2002 Technical & Maintenance Conference

TYRE WEAR

Barry Degenhardt

Manager National Fleet

Australia Post

TYRE WEAR STUDY GROUP

ANDREW MARTIN - **Hendrickson**

RICHARD STRAUGHAN - **Dunlop**

GREG BROWN - **Freighter Australia** (MaxiTrans)

PAUL MURPHY - **Goodyear**

BARRY DEGENHARDT - **Australia Post**

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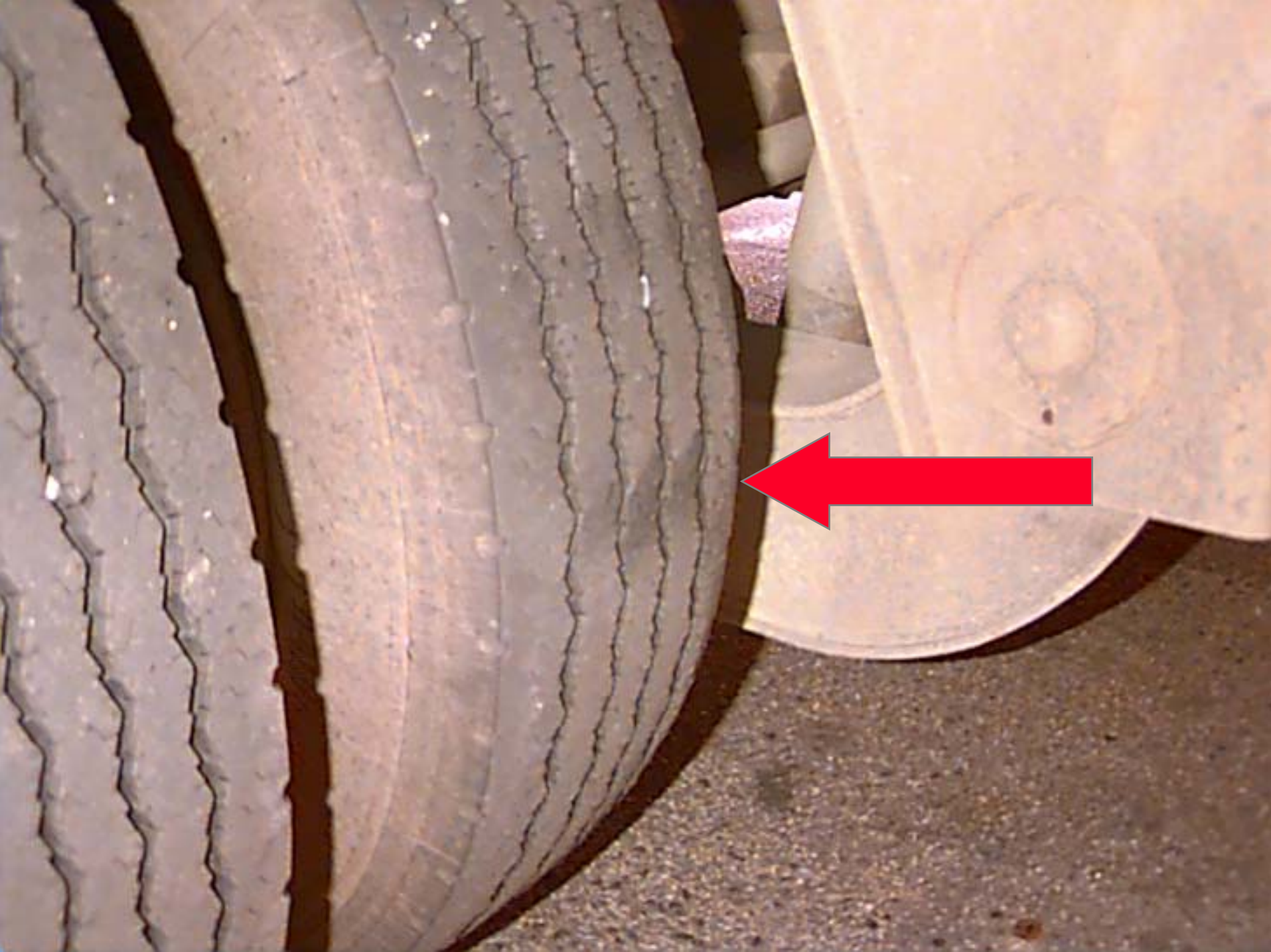


EXPERIENCE SHOWED

- TYRE LIFE WAS POOR
- CENTRE AXLE MOST AFFECTED
- ALIGNMENT HAD LITTLE EFFECT
- TYRE PRESSURES DID LITTLE
- RETREADS LASTED LONGER
- FLAT SPOTS WERE A CAUSE
- SHOCK ABSORBERS

TYRE SURVEY

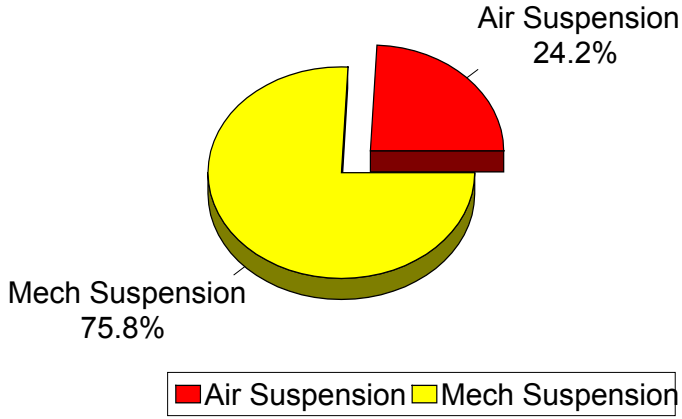
- **A survey was conducted of more than 35 Fleets which contained:**

