Rear Disc Brake Moan Investigation

Experimental Investigation and ADAMS Simulation

ADAMS User Conference

13MAY97

Agenda

- Introduction
- Moan Overview
- ADAMS Simulation Activity
- Simulation Verification
- Summary

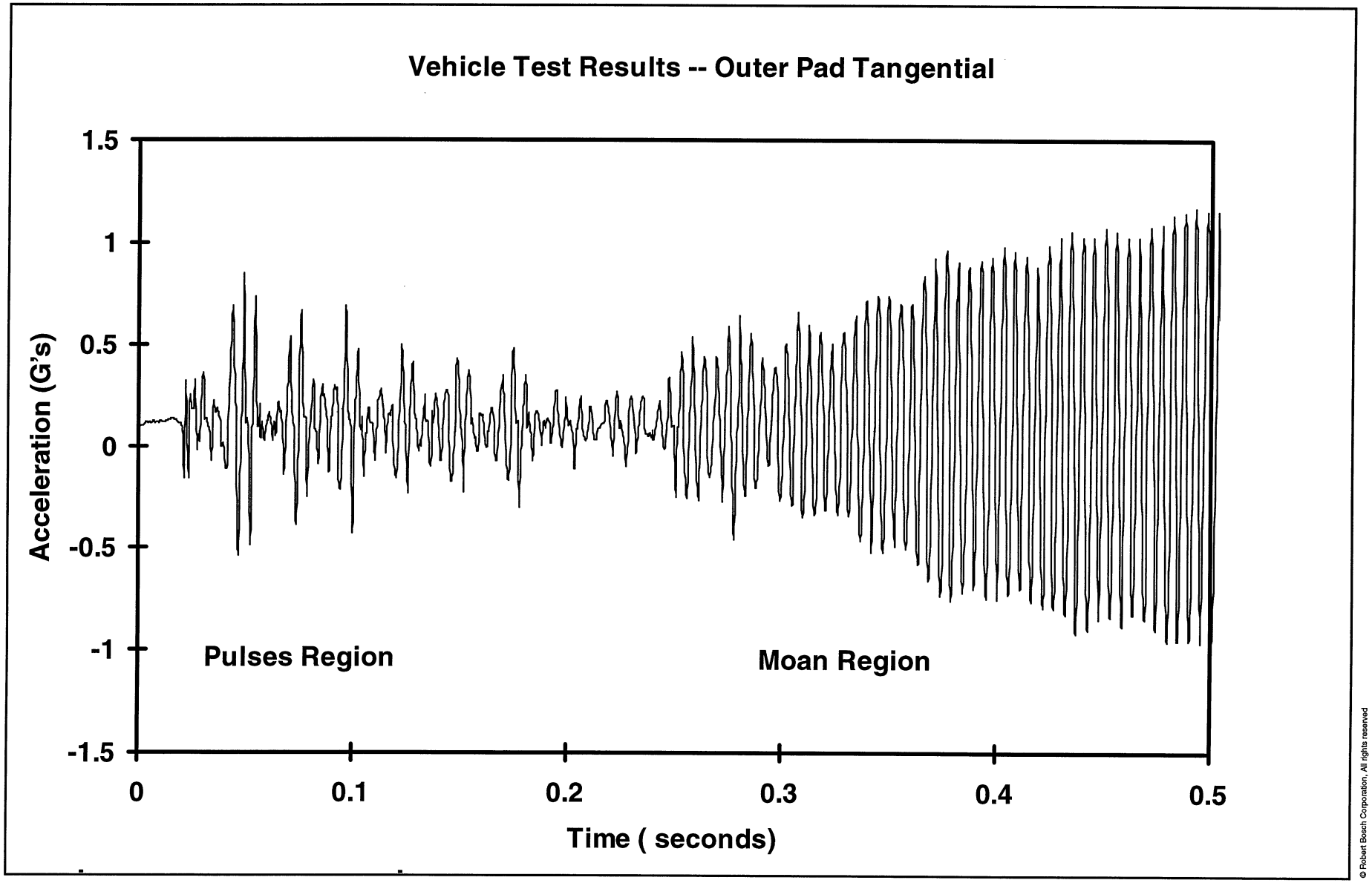
Moan Definition

An audible noise which occurs at low speed and light brake apply conditions. It usually contains a single stationary frequency in the 180 to 200 Hz range although other frequencies up to 1000 Hz have been measured. These frequencies usually correspond to one or more of the rigid or flexible body modes of the brake, axle, and suspension system. Modulation of the moan signature by some of these resonance's can also occur. Moan can occur on one or both brakes.

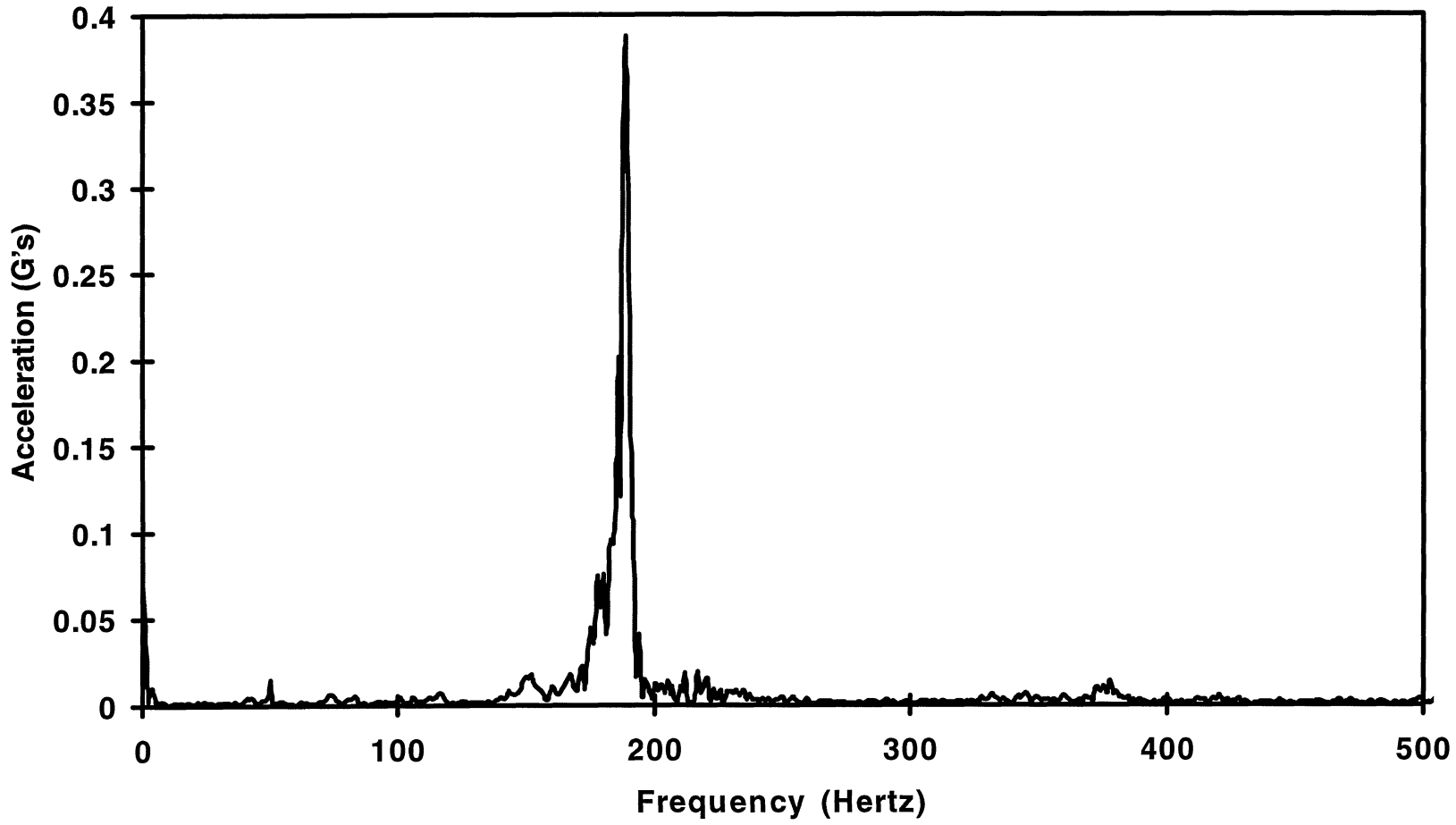
Operational Conditions of Moan:

- Mileage: new to ????? miles
- Vehicle Speed: < 1 to 5 mph
- Lining Temperature: < 75 F
- Fluid Pressure: < 100psi
- Vehicle Motion: Both forward and reverse

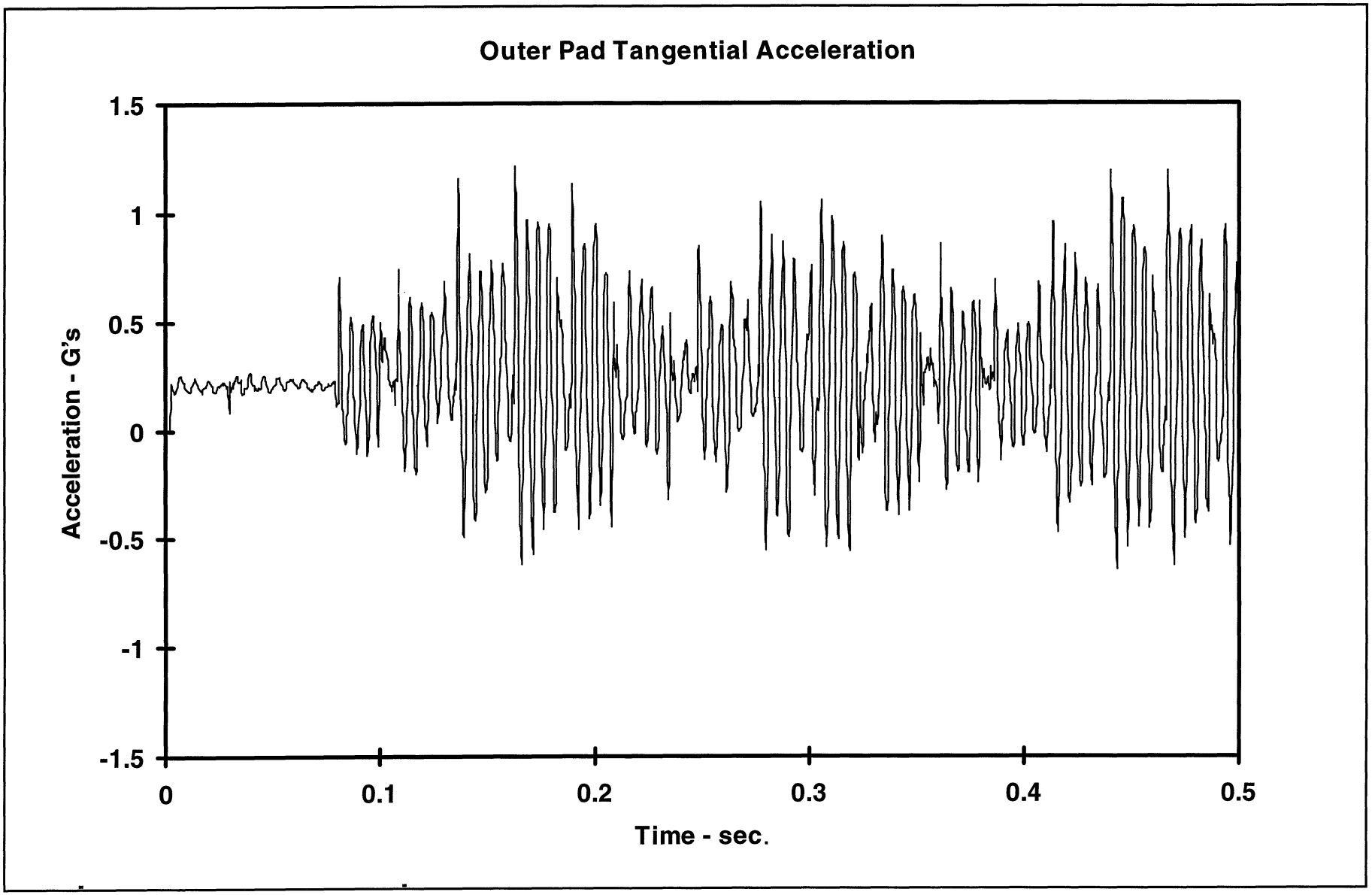
Typical Moan Time Signature -- Vehicle



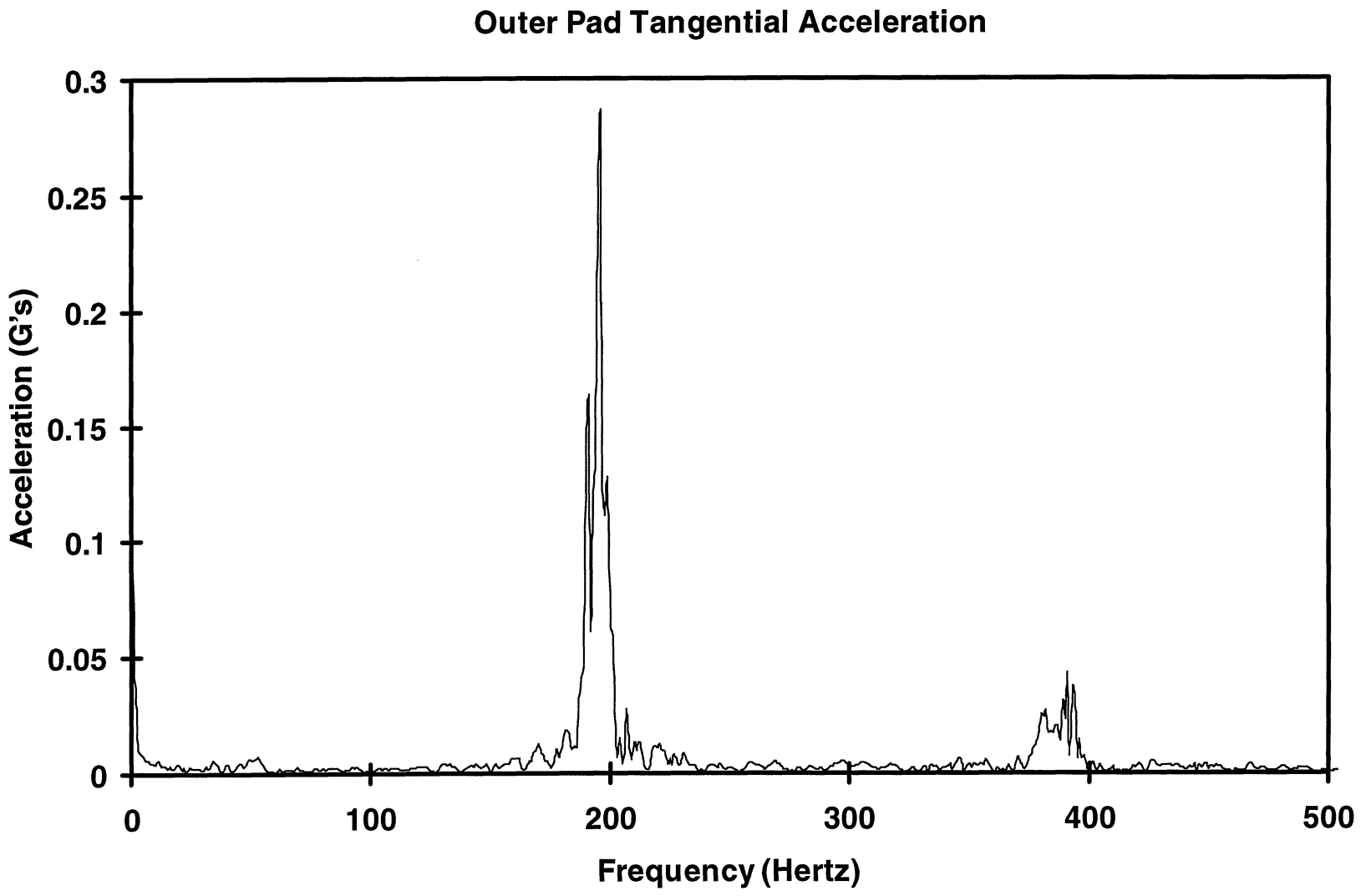
Typical Moan Frequency Signature -- Vehicle



