# Improving the lifetime of small-radius heavy vehicle tyres by understanding the interaction between axle-hop and tyre rotation

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*Kirk Berenger*

# ARTSA's Focus

- Improve safety, productivity and efficiency in the road transport industry.

- Encouraging young engineers to become involved in the road transport industry.

- Inaugural 2002 ARTSA Prize

# RMIT's Involvement

- Universities from around Australia invited to submit research proposals.
- Department of Aerospace at RMIT successful recipients.

***Improving the lifetime of small-radius heavy vehicle tyres by understanding the interaction between axle-hop and tyre rotation***

# Who's Involved

*Primary Participants:*

**ARTSA**

**RMIT University**

**Australia Post**

**Roaduser Systems**

*Supplementary Aid:*

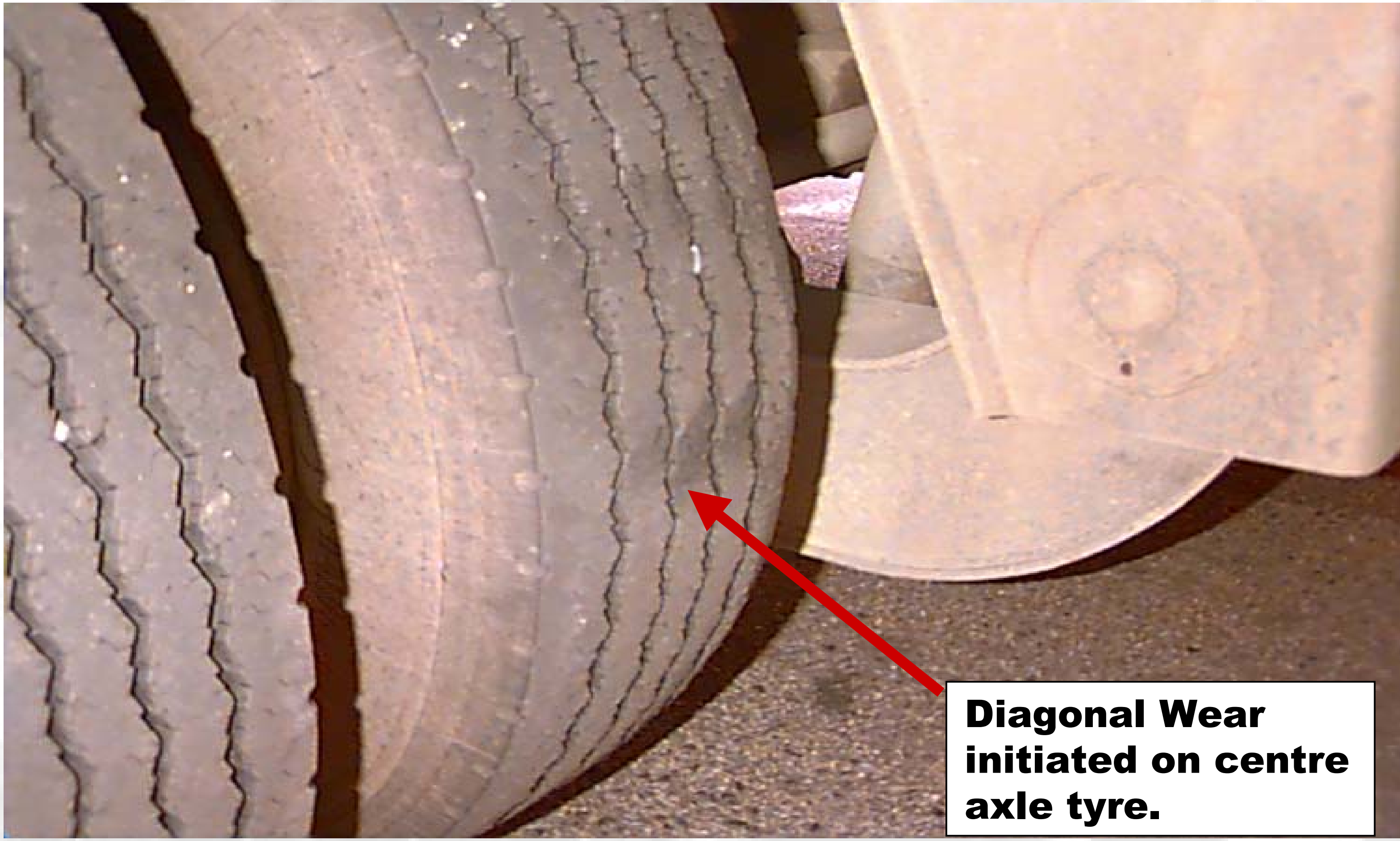
**~ Bridgestone ~ Hendrickson**

# The Problem

- **Australia Post designed new trailers**
  - Load capability of B-Double in a single vehicle
  - Small Tyres (drop deck height)
  - Air suspension
  - Tri-axial arrangement
- **Extreme tyre wear problem**
  - 35,000kms as opposed to 180,000kms previously
  - Problem not severe in prime mover

# The Problem

# The Problem



Diagonal Wear initiated on centre axle tyre.

# Past Research

- **Various trial modifications made**
  - Axle alignment
  - Wheel balance
  - Axle straightening
  - Shocker changes (type, size, location, dual)

- **Modifications effected but failed to eliminate the cause of the problem.**

- **Good tyre maintenance program improved tyre lifetime**
  - 35,000kms was extended to 100,000kms
  - Techniques:
    - Matching of tyres
    - Even tyre pressures
    - Rotation program
    - Regular inspection

# What is the Project?

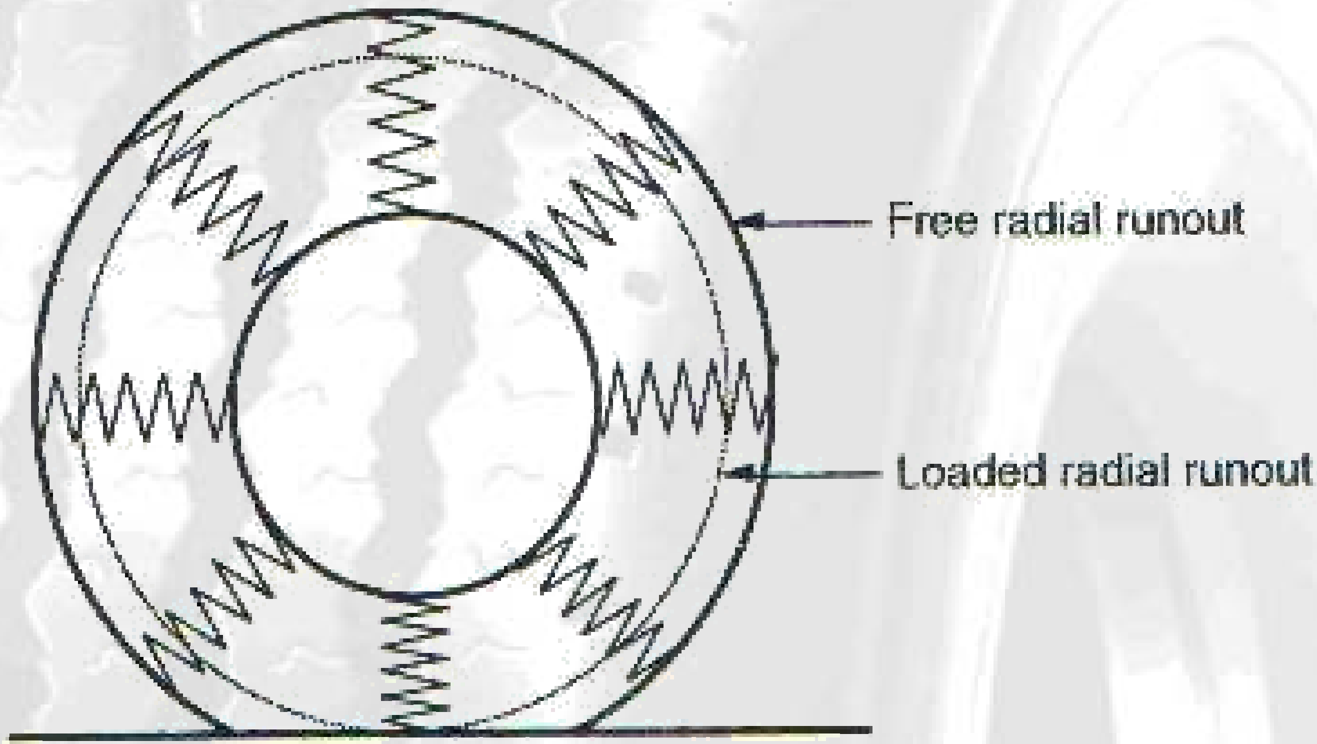
***Objectives:***

- Develop scientific understanding of tyre/suspension interaction
- Develop a Quarter Truck model
- Validation through Physical Testing
- Investigate effects on tyre wear and premature tyre failure

# Rationale

- Reduce running costs
- Improve productivity and efficiency
- Reduce environmental impacts
- Challenging and Complex