. 24 trailer makes

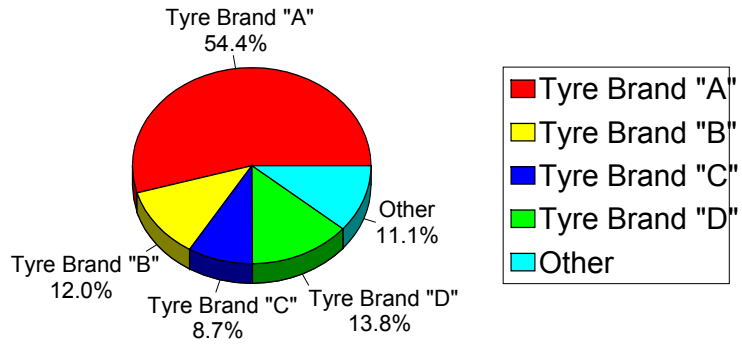
. 15 suspension suppliers

. > 4000 tyres spread over 10 tyre makes

Usage of Suspension

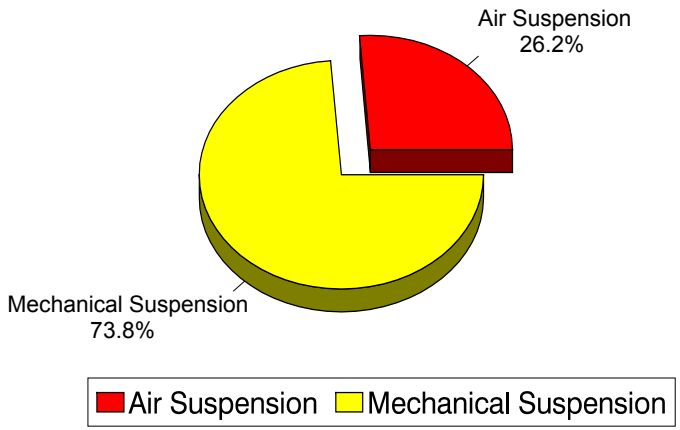


Usage of Tyre



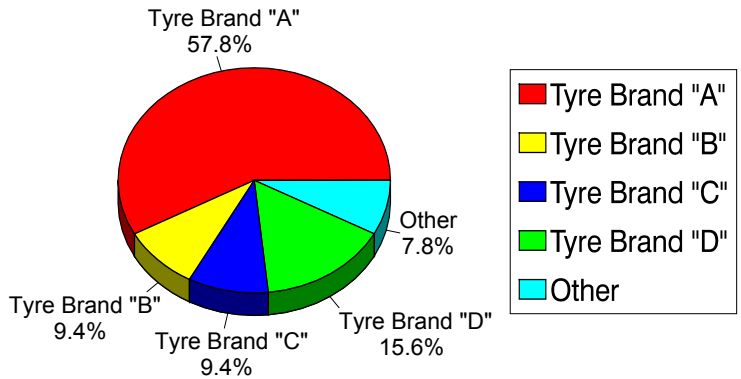
Type of suspension

Diagonal Wipe-out or Scalloping

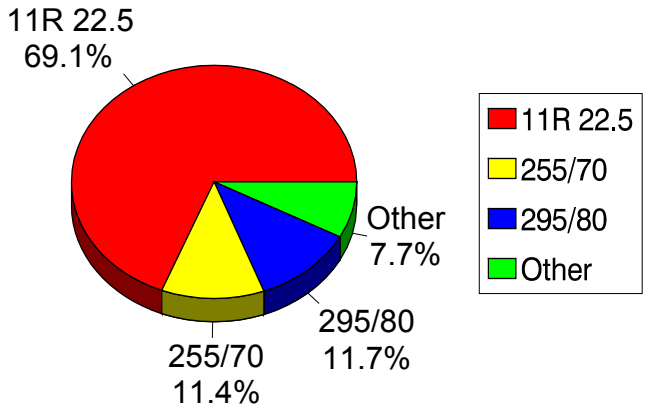


Brand of tyre

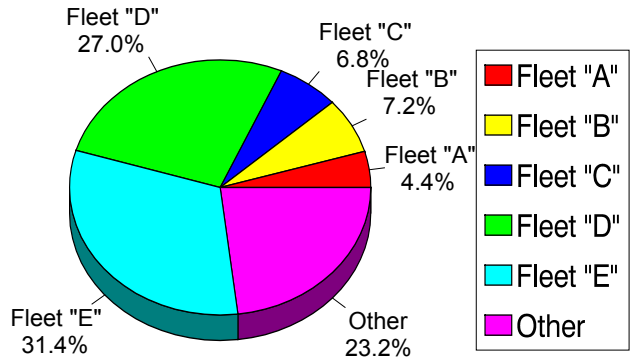
Diagonal Wipe-out or Scalloping



Tyre Size Usage



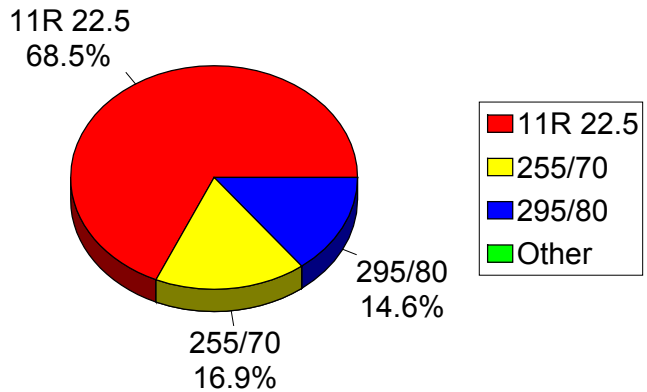
Fleet Size as Proportion of Sample



Tyre size

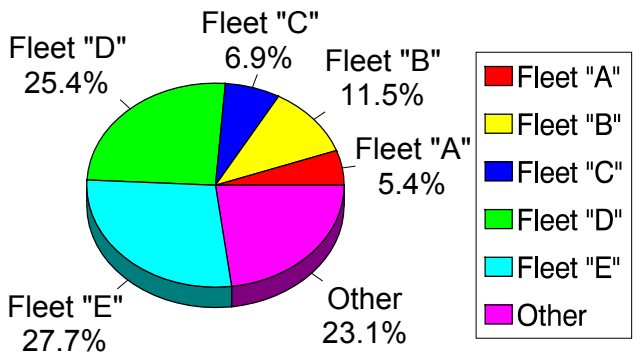
Diagonal Wipe-out or Scalloping

All Tyre Positions

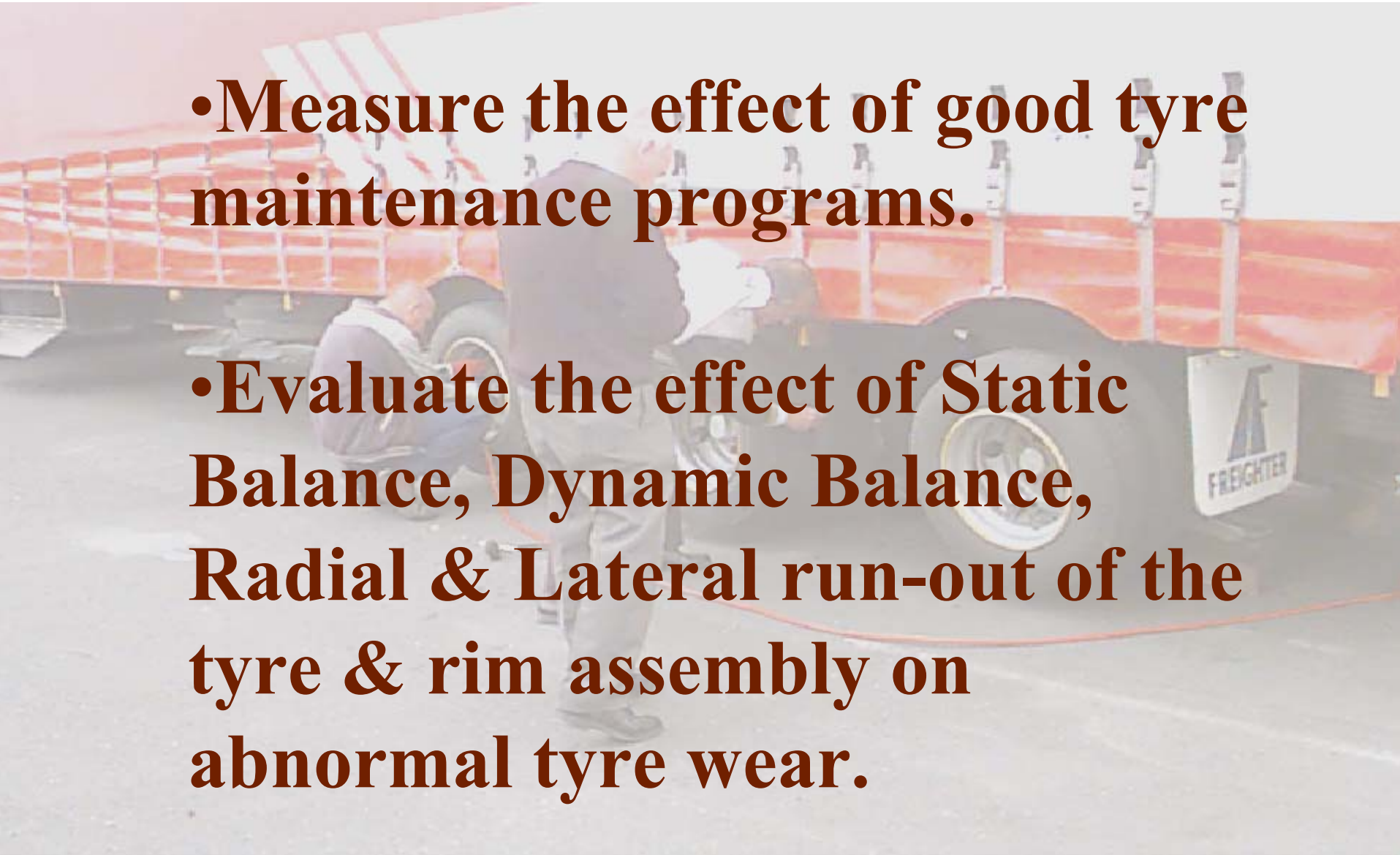


Different Fleets

Fleets with Diagonal Wipe-out or Scalloping



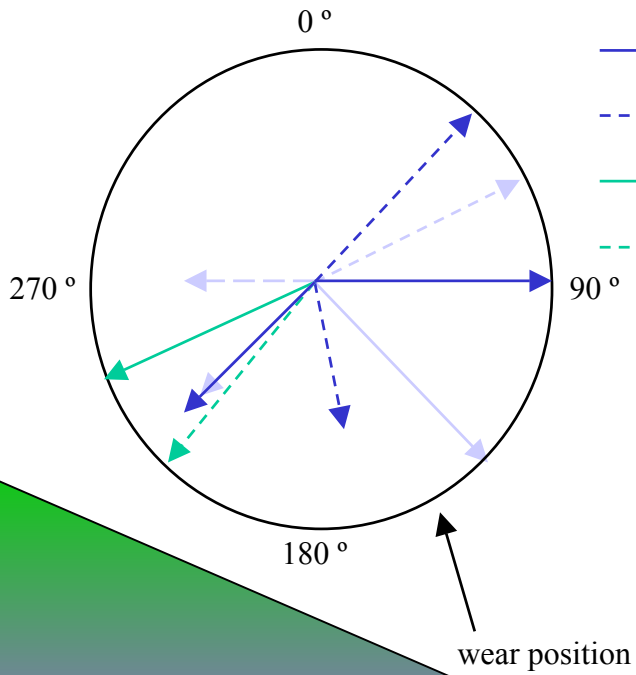
TYRE TRIAL



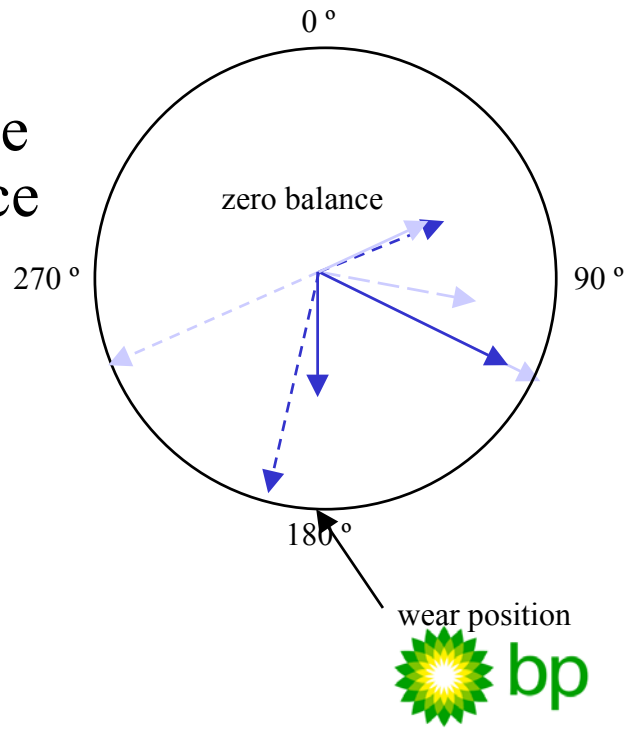
- Measure the effect of good tyre maintenance programs.