Typical Moan Time Signature -- Bench



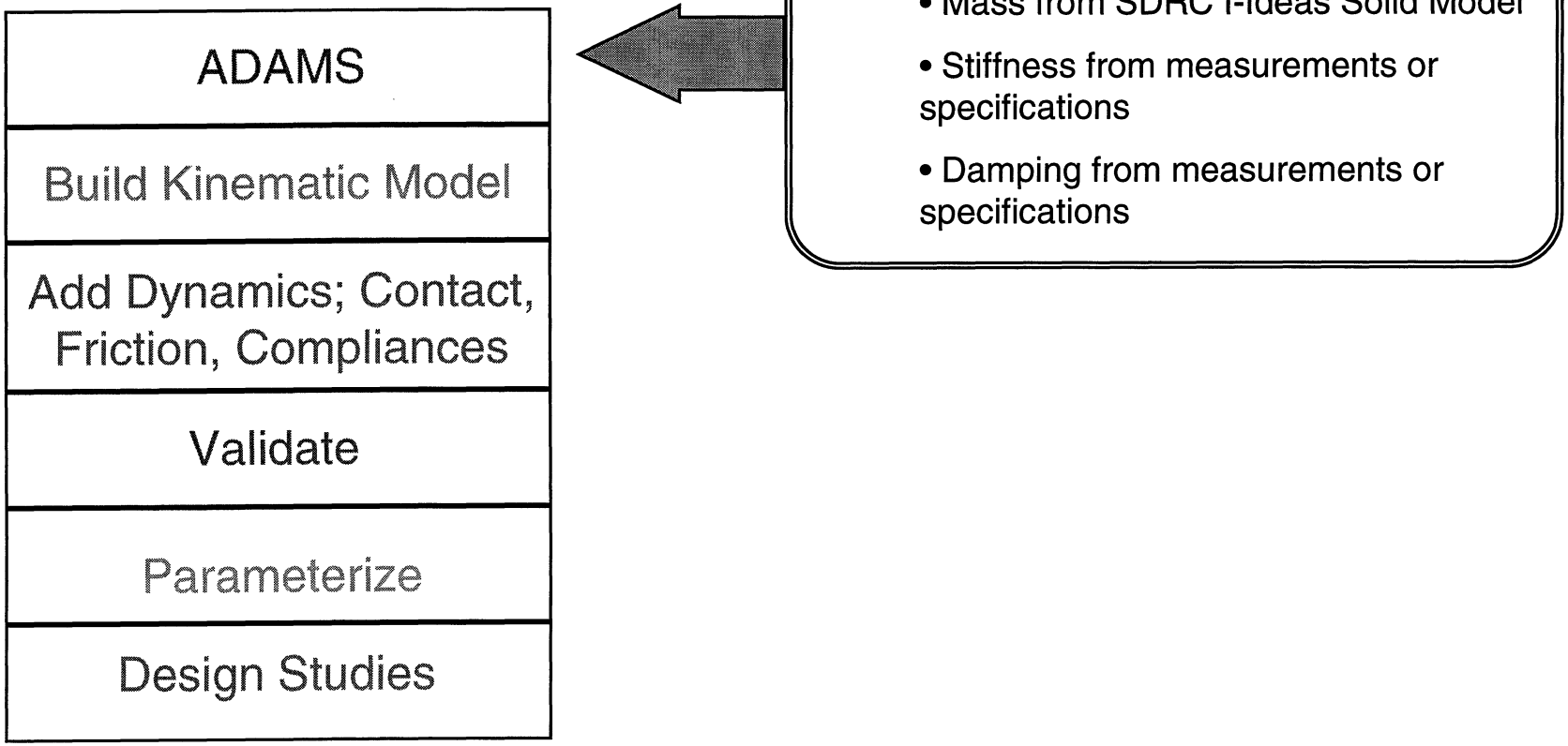
Typical Moan Frequency Signature -- Bench



Adams Simulation -- Project Overview

- Simulation Process
- Model Development and Tactics
- Design Study - Overview
- Design Study - Results
- Animation of Simulation Results