# Radial Stiffness Variation



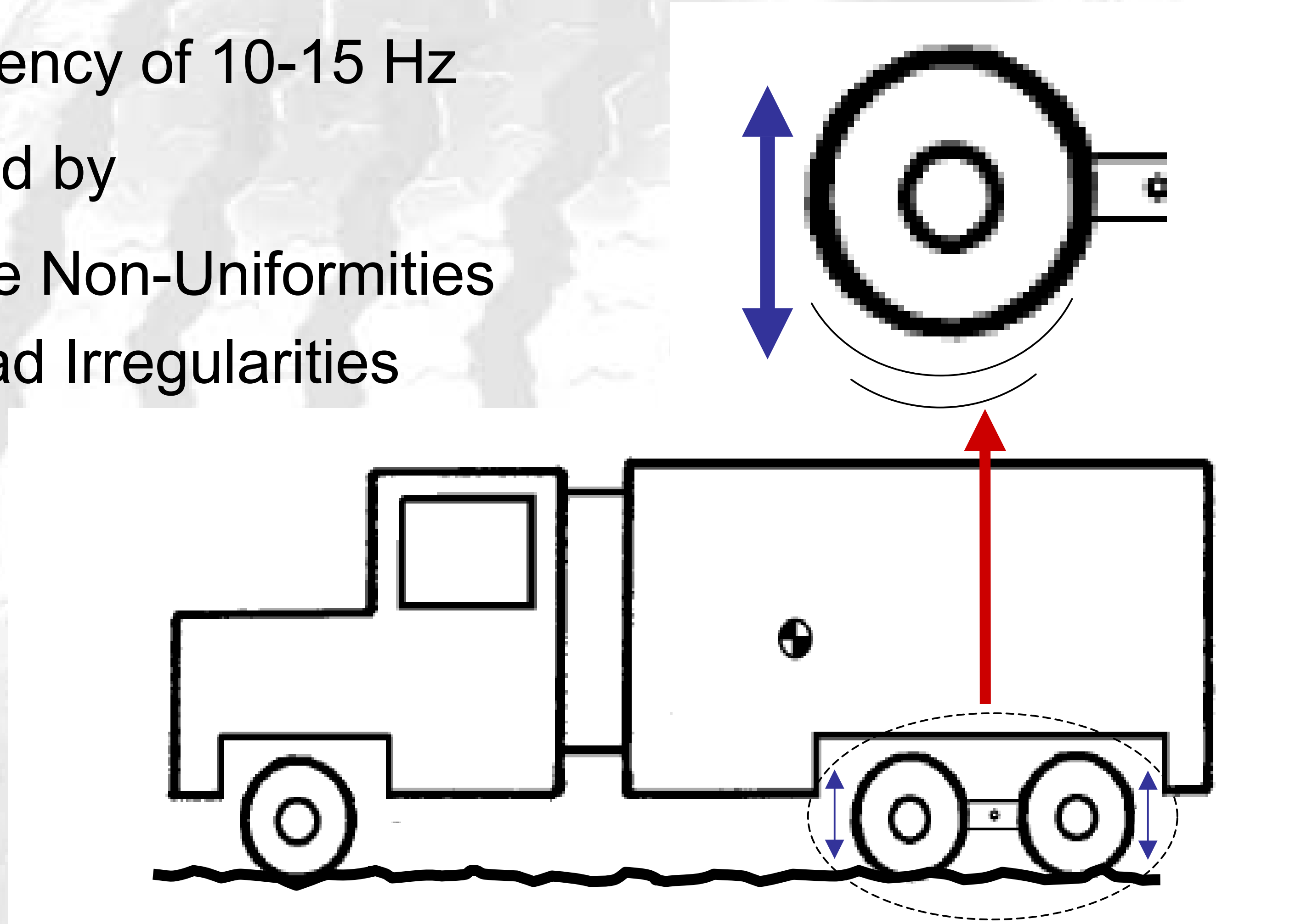

Tyre Radial Spring Model (Fundamentals of Vehicle Dynamics, Gillespie 1992)

# Axle Hop

Frequency of 10-15 Hz

Excited by

- Tyre Non-Uniformities
- Road Irregularities

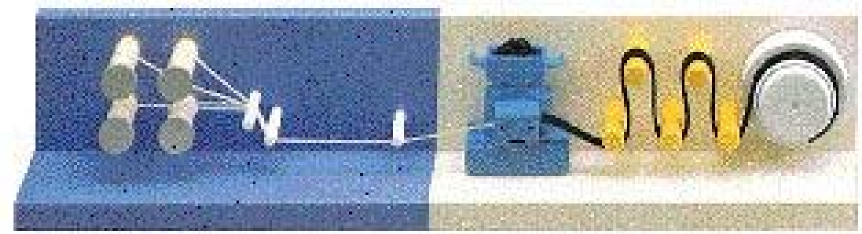


# Methodology

- Literature Review
- Physical Testing of Tyre Stiffnesses
- Create Quarter Truck Model
- Field Testing

# Industry Involvement

***Visit to Bridgestone Adelaide***



- Travelled to Adelaide on Australia Post Linehaul Equipment.
- Tour of Tyre Manufacturing Plant
- Visit to Bridgestone Truck Centre

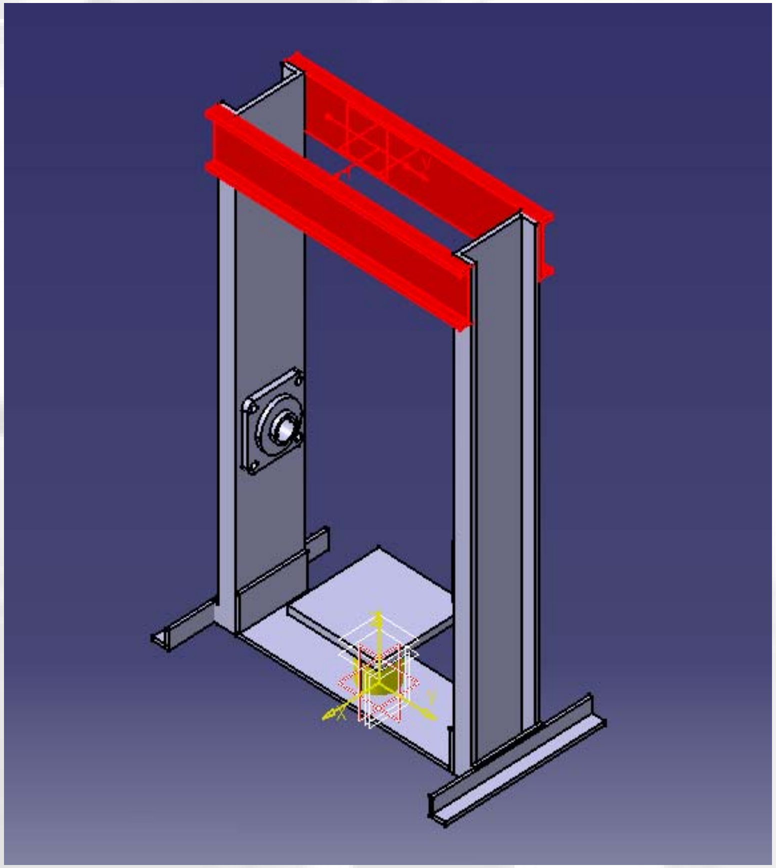
# Physical Testing

- Develop Testing Rig
- Measure Radial Stiffness Variation
- Compile Tyre Stiffness Database