- Evaluate the effect of Static Balance, Dynamic Balance, Radial & Lateral run-out of the tyre & rim assembly on abnormal tyre wear.

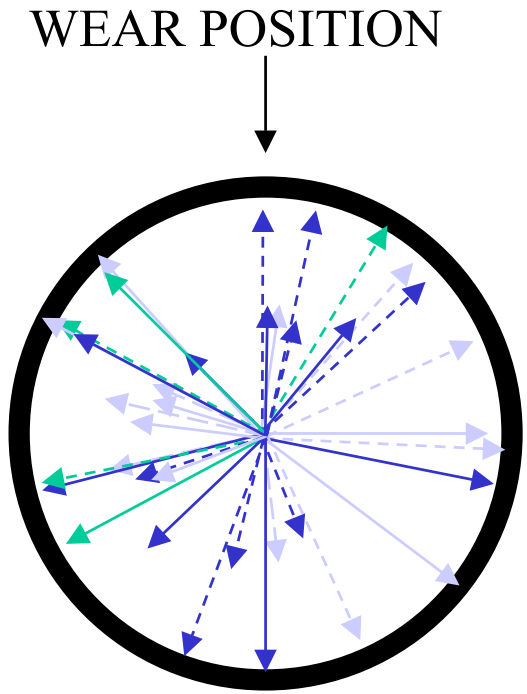
The tyre with maximum irregular wear did not require balancing and had less runout



rim radial outer
rim radial inner
tyre radial
tyre lateral
rim static balance
tyre static balance

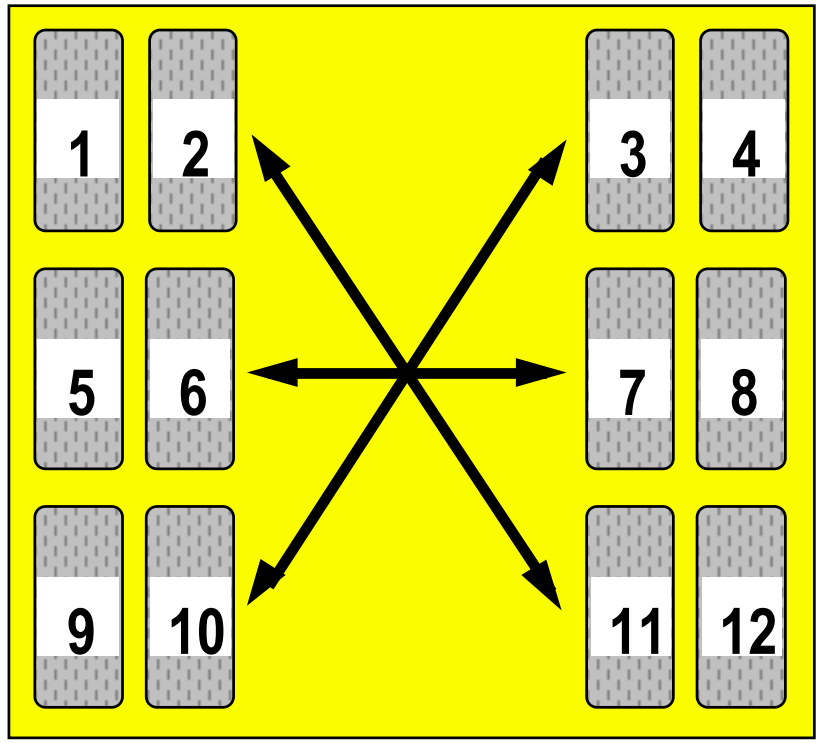


Overlapping the plots of four tyres indicated that balance or radial run-out were not the dominating factors.



Rotation

- **Tyres were rotated on one trailer every 25,000 km according to the following pattern.**
- **Tyres on the second trailer were <u>not</u> rotated.**



Tyre Wear Results

Trailer - no rotation

- Seven tyres removed
- Estimated average life: 81,387 km
  (range: 75,602 - 101,928 km)
- All tyres removed for uneven wear.

Trailer - tyres rotated

- One tyre removed due to damage
- Estimated average life: >120,000 km.
- All tyres flat even wear.

EFFECT OF CHANGES

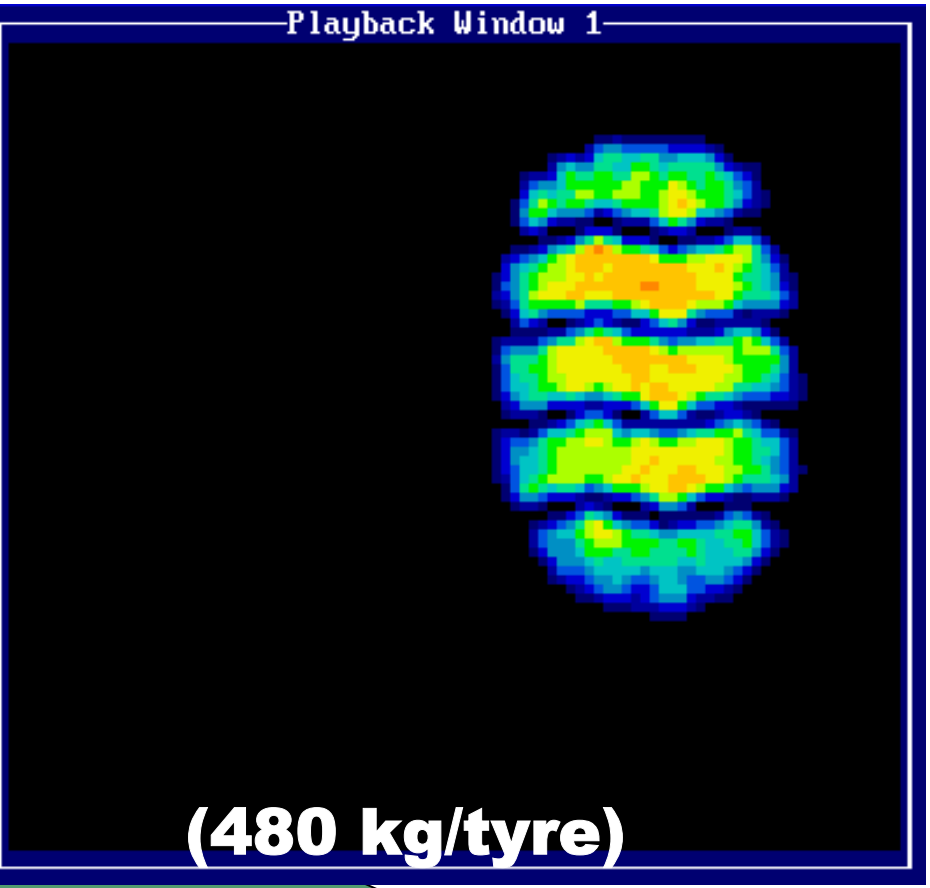
- **PROBLEM EXISTS REGARDLESS OF CHANGES.**
- **CHANGES HAVE EFFECT BUT DON'T ERADICATE THE PROBLEM.**
- **CAN MINIMISE PROBLEM BUT NOT STOP THE PROBLEM.**
- **SOURCE NOT IN TRAILER.**

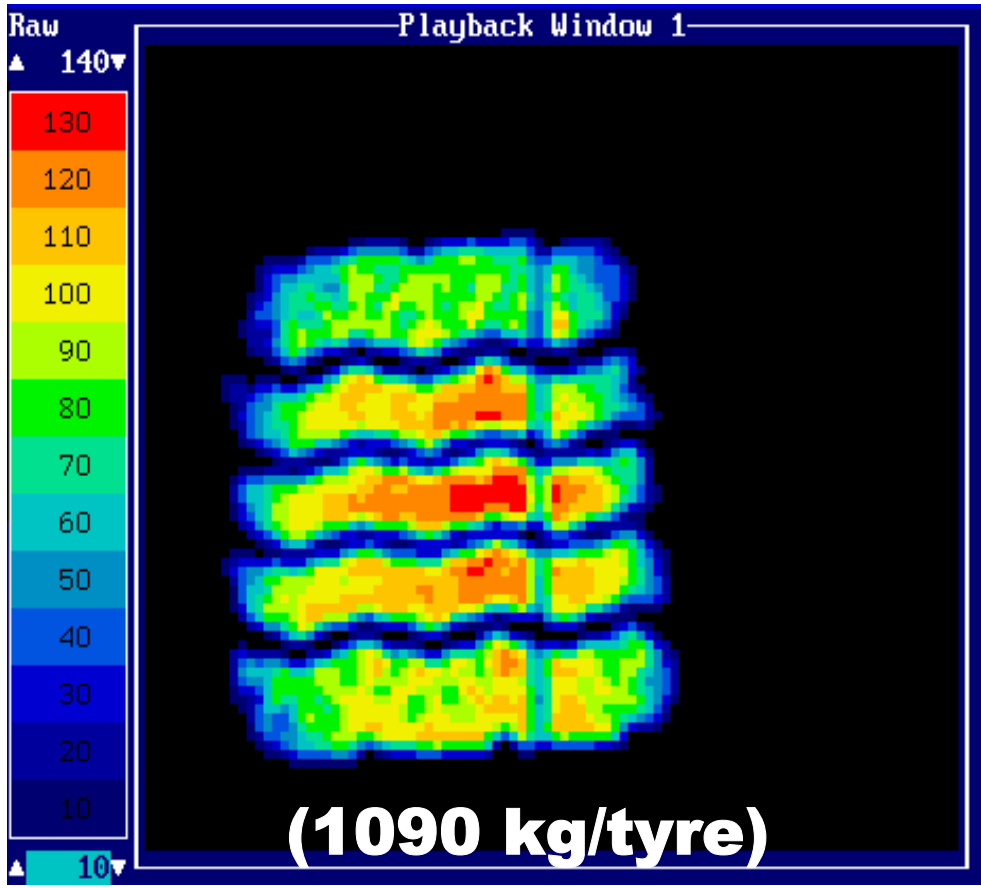
FINDINGS

- PROBLEM ACROSS MOST FLEETS
- ALL TYRE BRANDS AFFECTED
- AIR & SPRING SUSPENSIONS
- ALL TRAILER MAKES
- POOR MAINTENANCE CONTRIBUTES
- TYRE DIAMETER INFLUENCES