ADAMS Simulation -- Process



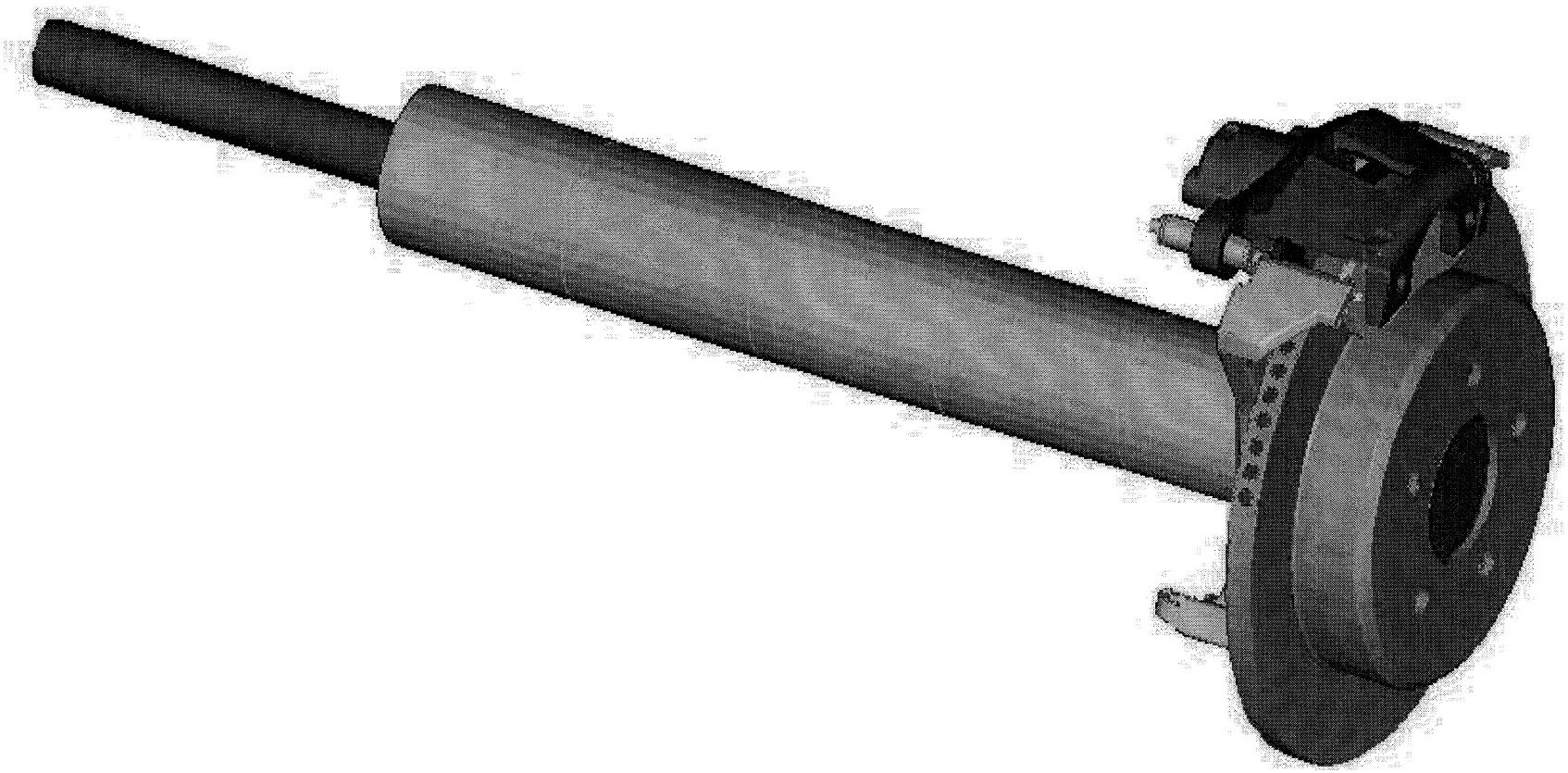
ADAMS Simulation -- Model Strategy and Tactics

- Solid Modeling
- Adams Kinematic Model
- Configuration
- Adams Dynamic Model
- Compliance
- Friction
- Pad to Rotor Contact
- Rigid or Flexible Parts
- Design Study -- Development and Analysis Results
- Animation of Simulation Results