# Radial Force Variation

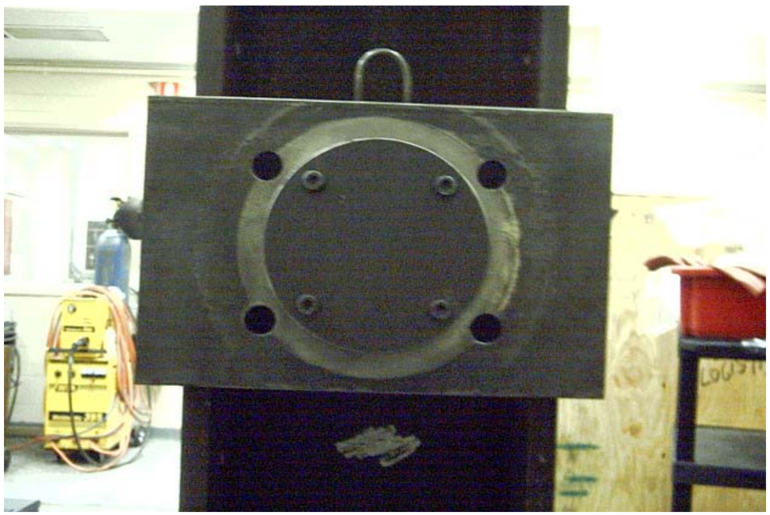
**Rig Design and Manufacture**

- Proposed various Rig Designs
- Rig Refinement
- Rig Manufacture



# Radial Stiffness Variation

***Completed Testing Rig:***



# Radial Stiffness Variation

***Physical Testing:***

8 new tyres

2 worn tyres

Ten positions around the tread

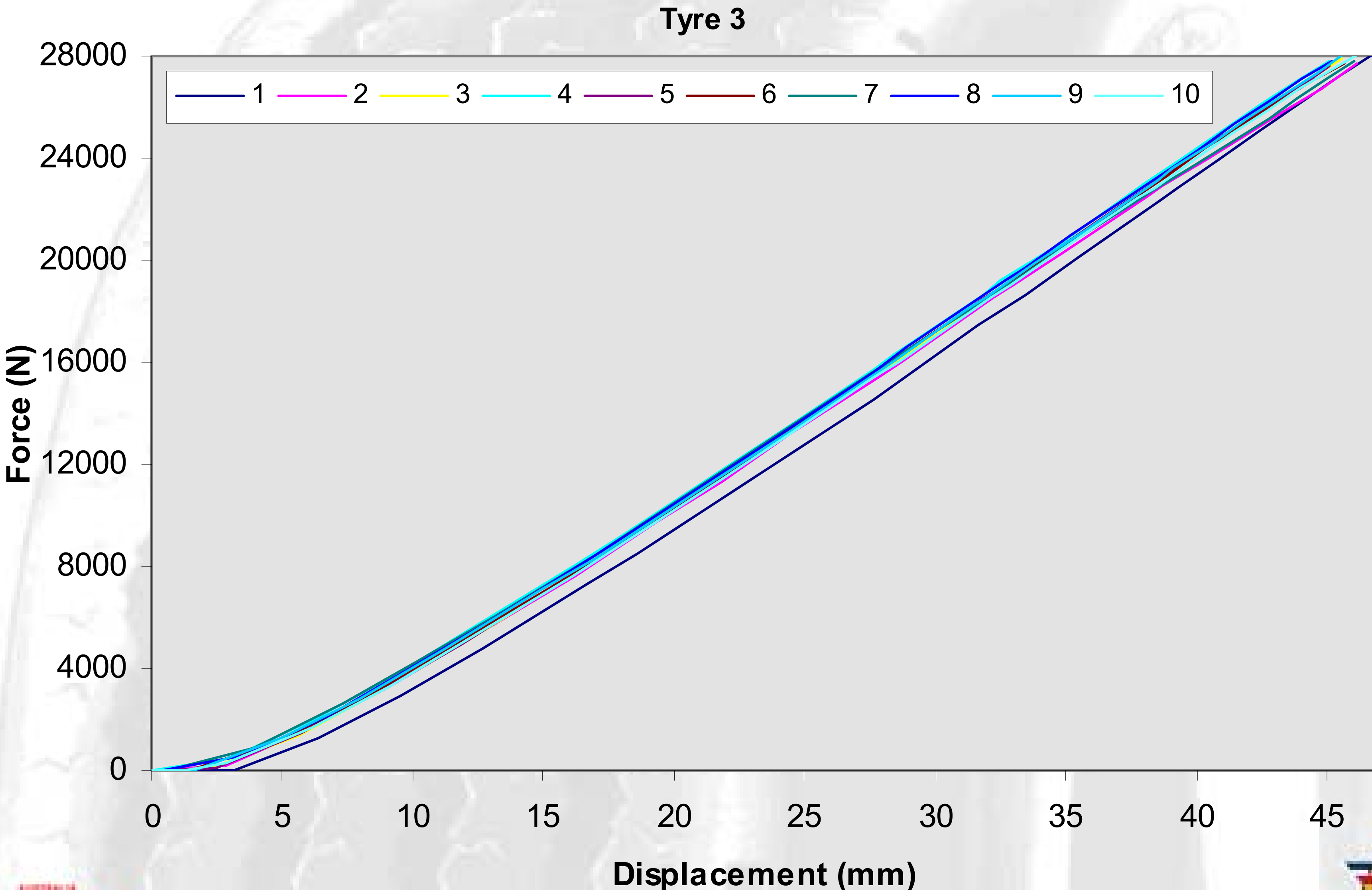
# Radial Stiffness Variation

***Stiffnesses around the tread:***

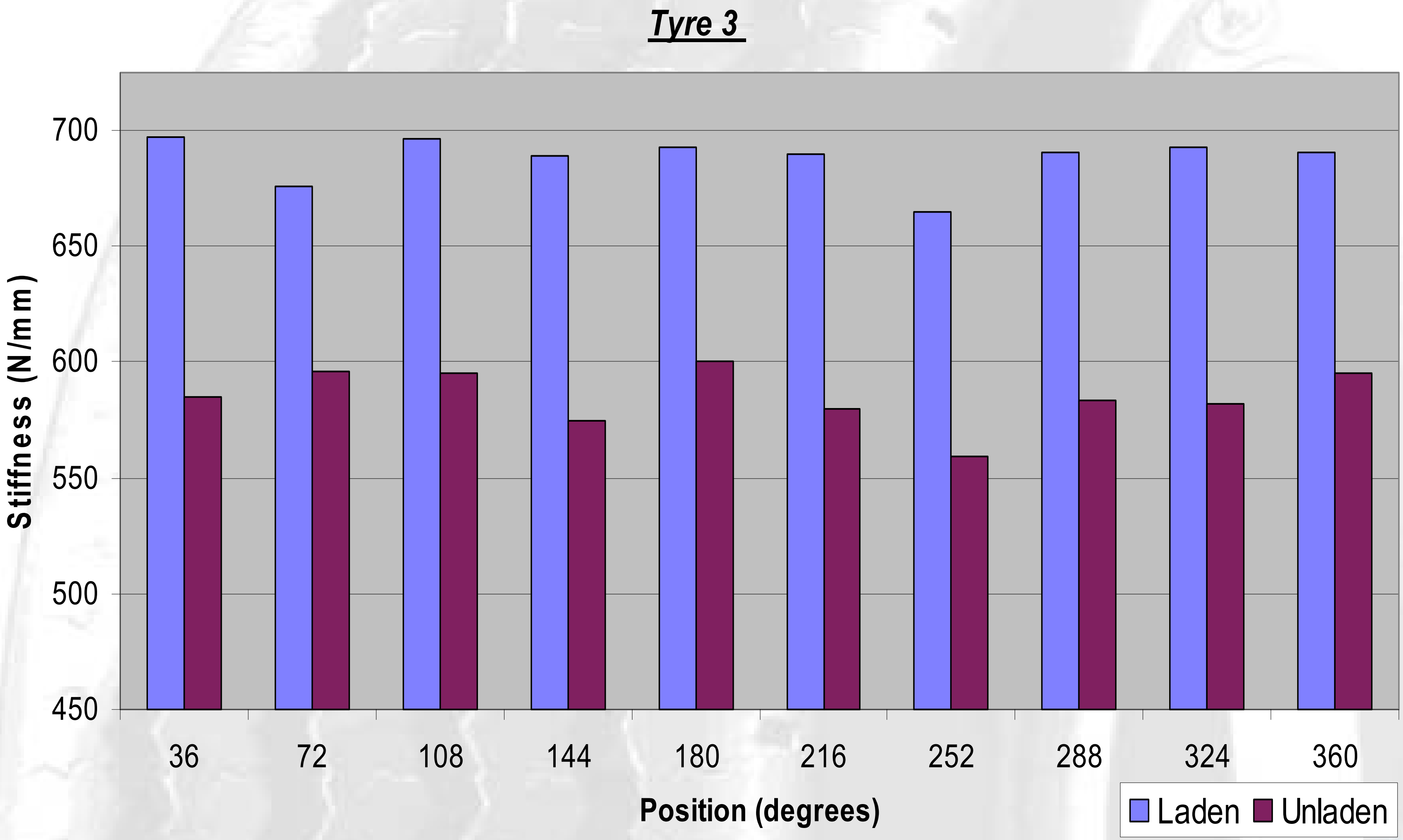
# Radial Stiffness Variation

***Stiffnesses across the tread:***

# Radial Stiffness Variation



# Tyre Stiffness Data



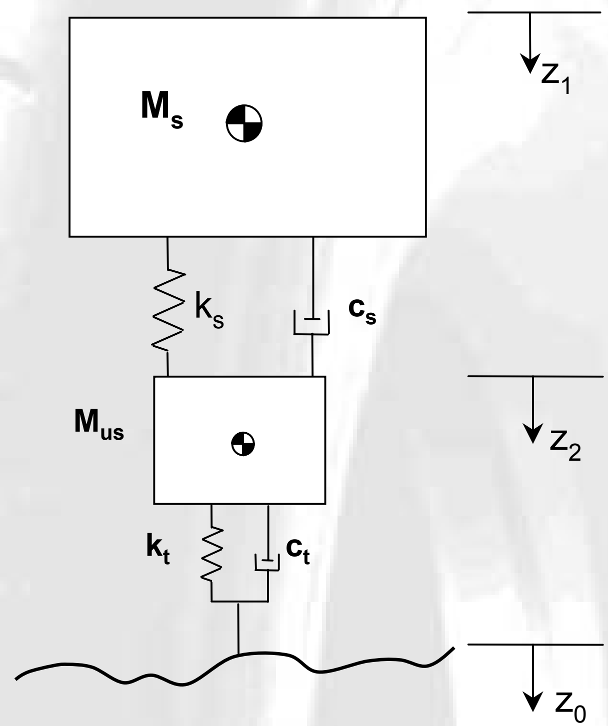
# Radial Stiffness Variation

| | | Laden | | Unladen | |
|---|---|---|---|---|---|
| | | Avg. Stiffness (N/mm) | % Stiffness Variation | Avg. Stiffness (N/mm) | % Stiffness Variation |
| Brand New Tyres | Tyre 1 | 704 | 1.5% | 584 | 3.7% |
| | Tyre 2 | 698 | 2.4% | 592 | 6.3% |
| | Tyre 3 | 688 | 4.7% | 585 | 7.1% |
| | Tyre 4 | 709 | 1.5% | 591 | 4.5% |
| | Tyre 5 | 695 | 2.5% | 585 | 6.3% |
| | Tyre 6 | 703 | 2.1% | 589 | 5.5% |
| | Tyre 7 | 696 | 2.3% | 586 | 5.1% |
| | Tyre 8 | 701 | 1.4% | 589 | 3.7% |
| Worn Tyres | Tyre 9 | 699 | 3.0% | 555 | 10.7% |
| | Tyre 10 | 695 | 3.1% | 524 | 6.8% |