FOOT PRINTING

(Centre Axle Right Side Outer Dual)





Flat Road - Static

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Findings so Far

- **alignment, balance, suspension, tyre make, shockers, trailer make may influence but don't cause the problem.**
- **good tyre maintenance reduces effect and increases tyre life.**
- **smaller the tyre - bigger the problem.**
- **cause still unknown**

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TYRE WEAR – TESTING OF SMALL DIAMETER, LOW PROFILE TYRES

Christos Tsangalis

Kirk Berenger

Undergraduate Students

B.E. (Aerospace) RMIT

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

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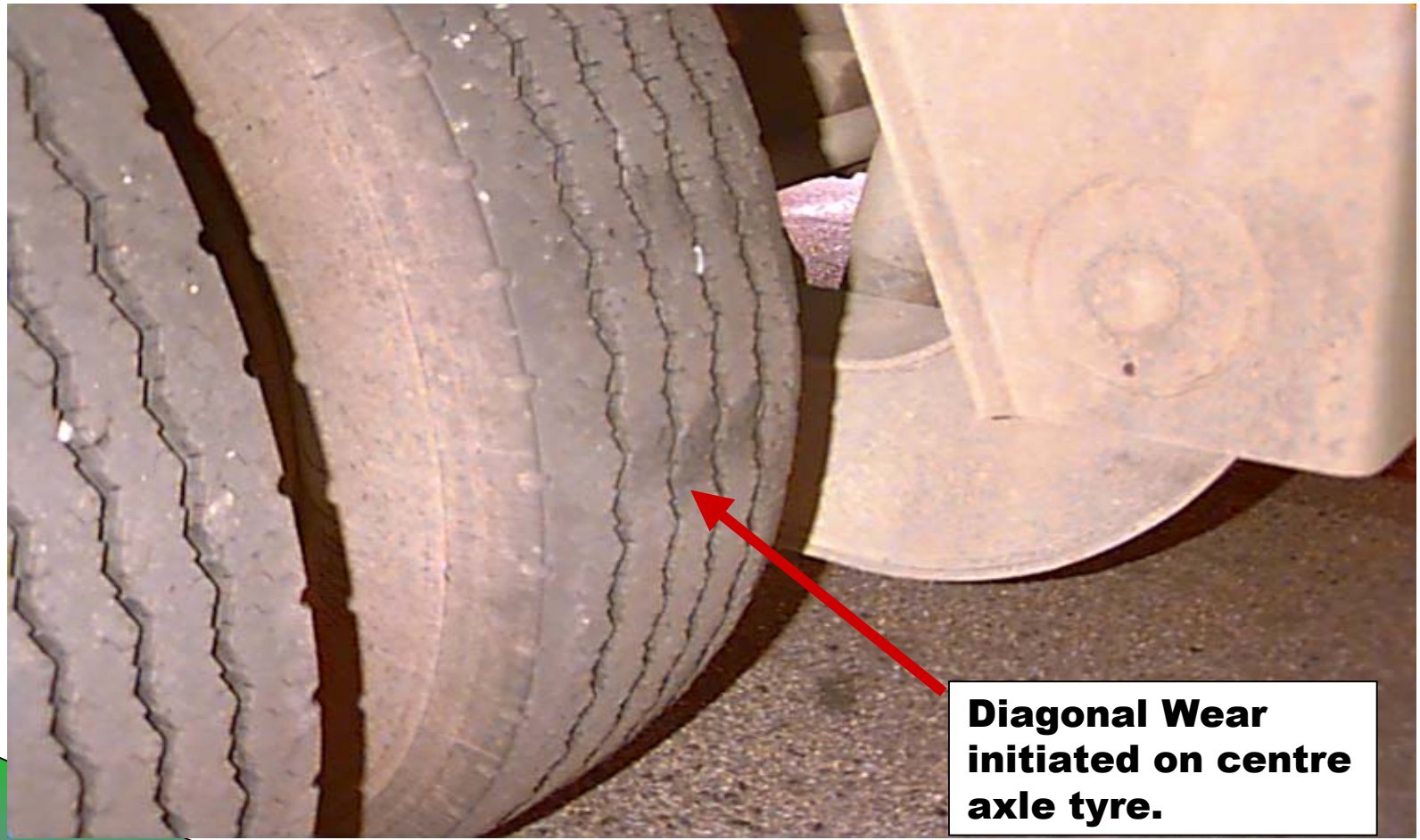
The Problem

The Problem



What is the Project?

Objectives:

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

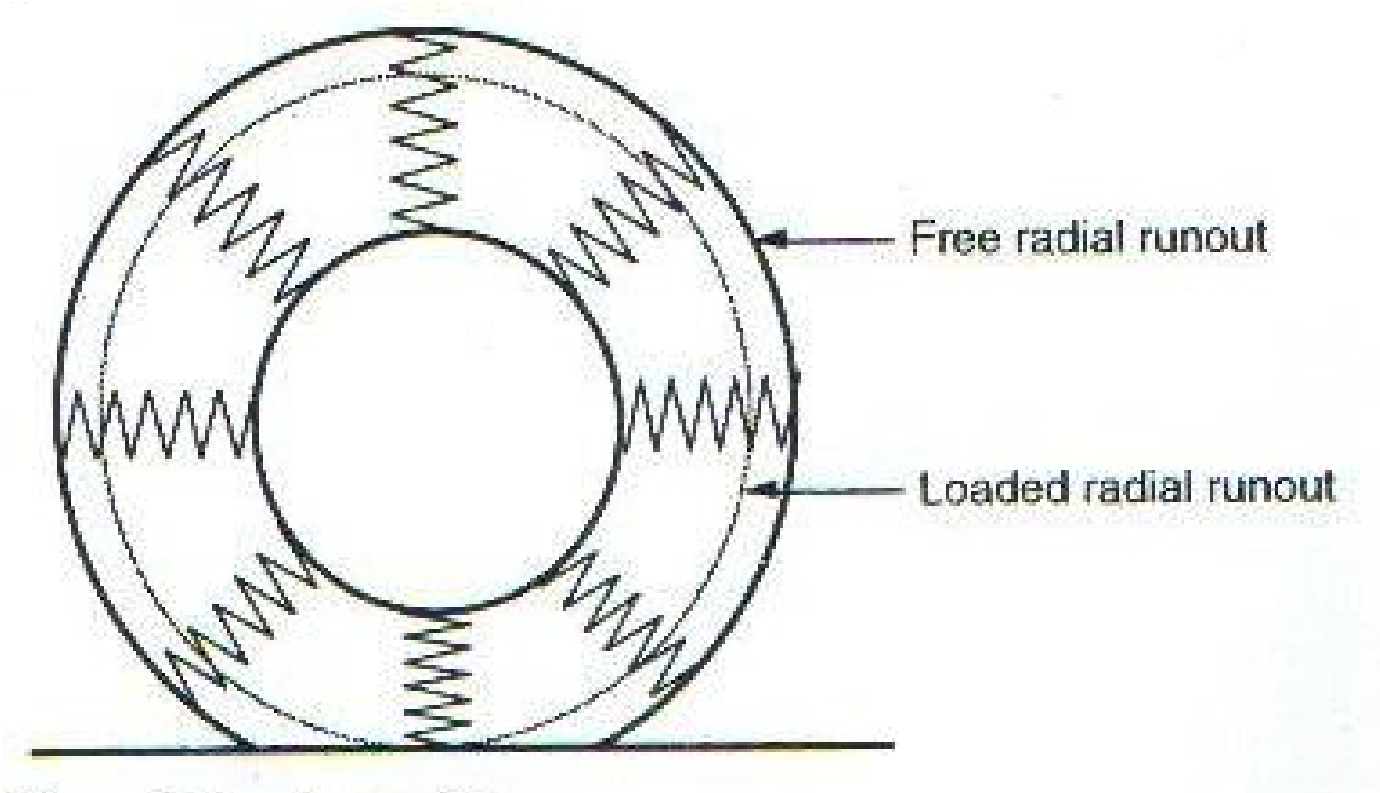
Rationale

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

Methodology

- **Physical Testing of Tyre Stiffnesses**
- **Create Computer Model**
- **Field Testing**