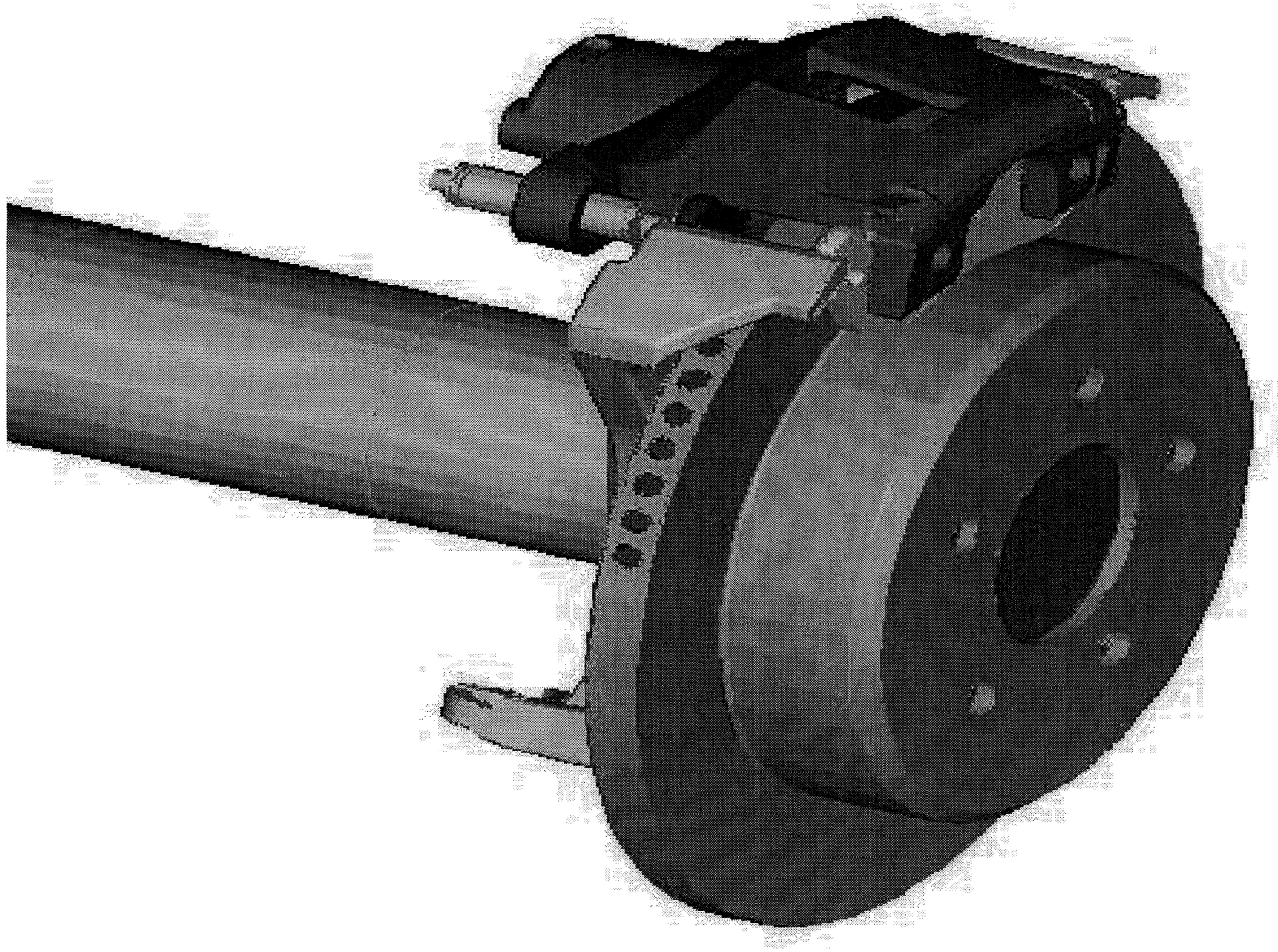
ADAMS Simulation -- Model Configuration

Components	Caliper, Inner / Outer Pad, Rotor, Axle Tube, Axle Shaft, Axle Bearing
Axle	½ Axle --Tube and Shaft and Bearing
Coefficient of Friction	Nominal: Static (0.48), Dynamic (0.32)
Pressure Apply	Ramp: 0 - 25 psi in 0.200 seconds
Rotor Rotational Speed	Vehicle: 6 - 7 deg/sec (Vehicle 0.2 mph) Bench : 5 - 10 deg/sec
Assumptions	All rigid parts except Axle Tube and Shaft Cantilevered Axle Tube and Shaft No tire/wheel

ADAMS Simulation -- Model



ADAMS Simulation -- Model



ADAMS Simulation -- Design Study

- Bearing stiffness (lbf/inch)
- Bearing clearance (inch)
- Tube stiffness (inch^4)
- Shaft stiffness (inch^4)
- Pad contact stiffness (lbf/inch)

ADAMS Simulation -- Design Study Results

Summary

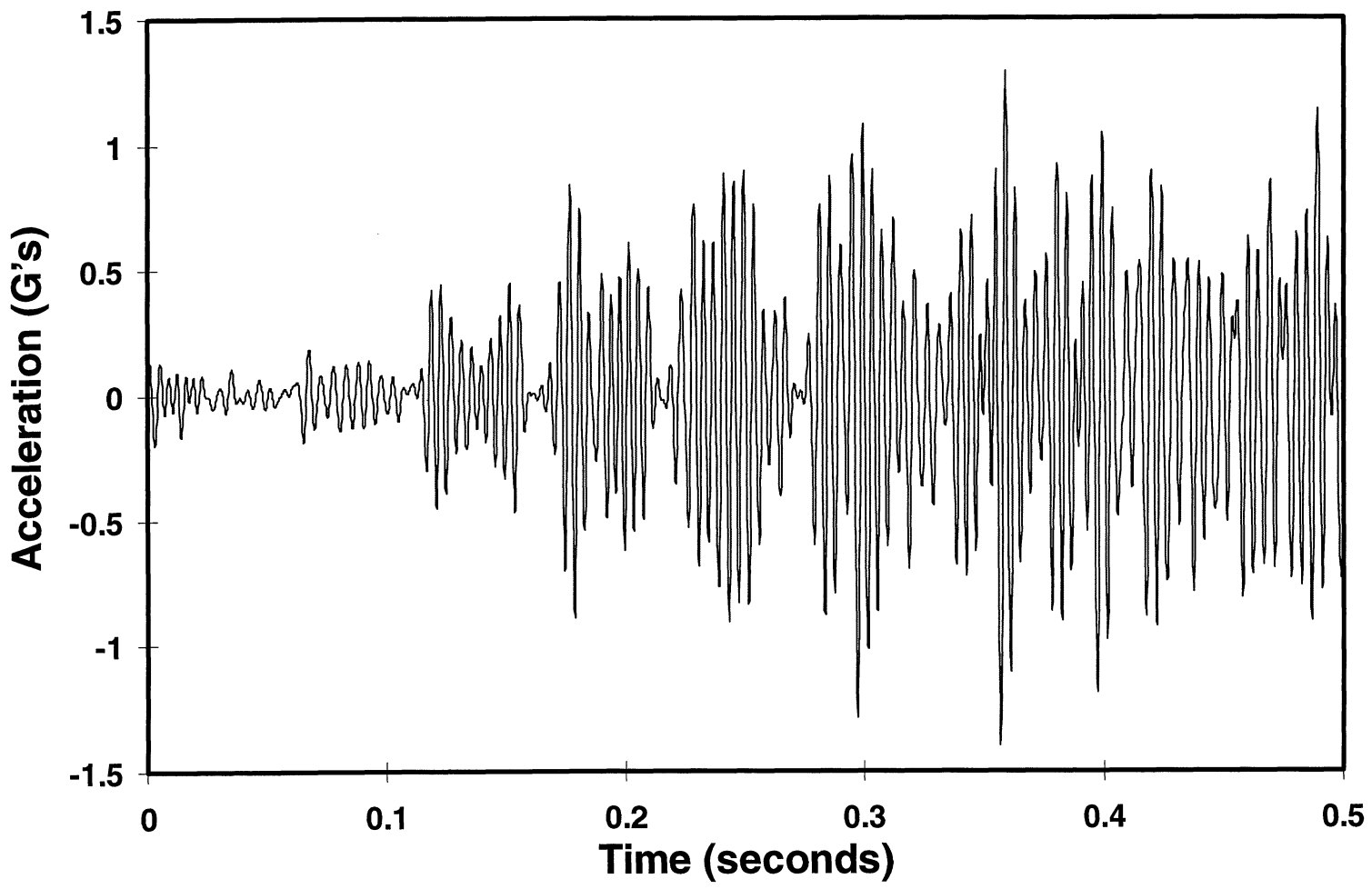
	Moan Characteristic	Effect on Moan
Bearing Stiffness	Frequency	No
	Amplitude	Yes
Bearing Clearance	Frequency	No
	Amplitude	Yes
Tube Stiffness	Frequency	Yes
	Amplitude	Yes
Shaft Stiffness	Frequency	No
	Amplitude	No
Pad Contact Stiffness	Frequency	No
	Amplitude	Yes