# Quarter Truck Model

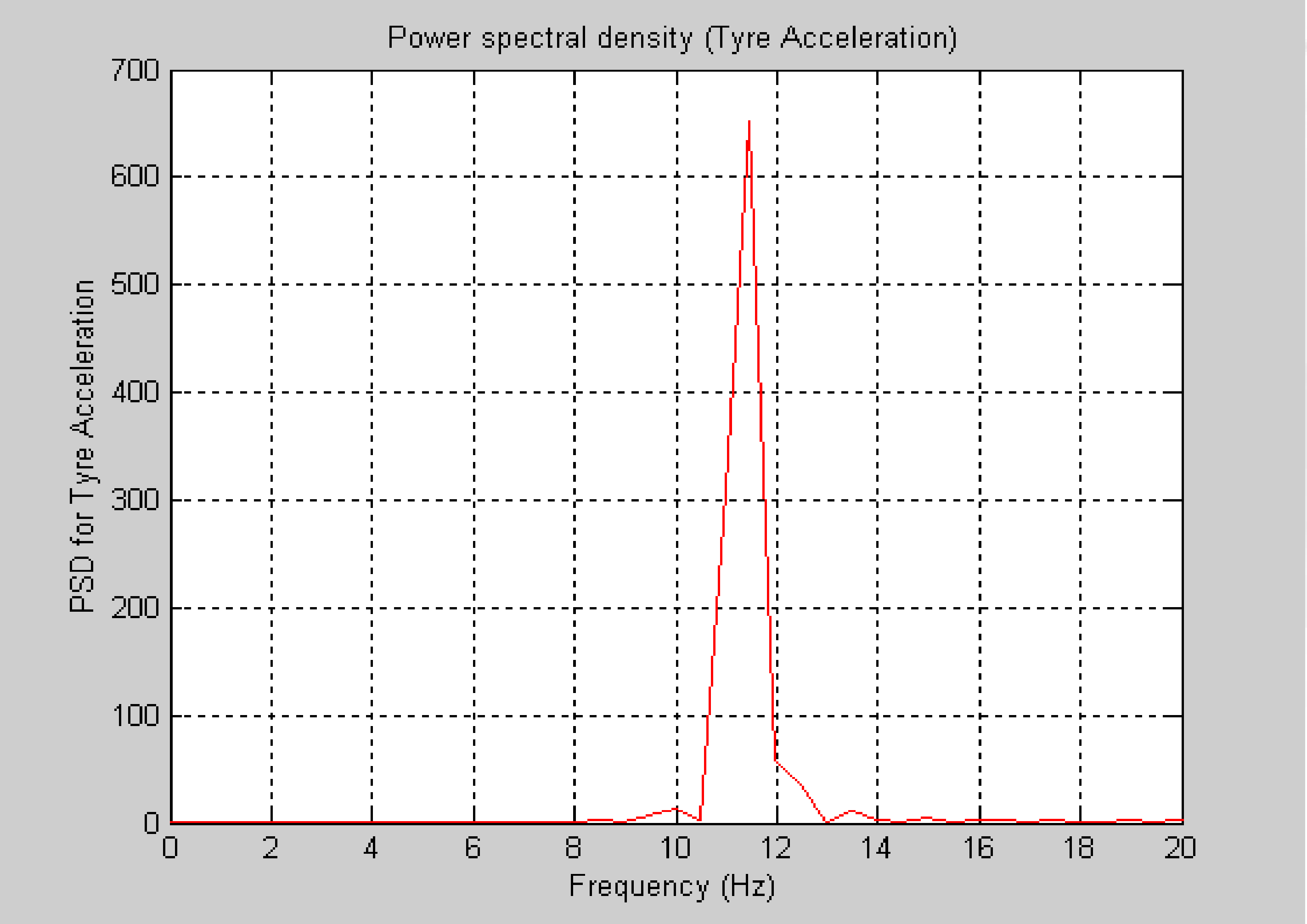
***System Parameters:***

- Variable Tyre Stiffness
- Mass Imbalance
- Ground profiles
- Payload weights
- Operating speeds



