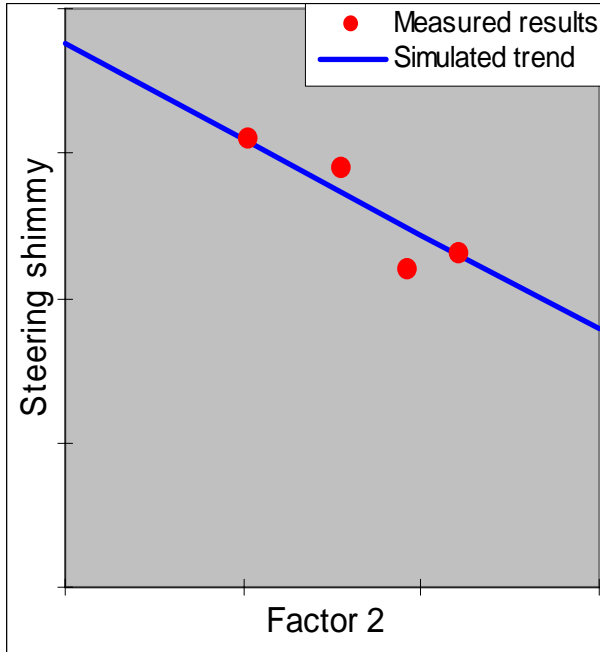
Improve the steering vibration sensitivity by the virtual tuning of critical factors



Application



Countermeasure prediction



The simulation tool is used to predict the effect of specification change on steering rotational vibrations



Conclusions

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- ✓ A simulation tool for analyzing the fluid-mechanically-coupled, rotational steering vibration sensitivity of hydraulic power steering systems has been created, by using MSC.ADAMS.
- ✓ The simulation model was well correlated with an actual steering system under various excitation conditions corresponding to steering shimmy and brake judder.
- ✓ It has been proven to accurately predict the non-linear, coupling vibration behavior of steering mechanical and hydraulic sub-systems within the frequency range of interest.
- ✓ The tool has been used to identify the most influential steering factors, provide countermeasure ideas, predict the effect of steering part change, and integrate with the models of other sub-systems to perform full transmissibility analysis.