ADAMS Simulation -- Design Study Results

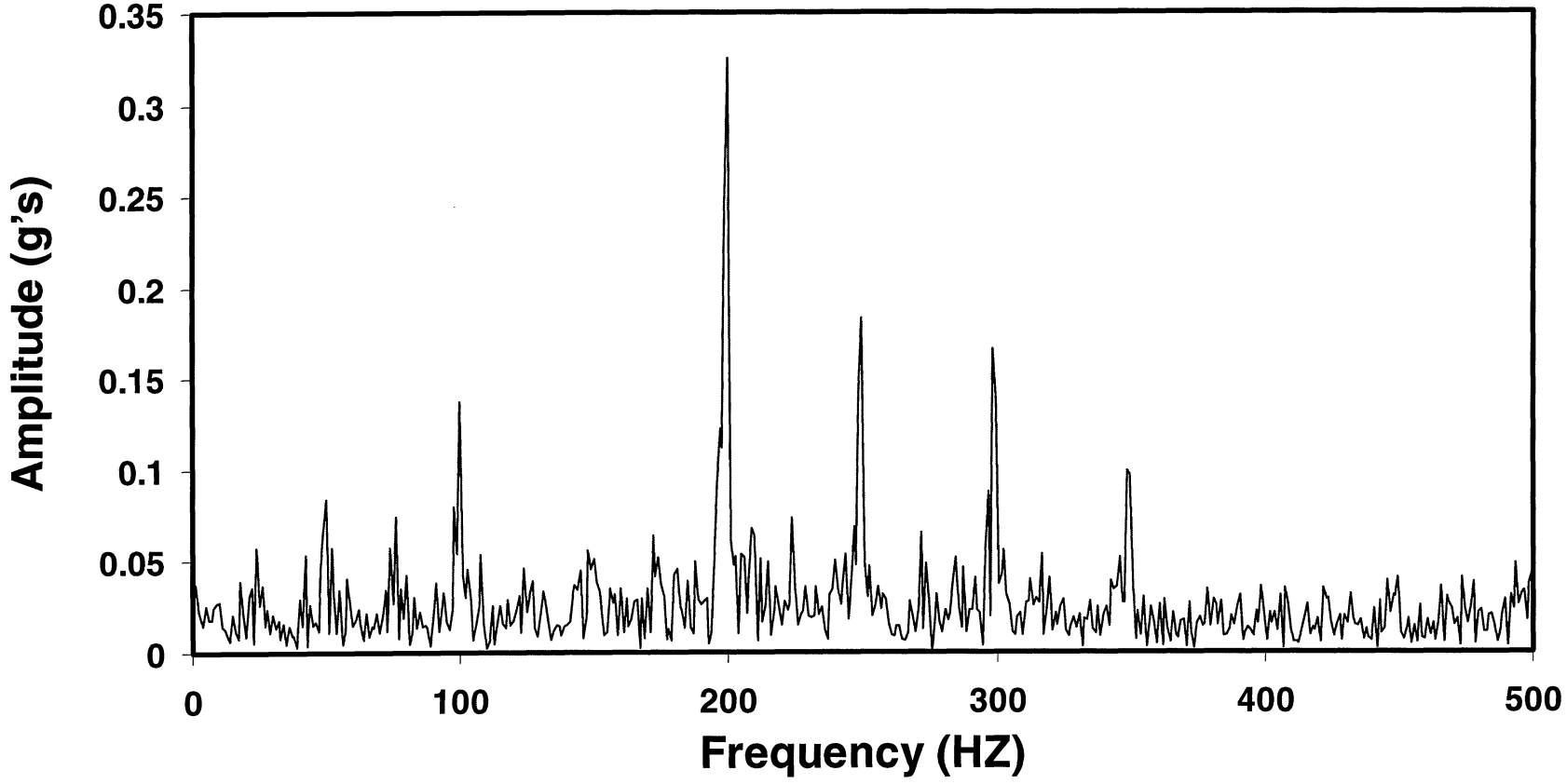
Time and Frequency Signature Features with and without Axle Tube and Shaft

	Full Model	Shaft Only	Tube Only	Without Tube & Shaft
Pulses	**Yes**	**Yes**	**Yes**	**No**
Moan Signature	**199-250**	**No**	**No**	**No**
Moan Modulation (Hz)	**48**	**No**	**No**	**No**

ADAMS Simulation -- Results



ADAMS Simulation -- Results



ADAMS Simulation -- Verification

Aspects of Model Verification

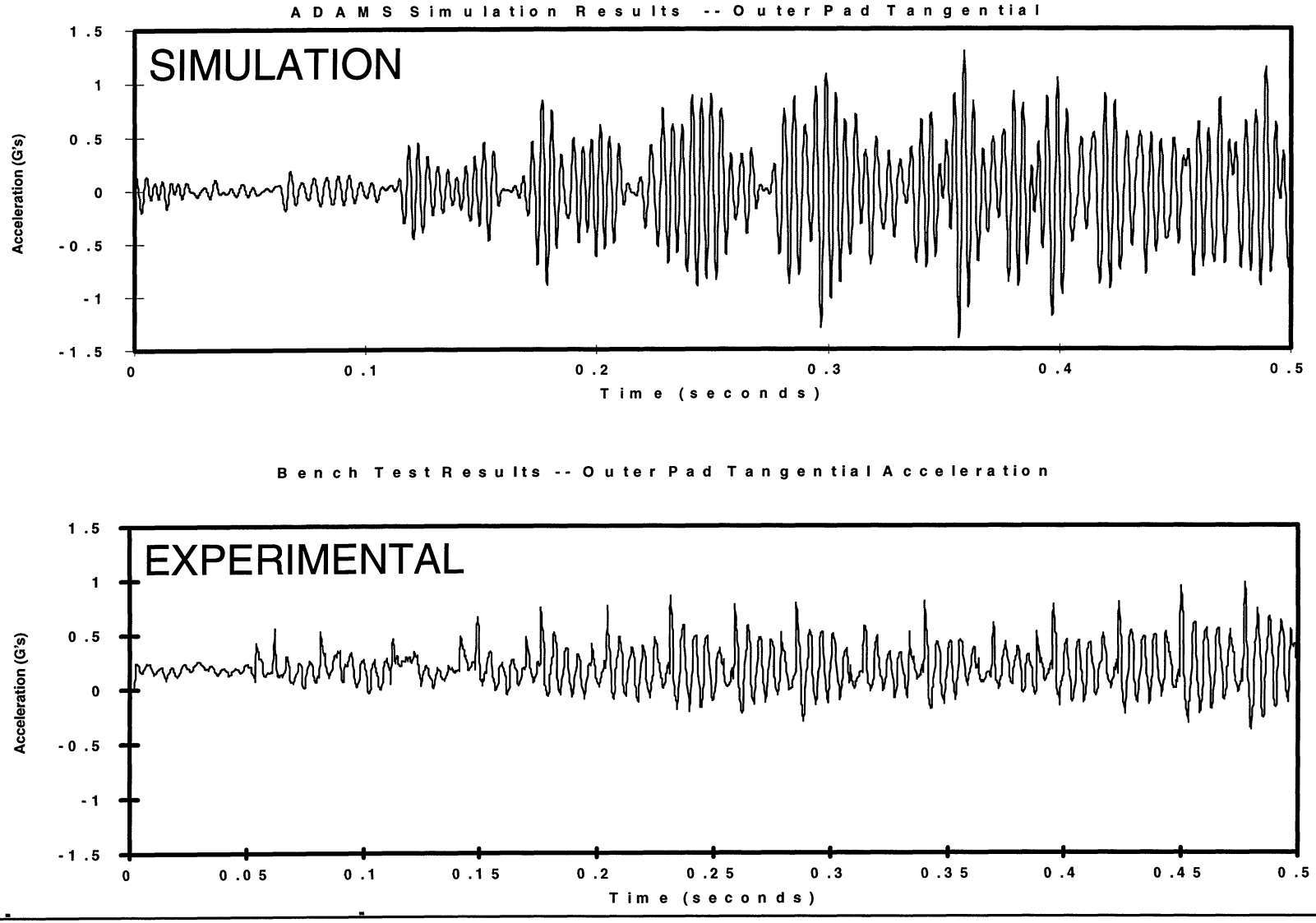
- Time History
- Frequency and amplitude
- Mode shape(s) and frequency
- Design Study Comparison