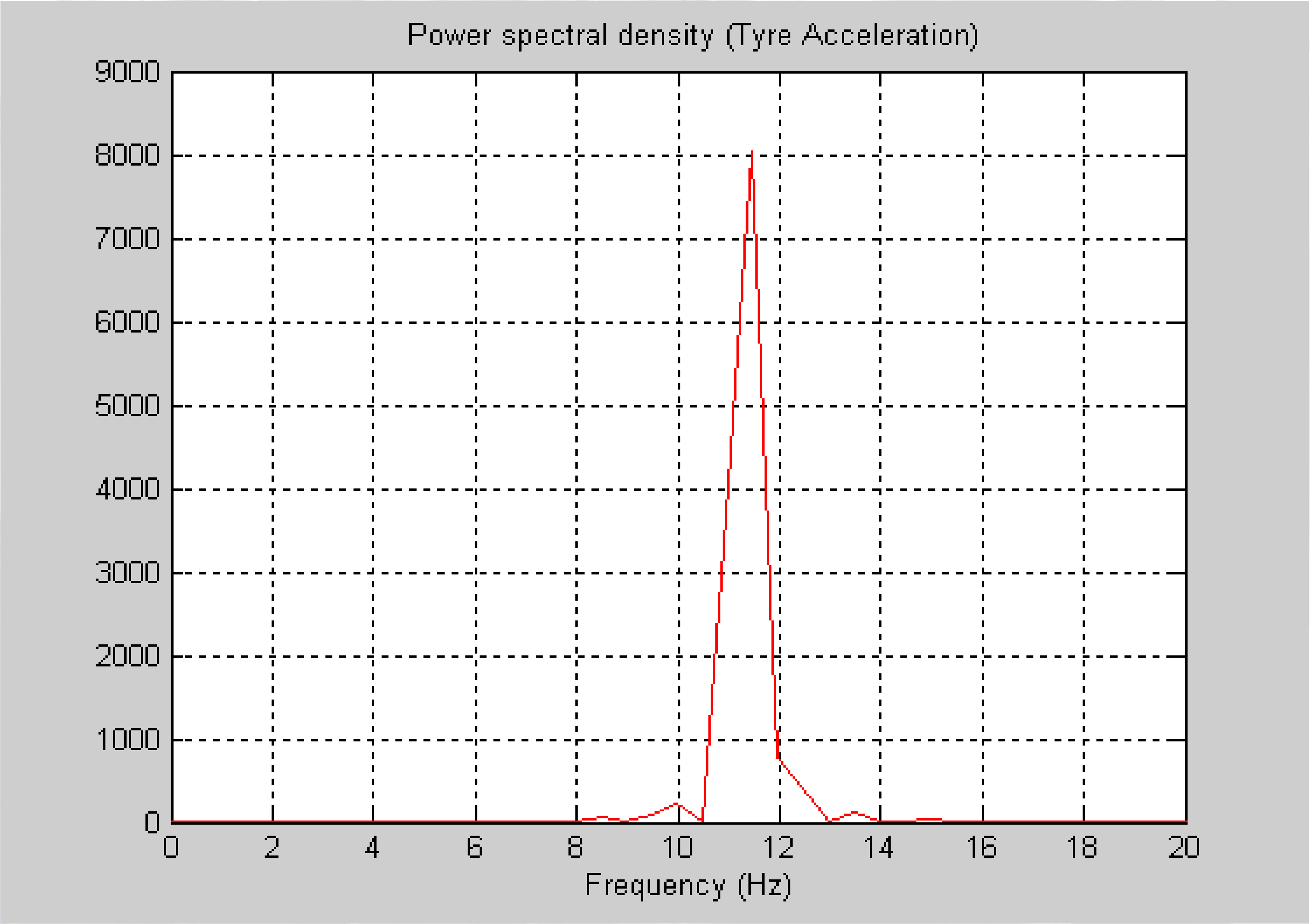
# Dynamic Modelling

***Stiffness Variation:***



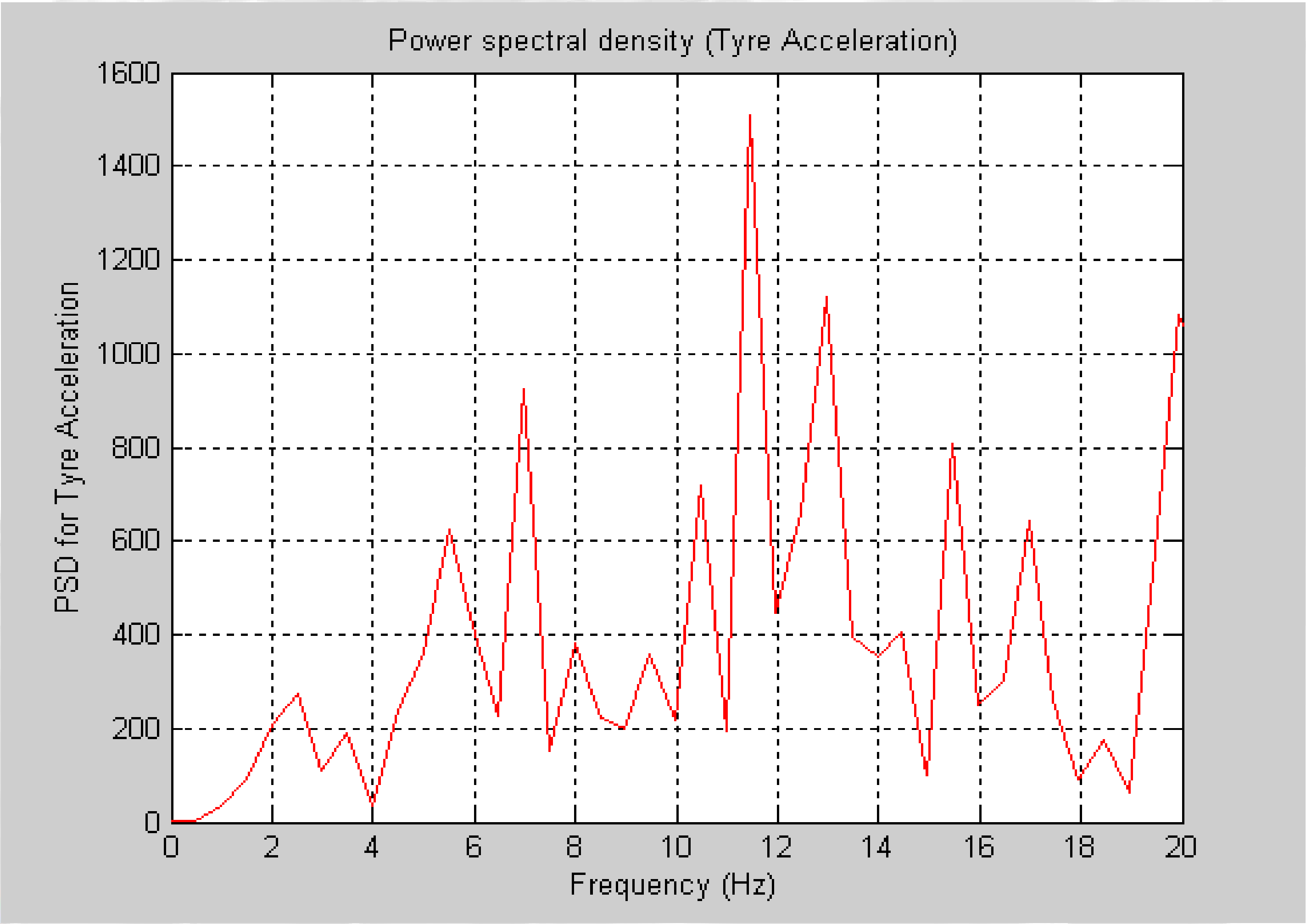
# Dynamic Modelling

## *Mass Imbalance:*



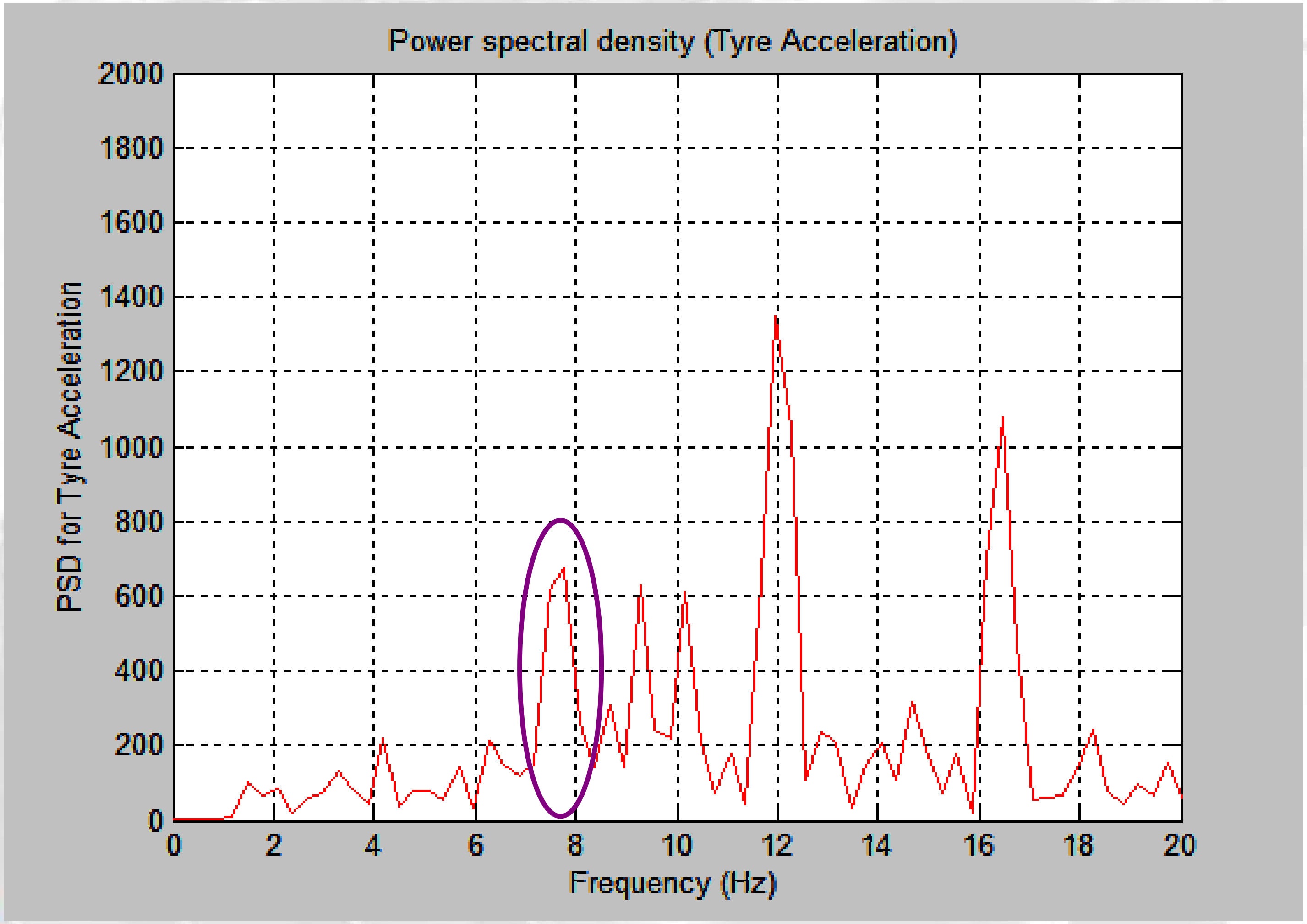
# Dynamic Modelling

***Road Profile:***



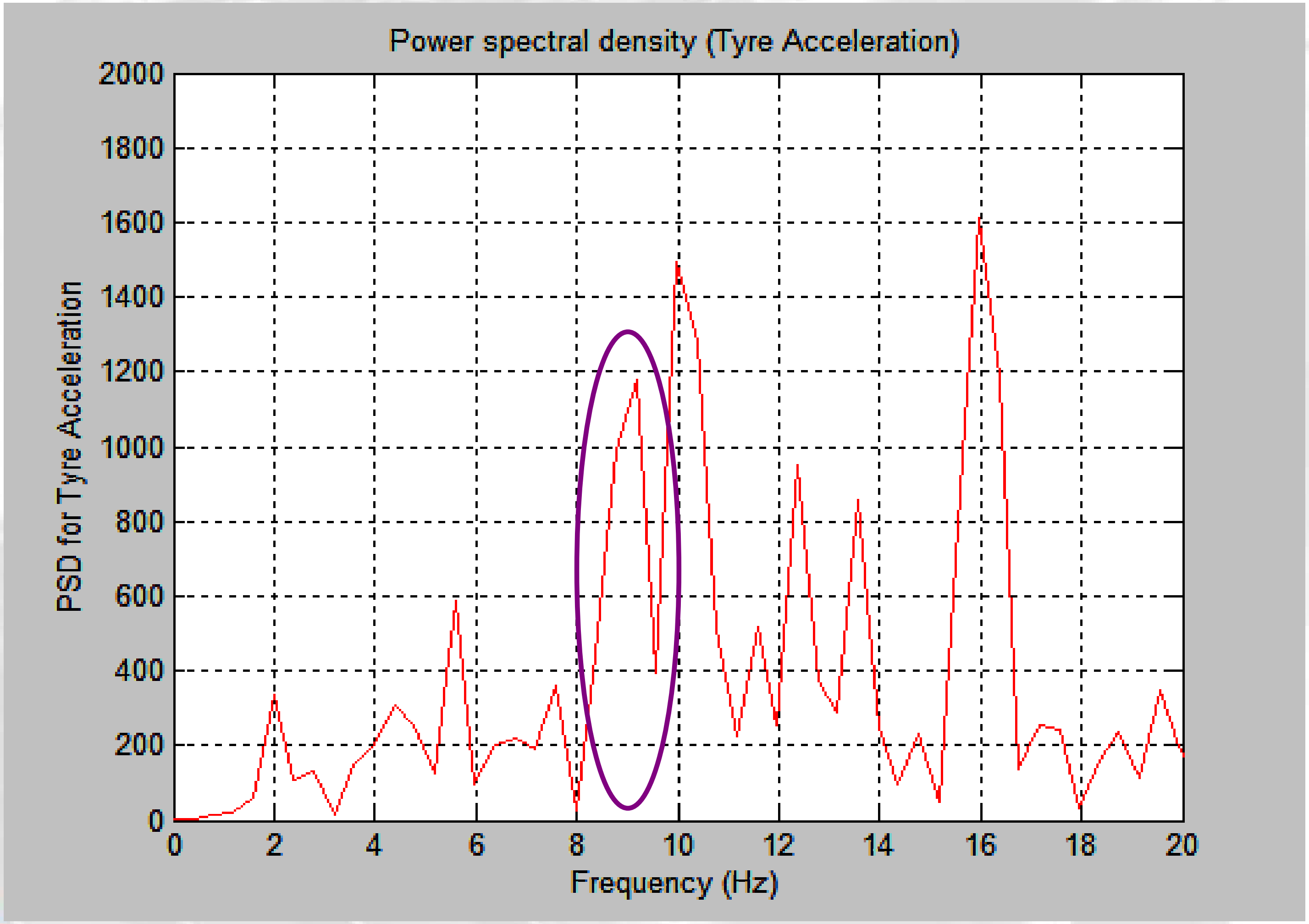
# Dynamic Modelling

***60km/h:***



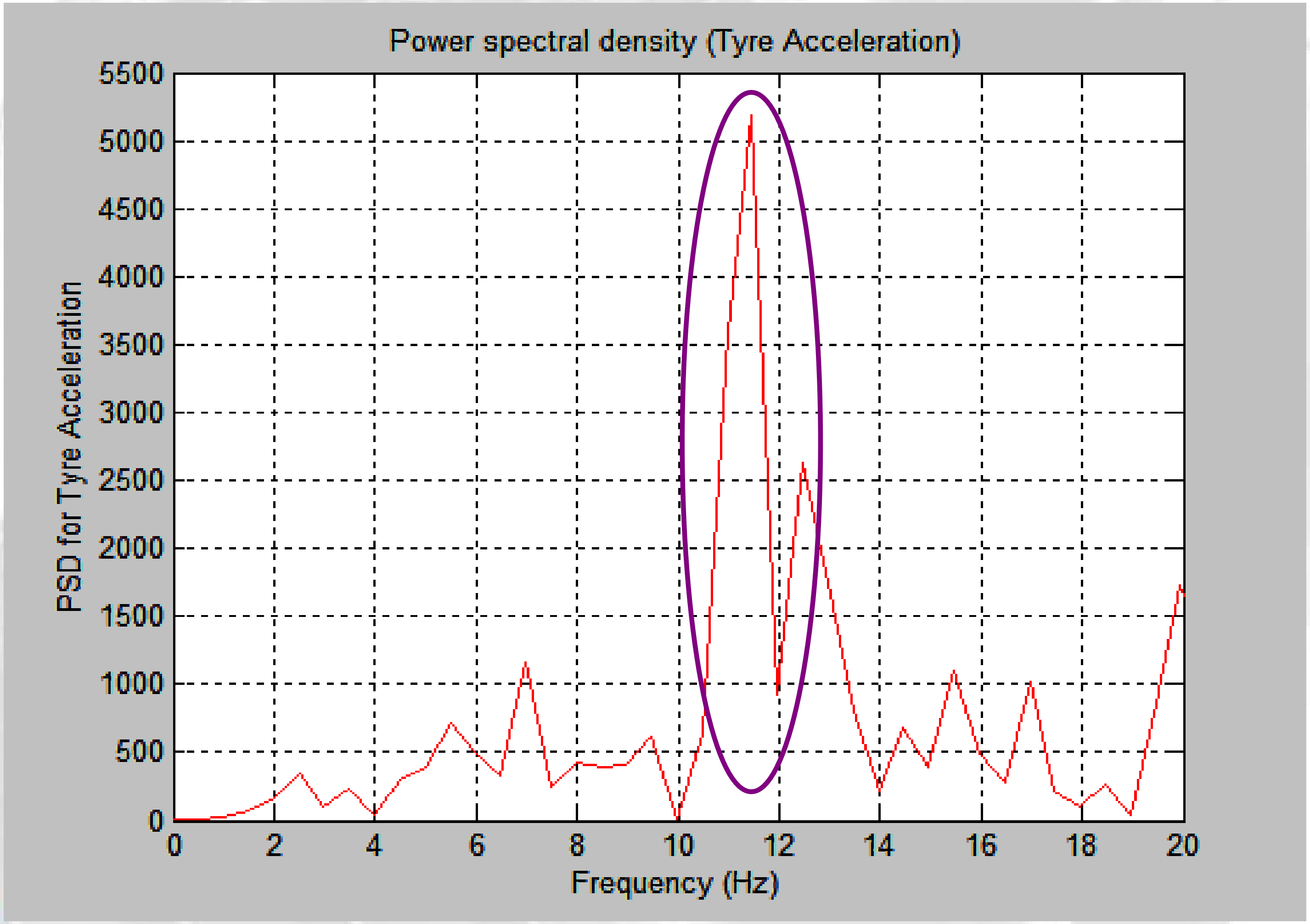
# Dynamic Modelling

***80km/h:***



# Dynamic Modelling

***100km/h:***



# Field Testing

***Attempt to initiate axle-hop vibration on trailer***

***Testing Parameters:***

- Vehicle Velocity