Radial Stiffness Variation



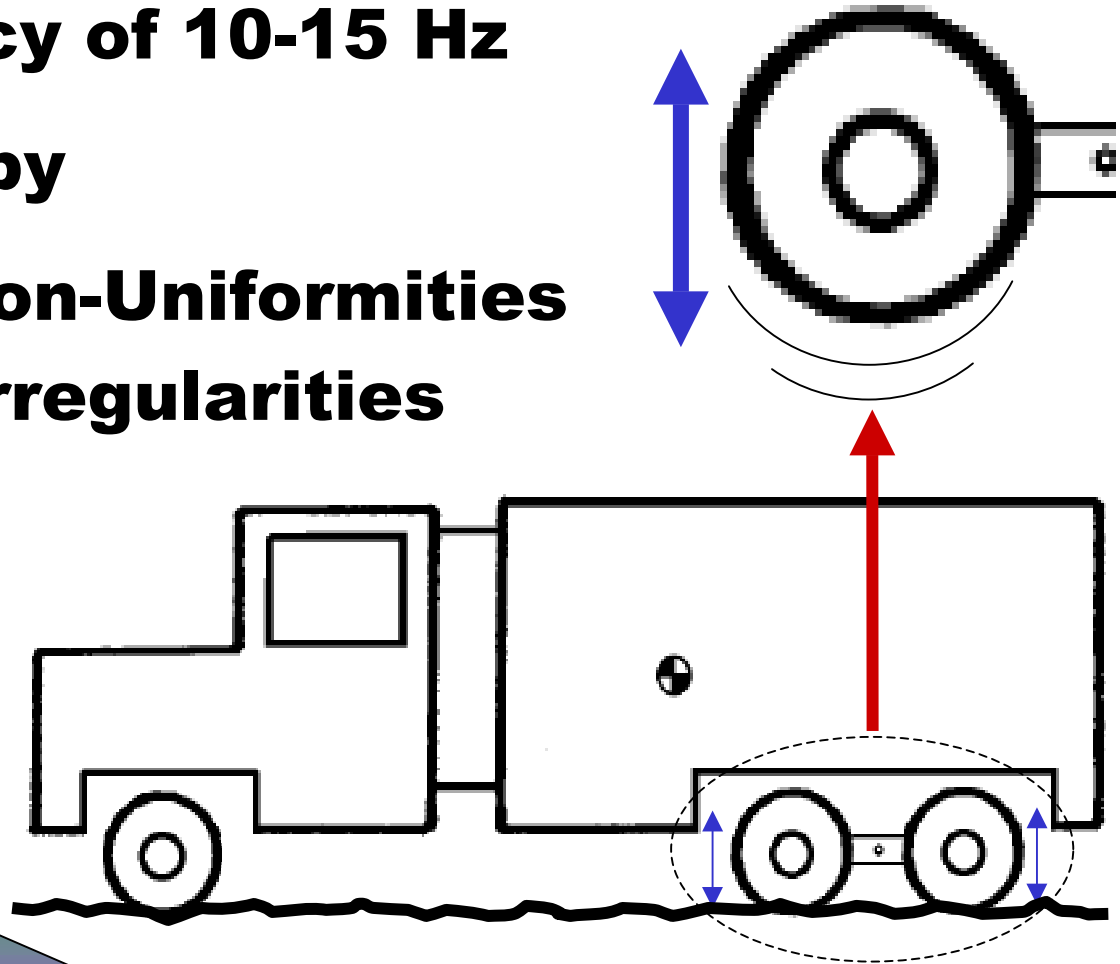
Tyre Radial Spring Model (Fundamentals of Vehicle Dynamics, Gillespie 1992)

Axle Hop

Frequency of 10-15 Hz

Excited by

- **Tyre Non-Uniformities**
- **Road Irregularities**



Industry Involvement

Visit to Bridgestone Adelaide

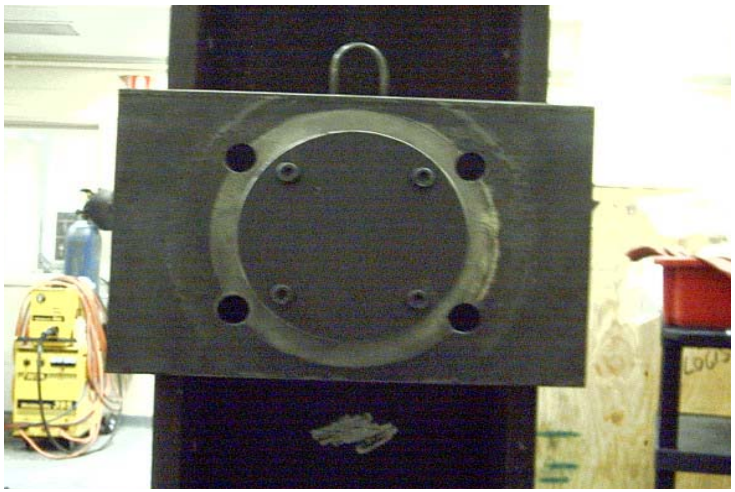
- **Travelled to Adelaide on Australia Post Linehaul Equipment.**
- **Tour of Tyre Manufacturing Plant**
- **Visit to Bridgestone Truck Centre**

Physical Testing

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

Radial Stiffness Variation

Completed Testing Rig:



Radial Stiffness Variation

Physical Testing:

8 new tyres

2 worn tyres

Ten positions around the tread

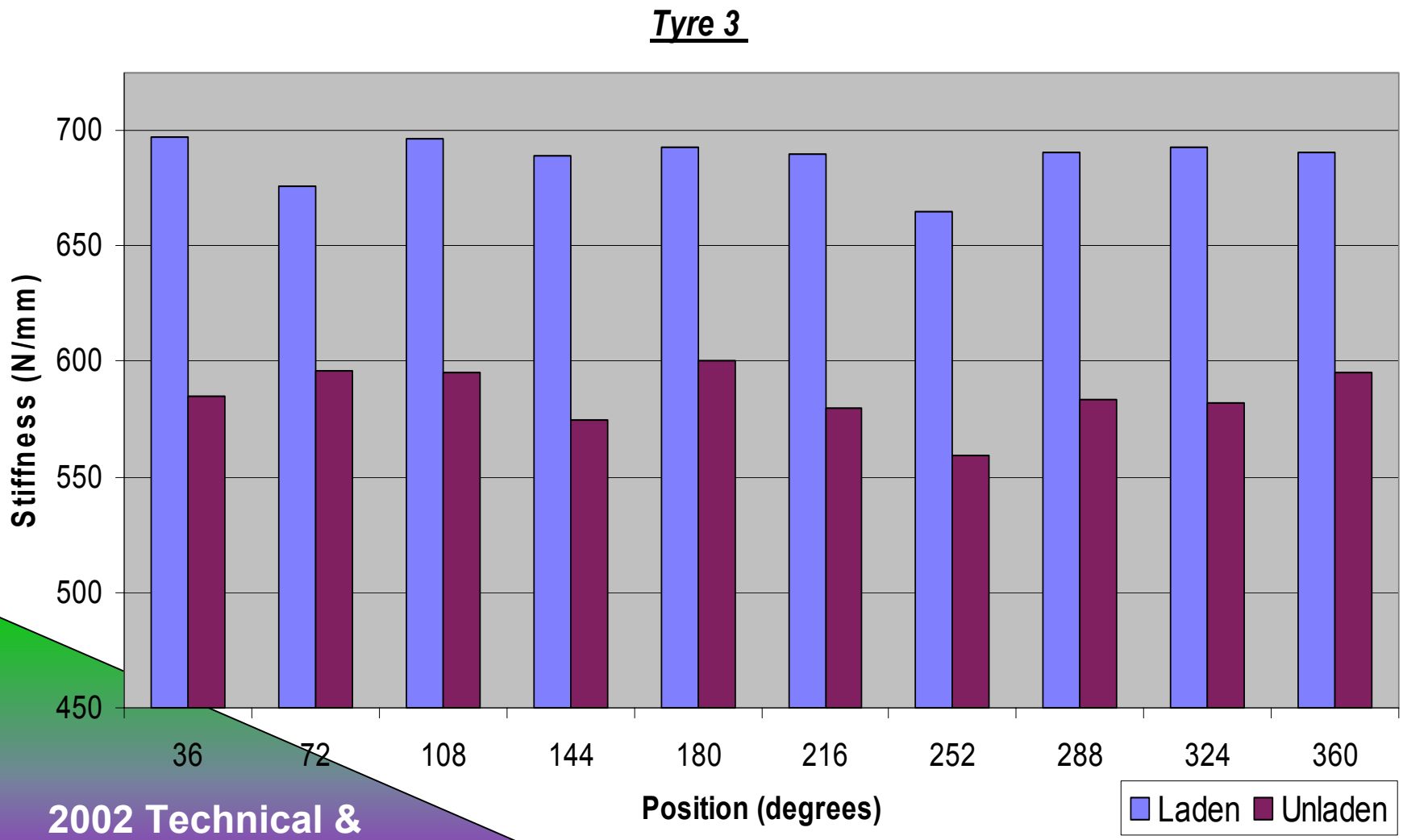
Radial Stiffness Variation

Stiffnesses around the tread:

Radial Stiffness Variation

Stiffnesses across the tread:

Tyre Stiffness Data



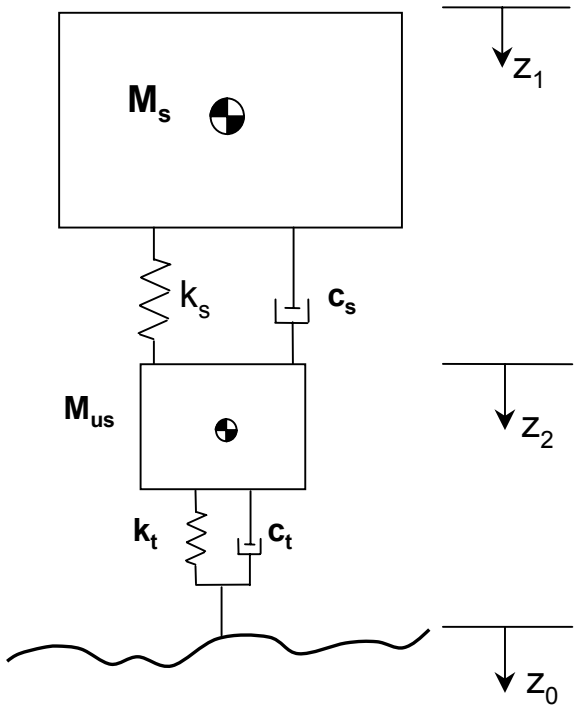
Radial Stiffness Variation

		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%

Computer Model

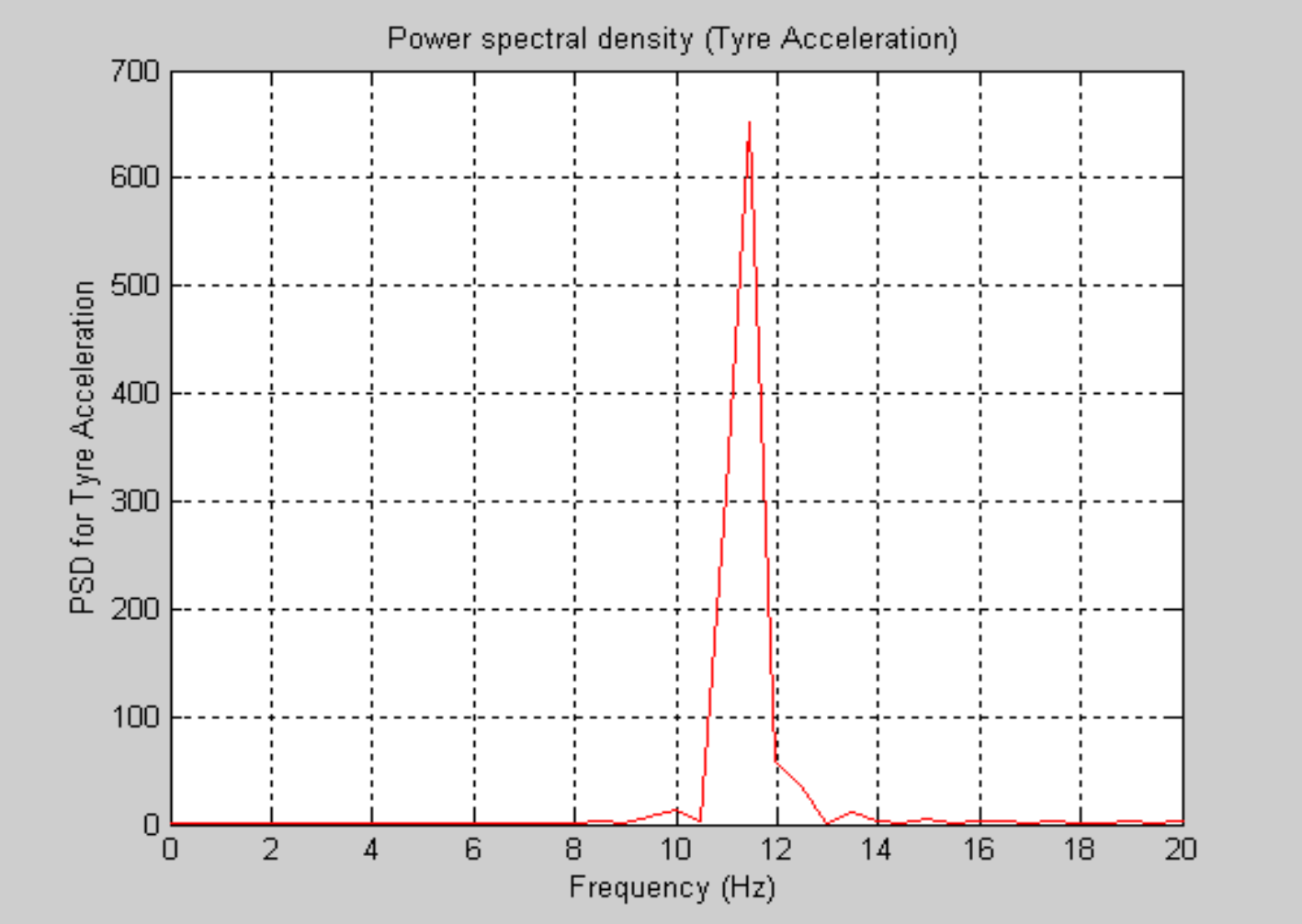
Develop quarter truck model

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



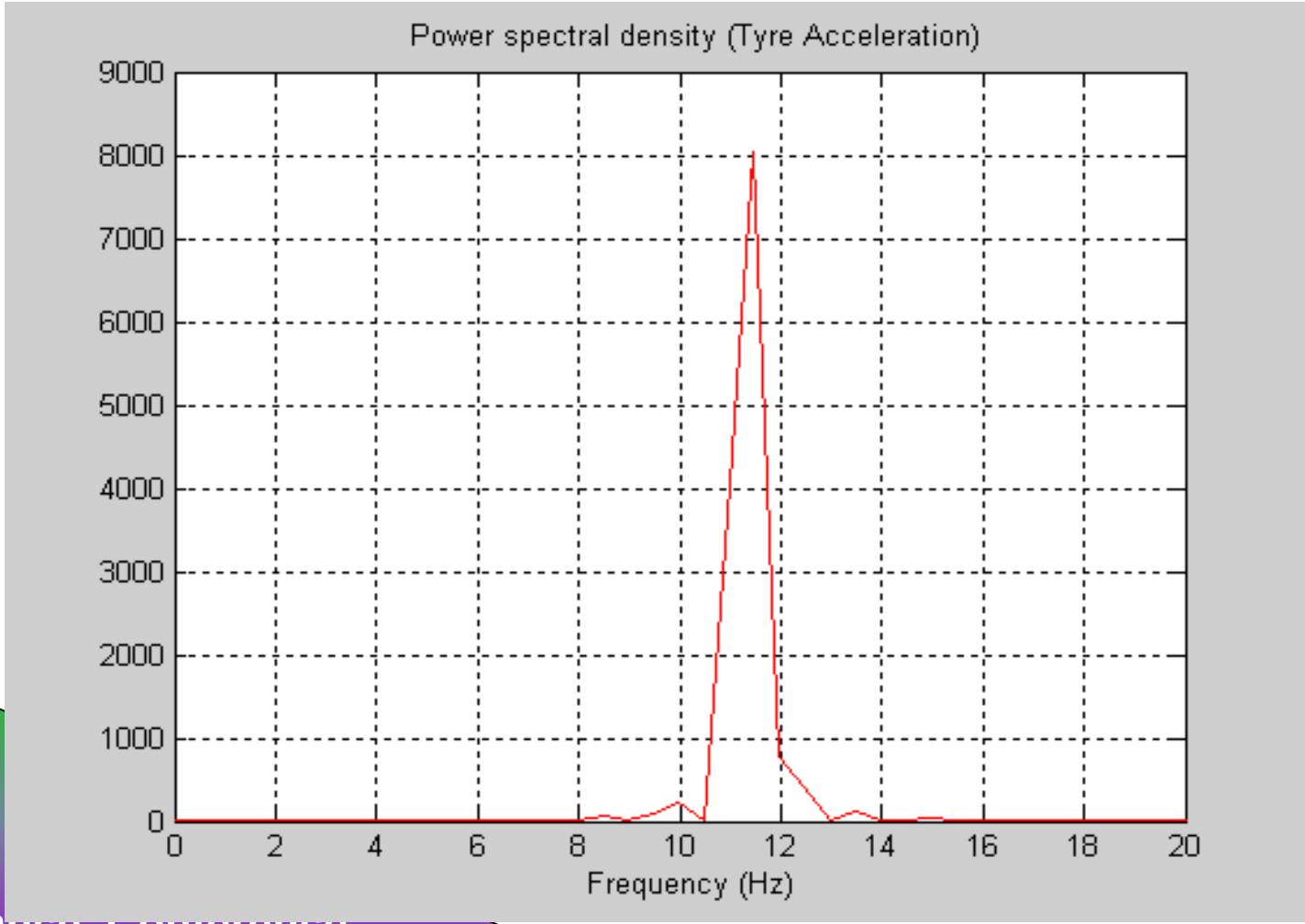
Dynamic Modelling