ADAMS Simulation -- Model Verification

Time History Features

	ADAMS Model	Vehicle ODS	Bench Test
Pulses (Frequency -HZ)	**Yes**	**Yes**	**Yes**
Moan Frequency (HZ)	**199-250**	**190**	**195**
Moan Modulation (Hz)	**48**	**50**	**50**

ADAMS Simulation -- Verification (Bench)



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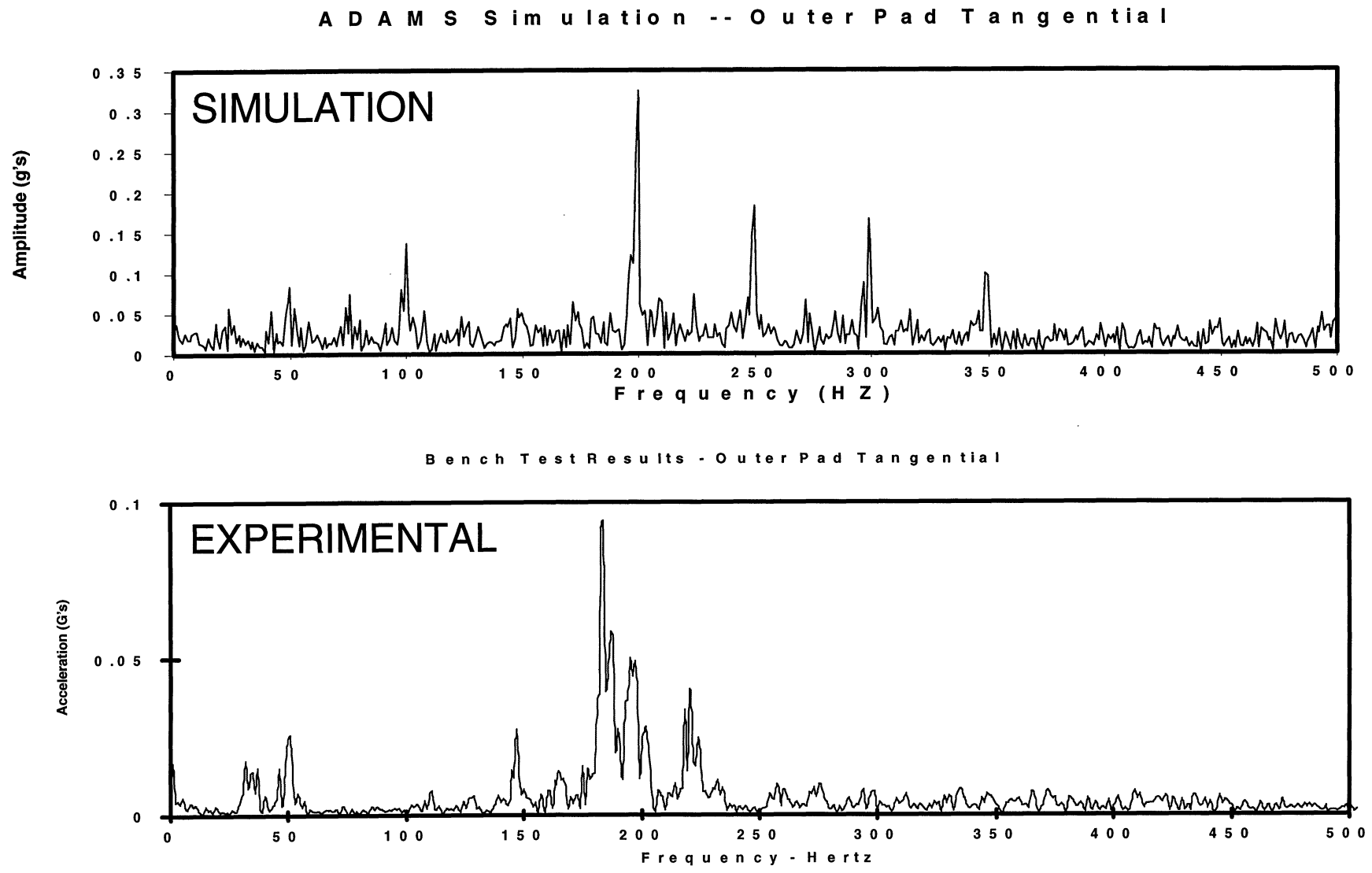