- Loading Regimes
- Tyre Quality
- Road Roughness

# Field Testing

***Tread Depth Measurement:***


# Field Testing

***Matching Weakest Point on the Tyres:***

# Field Testing

Bad Tyres (Trailer 1)

| | Tyre | Position | Min. Stiffness (N/mm) |
|---|---|---|---|
| Dual Configuration 1 | 2 | 6 | 570 |
| | 6 | 1 | 572 |
| Dual Configuration 2 | 3 | 7 | 559 |
| | 5 | 8 | 563 |

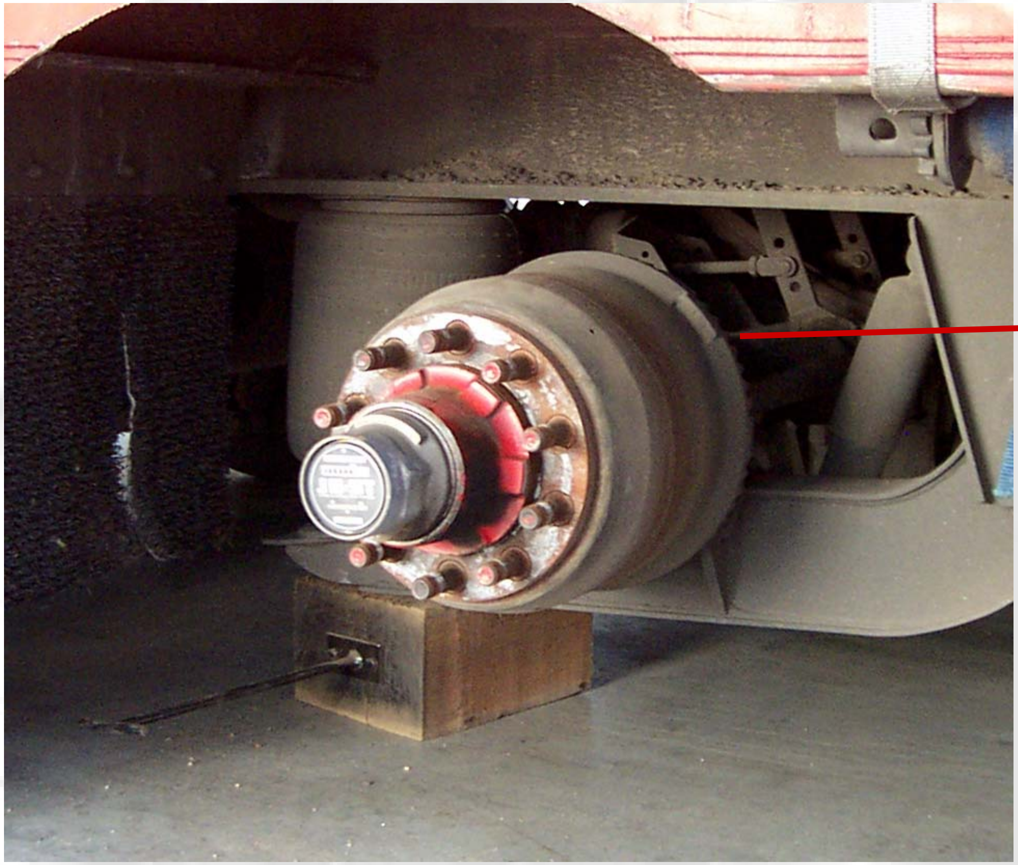
Good Tyres (Trailer 2)