Radial Force Variation



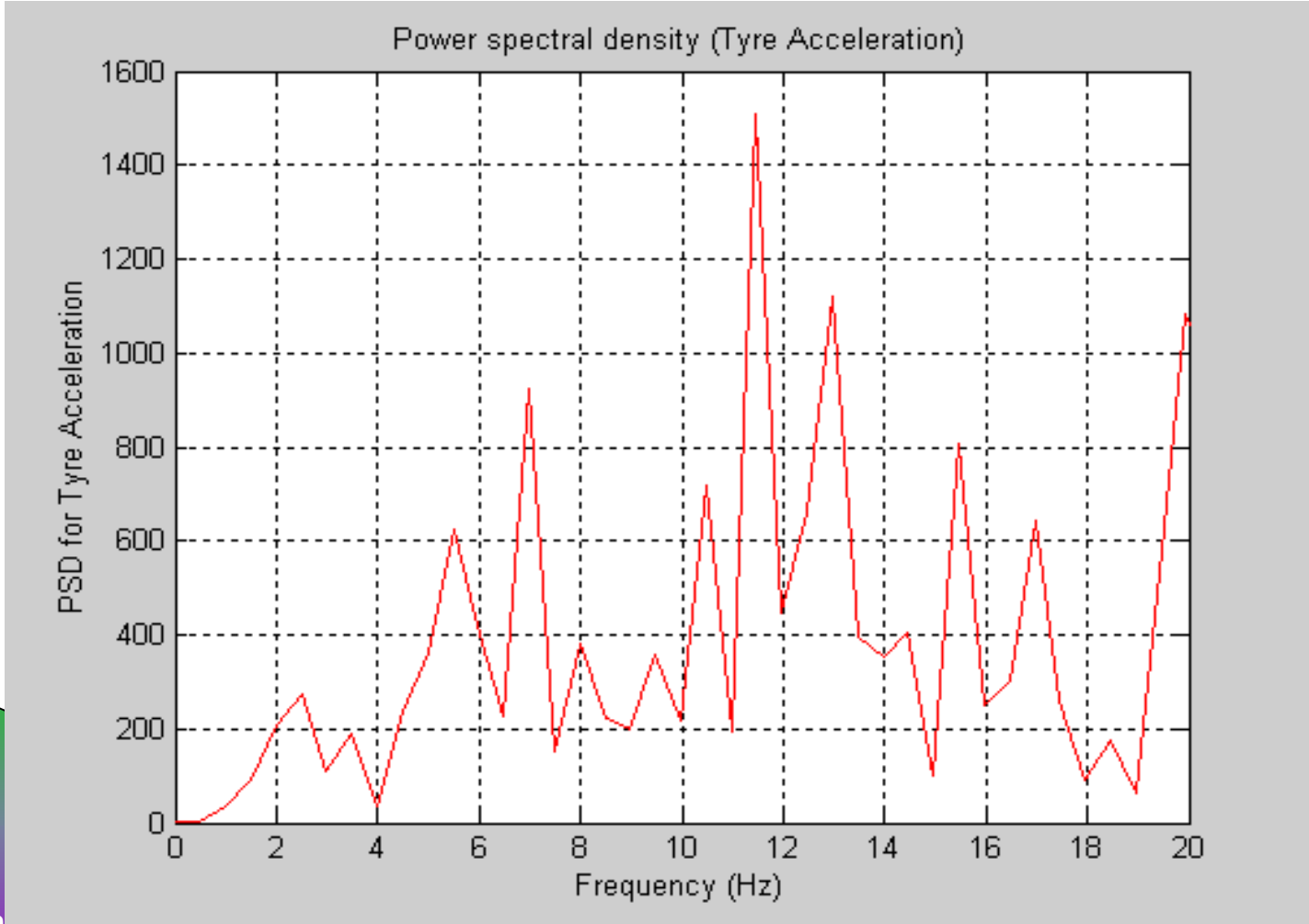
Dynamic Modelling

Wheel Mass Imbalance



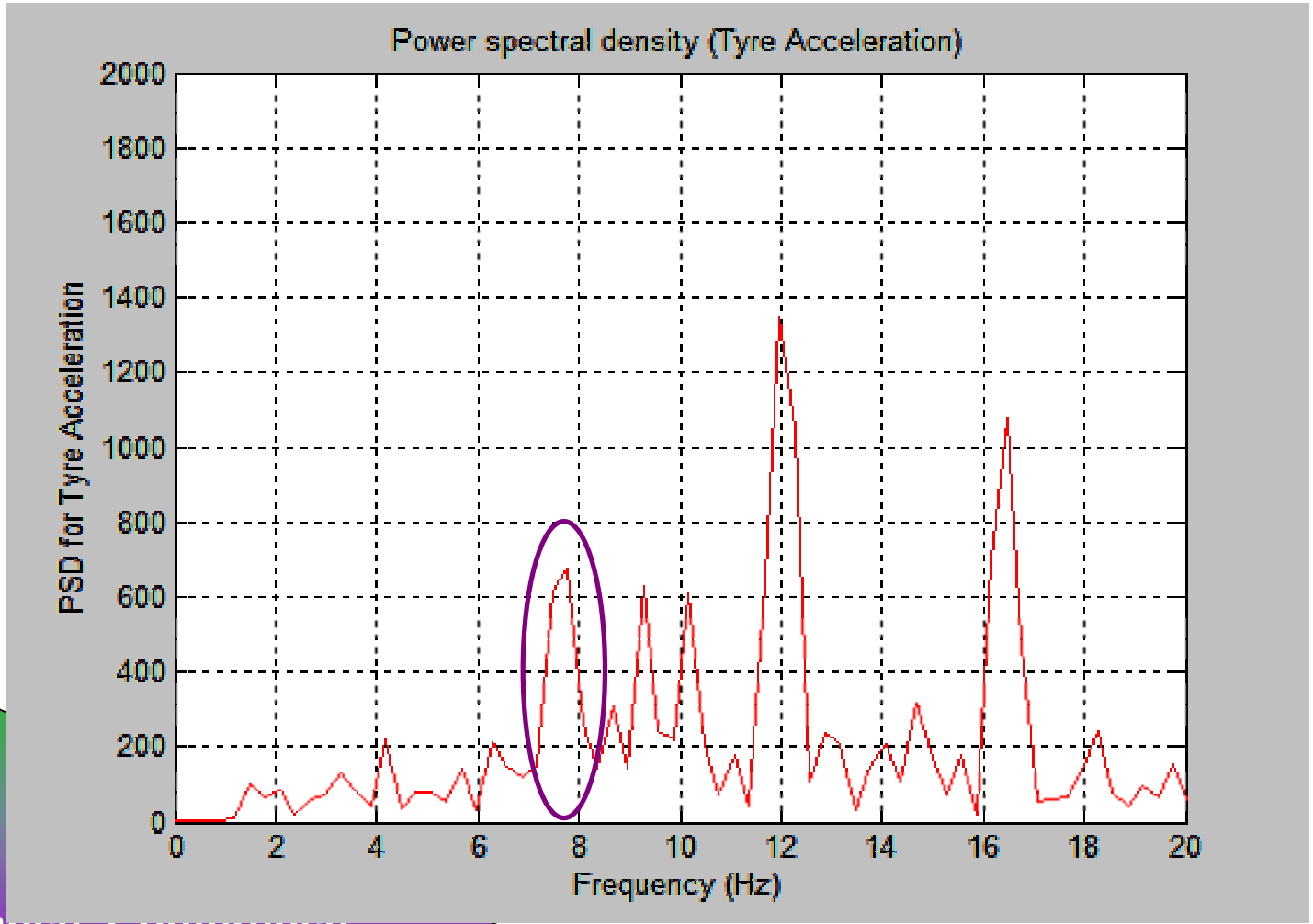
Dynamic Modelling

Road Profile



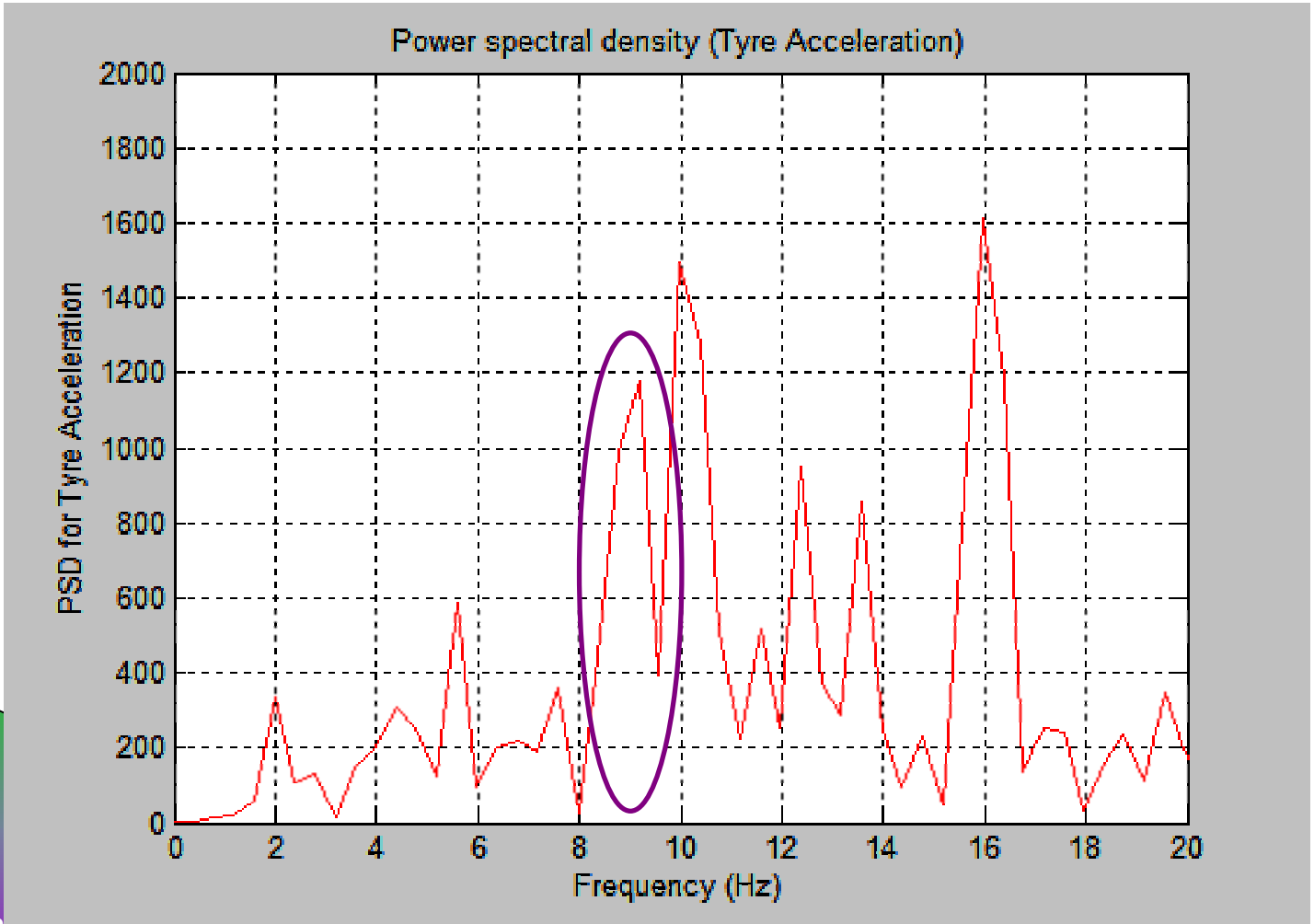
Dynamic Modelling

60km/h



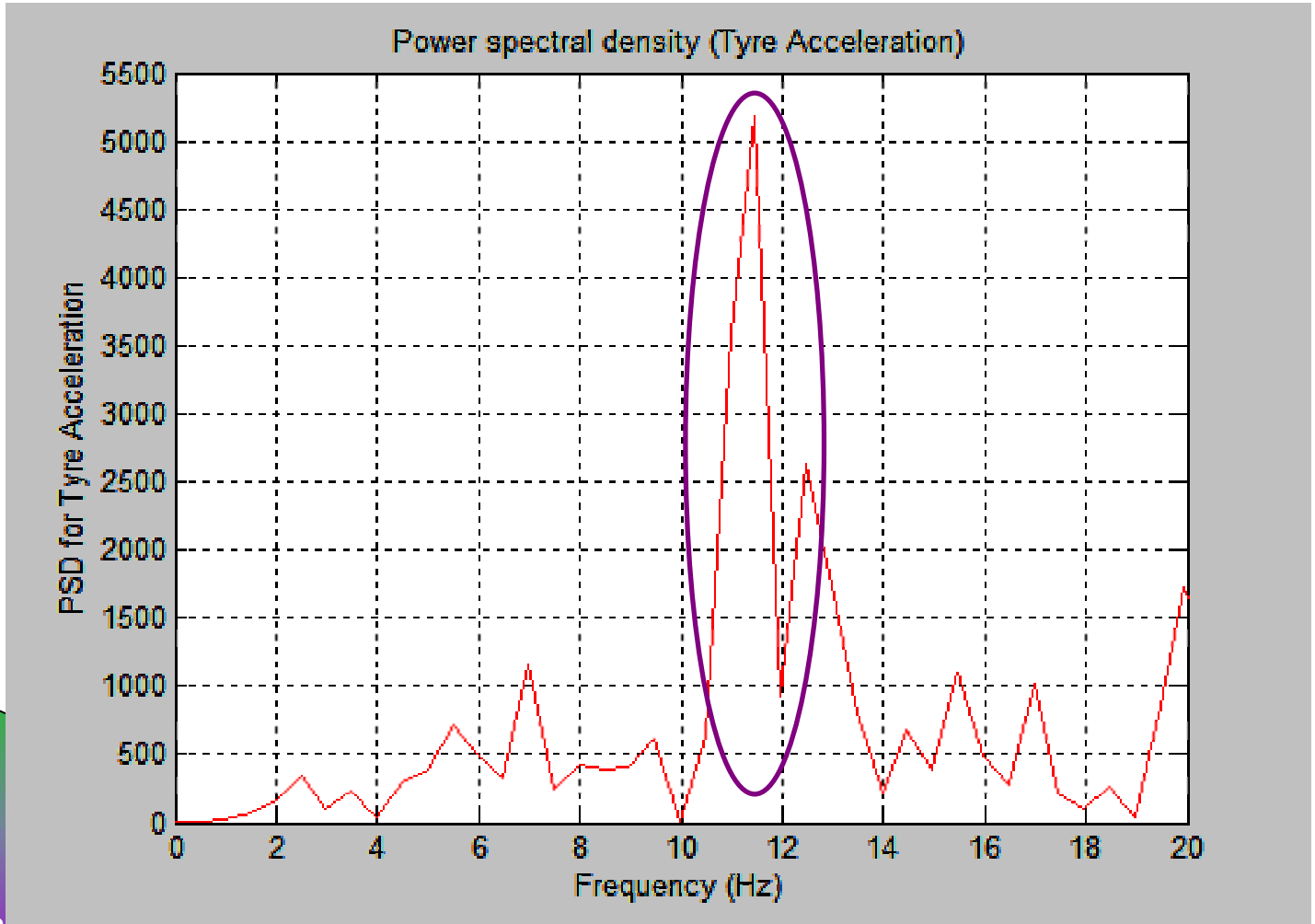
Dynamic Modelling

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