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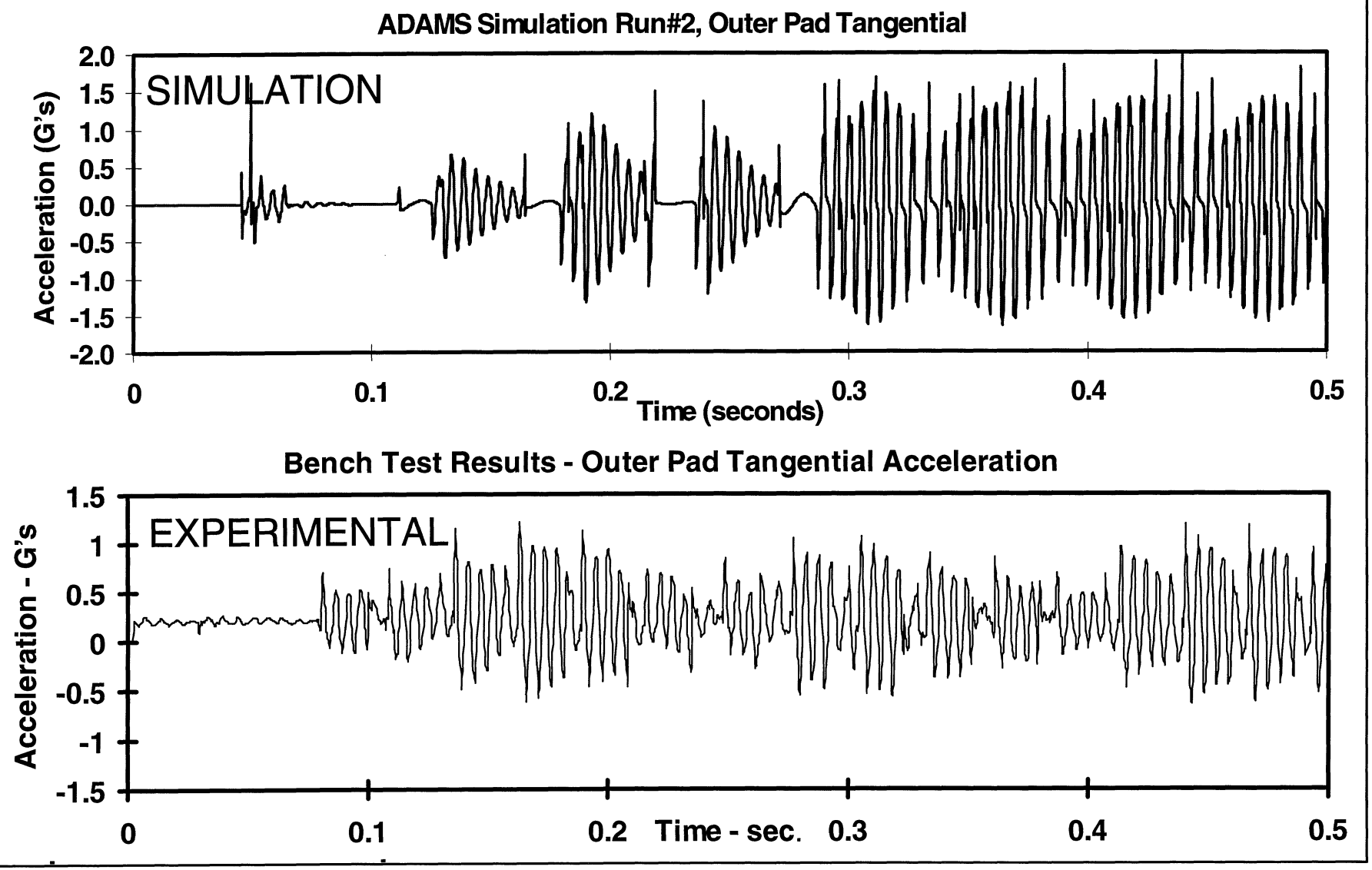
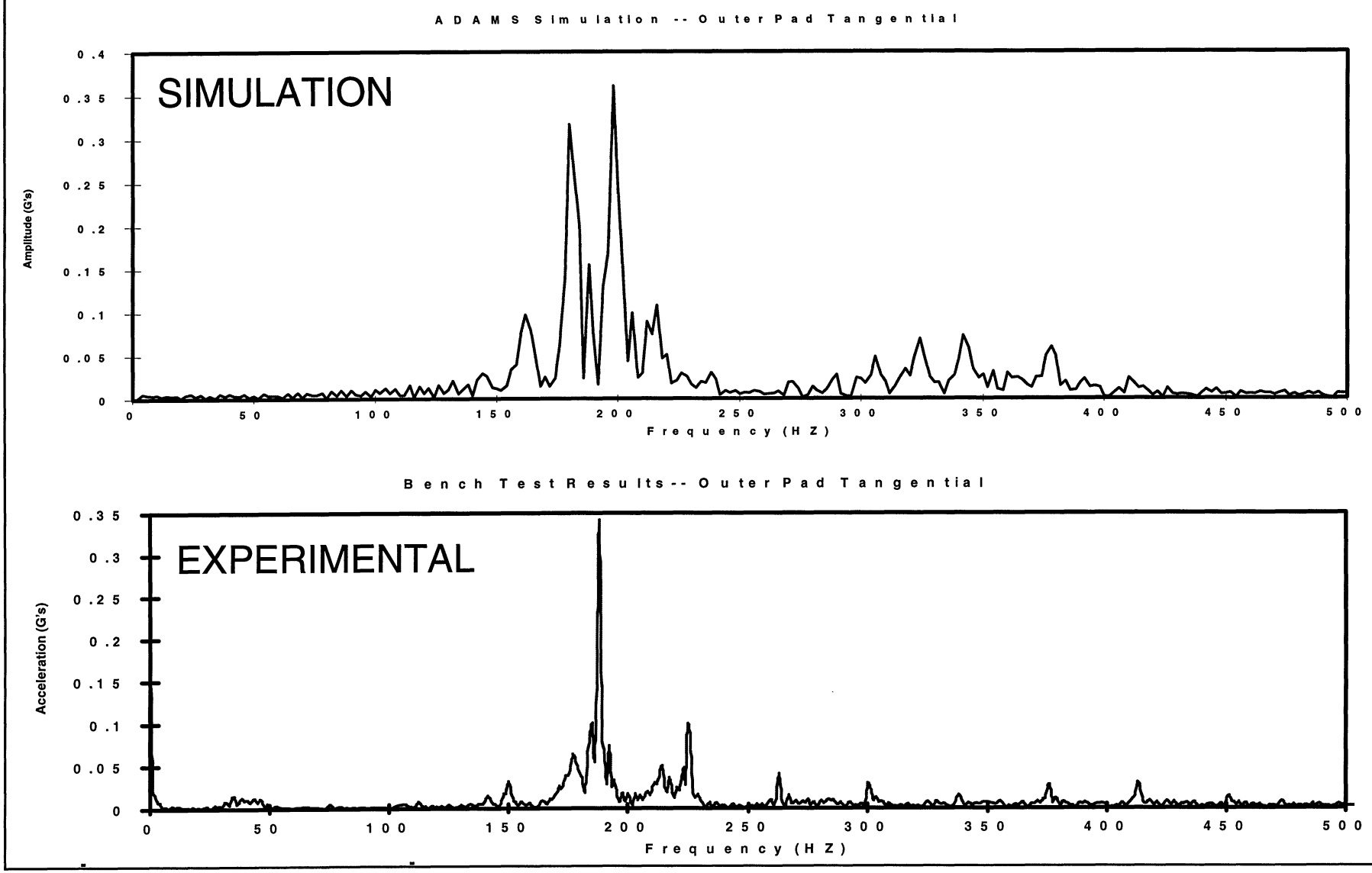


ADAMS Simulation -- Verification (Bench)



ADAMS Simulation -- Verification

Model vs. Experimental

Mode	Natural Frequency (Hz)	
	ADAMS Model	Experimental
Axle Shaft Torsion	19	25
Shaft and Tube 1st Bending	54	55
Shaft 2nd Bending	185	187*
Axle Tube Torsion	199	205
Shaft 3rd Bending	275	Unknown

* Frequency measured, axle shaft shape undetermined

ADAMS Simulation -- Verification

Design Study -- Frequency and Amplitude Correlation

	Characteristic	Model Results Effect	Experimental Testing
Bearing Stiffness	Frequency	No	Correlates
	Amplitude	Yes	Not Tested*
Bearing Clearance	Frequency	No	Correlates
	Amplitude	Yes	Not Repeatable
Tube Stiffness	Frequency	Yes	Correlates
	Amplitude	Yes	Correlates
Shaft Stiffness	Frequency	No	Not Tested*
	Amplitude	No	Not Tested*
Pad Contact Stiffness	Frequency	No	Correlates
	Amplitude	Yes	Correlates

* However, experiment trends are consistent with model behavior

Summary

- Model correlates with real world (both vehicle and lab):
  - Frequency
  - Amplitude
  - Typical time history signature correlation:
    - Pulse exists
    - Moan modulation exists
    - Many signature features comparable
    - Amplitude comparable
- Moan signature does not occur with brake assembly only.
- Moan requires flexible axle (tube and shaft).
- Tube properties & pad contact stiffness significantly influence moan.
- The model did not need to be as complex as originally expected.
- Special tests were required to measure component mechanical characteristics (stiffness / damping) which were not otherwise available.