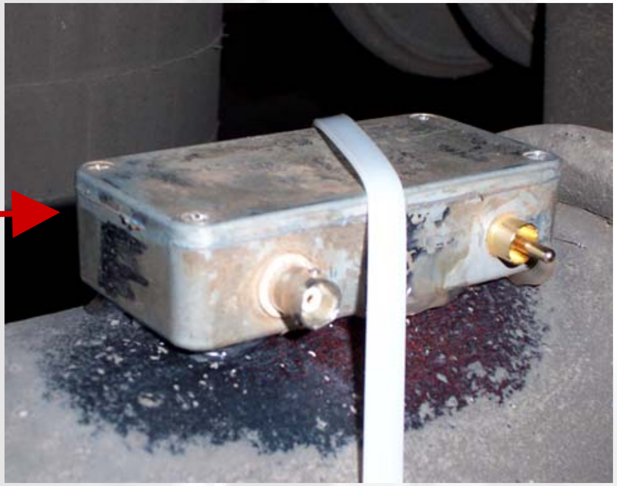
| | Tyre | Position | Min. Stiffness (N/mm) |
|---|---|---|---|
| Dual Configuration 1 | 1 | 9 | 575 |
| | 8 | 10 | 574 |
| Dual Configuration 2 | 4 | 2 | 577 |
| | 7 | 8 | 570 |

# Field Testing

# Field Testing

***Accelerometer Attachment:***





# Field Testing

***Tyre Fitment:***

# Field Testing

***Data Acquisition:***

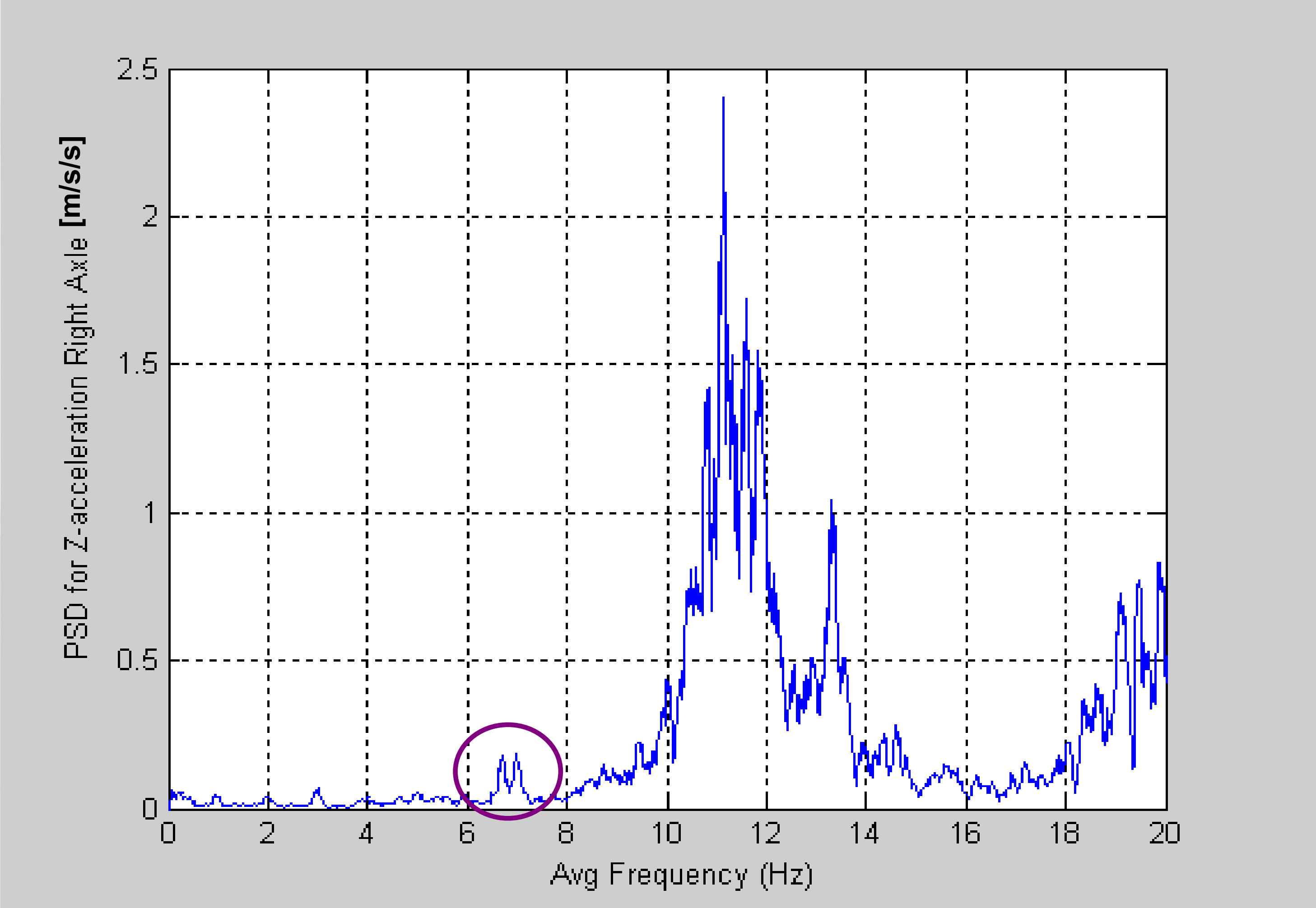
# Field Testing

***Trailer Loading:***

# Field Testing

# Field Testing

***60km/h:***



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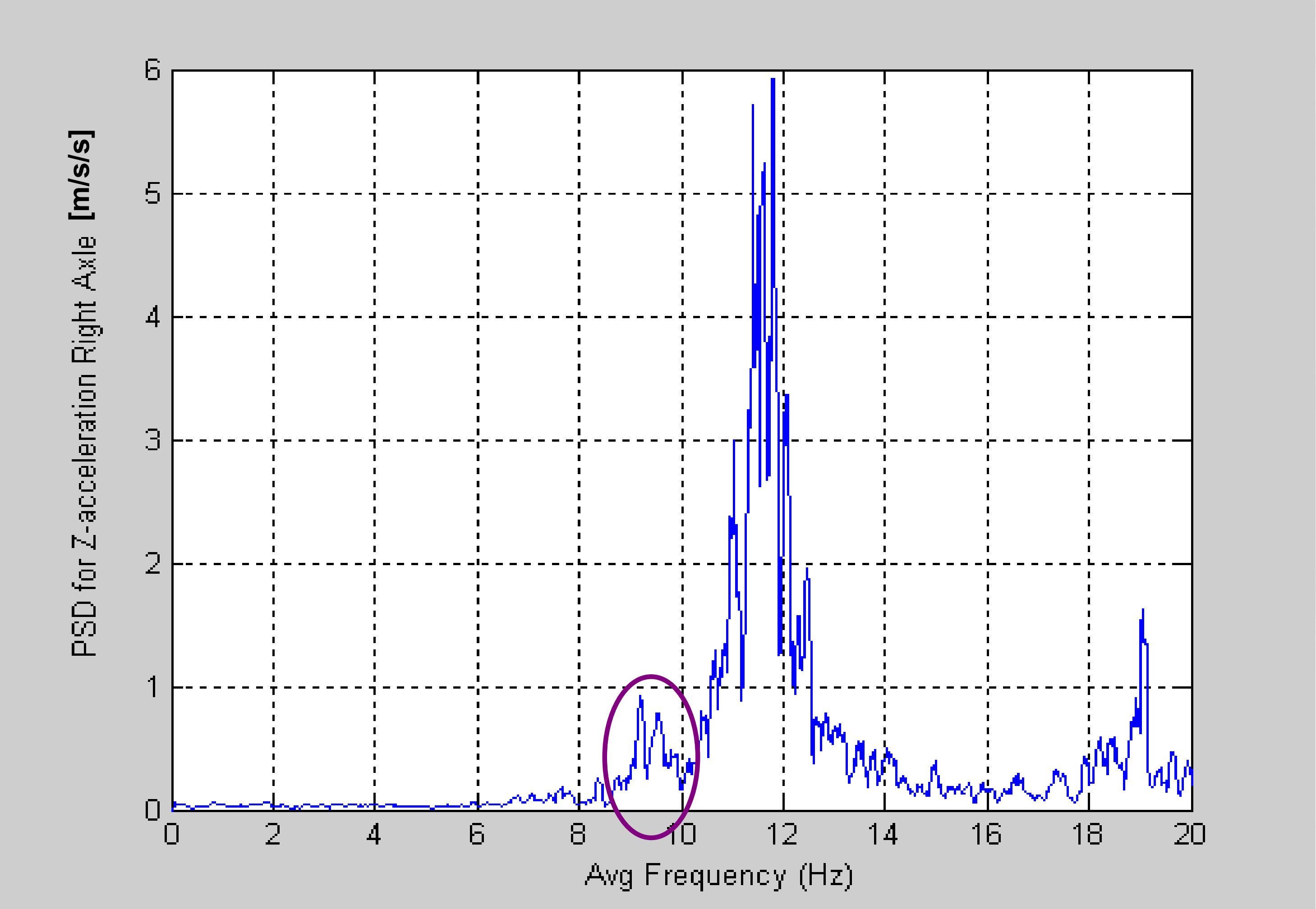
***80km/h:***



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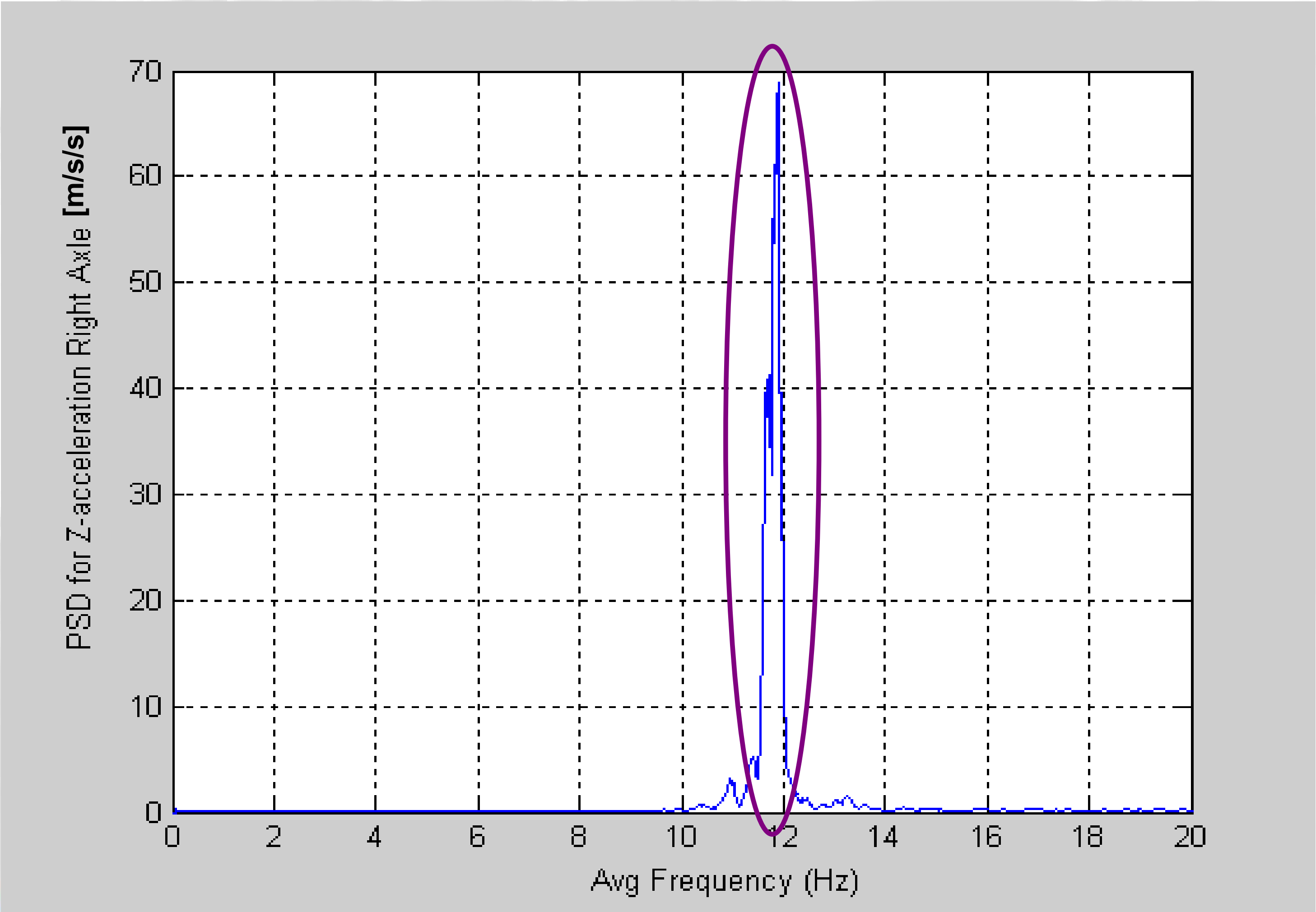
***100km/h:***



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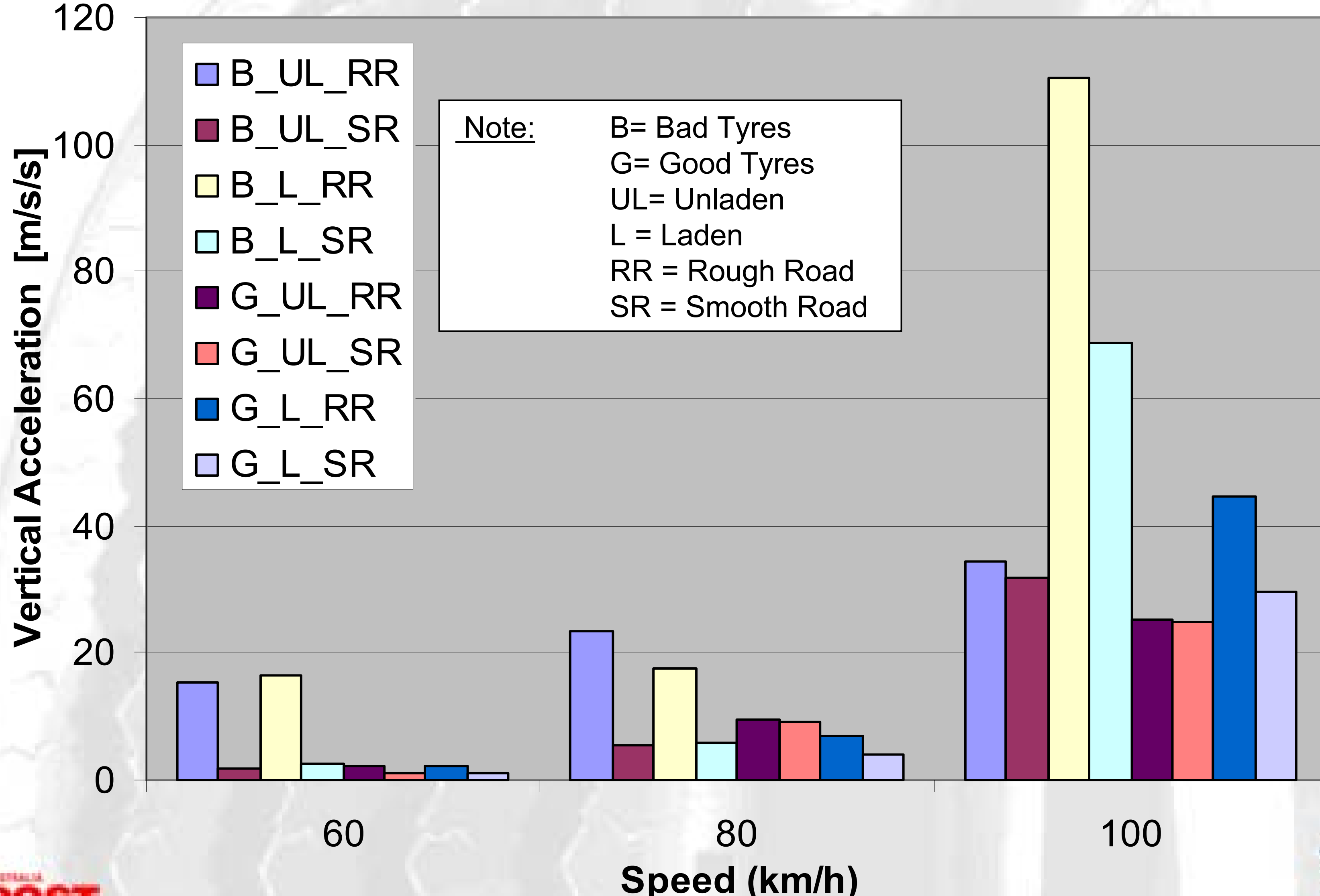


# Findings

***Tyre Stiffness Testing:***

- Radial Stiffness Variation of up to 7%
- Cyclic Variation of Stiffness around Circumference
- Different Stiffness for Laden and Unladen Conditions

# Findings

***Quarter Truck Model:***

- Effects of Radial Stiffness Variation, Mass Imbalance and Road Profile analysed
- Road Profile required to initiate axle hop
- Largest interaction observed at 100km/h

# Findings

***Field Testing:***

- Interaction was greatest at 100km/h, Bad Tyres on Rough Road
- Effects of Radial Stiffness Variation Integral
- Validation of Computer Model SUCCESSFUL

# Recommendations

Investigate reaction speed of shock absorbers

Increase Suspension Stiffness

Increase Tyre Stiffness

Decrease Unsprung Mass
(Axle, Wheel, Rim, Tyre, Suspension, Brakes)

# Future Work

Further Investigate Tyre Stiffness

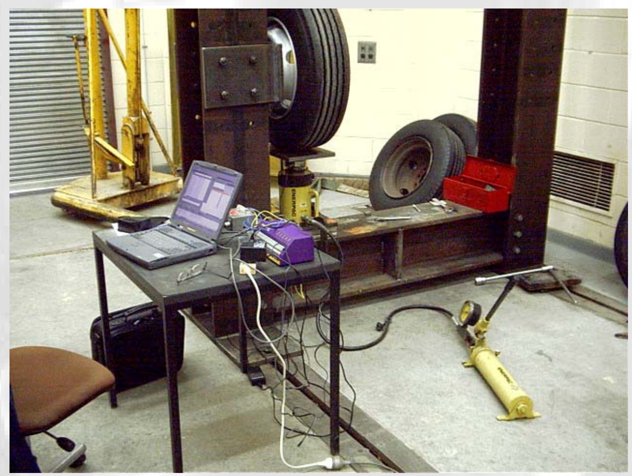
Analyse Tri Axle Behaviour

Develop Dynamic Tyre Wear Model

RMIT UNIVERSITY

ARTSA


# Questions???



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