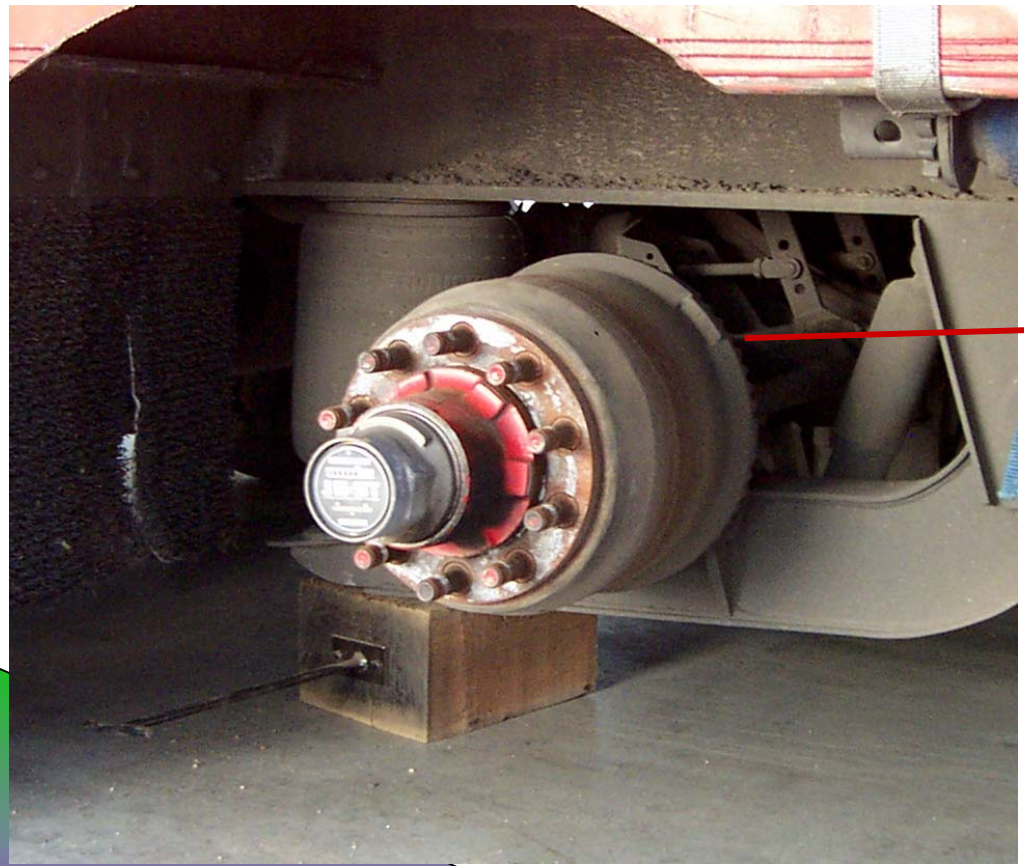
Good Tyres (Trailer 2)

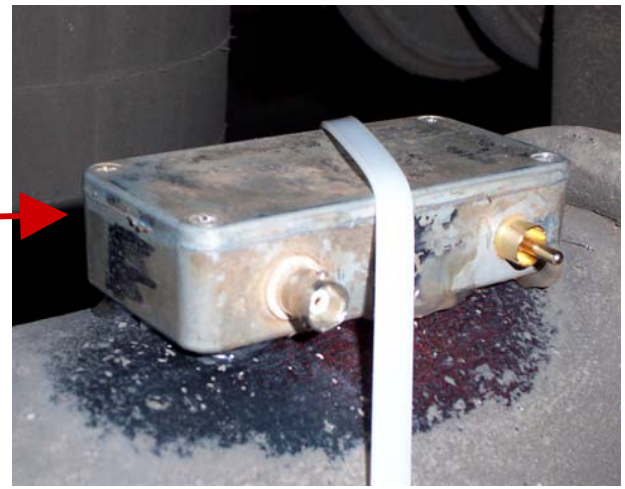
	Tyre	Position	Min. Stiffness (N/mm)
Dual Configuration 1	1	9	575
	8	10	574
Dual Configuration 2	4	2	577
	7	8	570

Field Testing

Field Testing

Accelerometer Attachment





Field Testing

Tyre Fitment

Field Testing

Data Acquisition

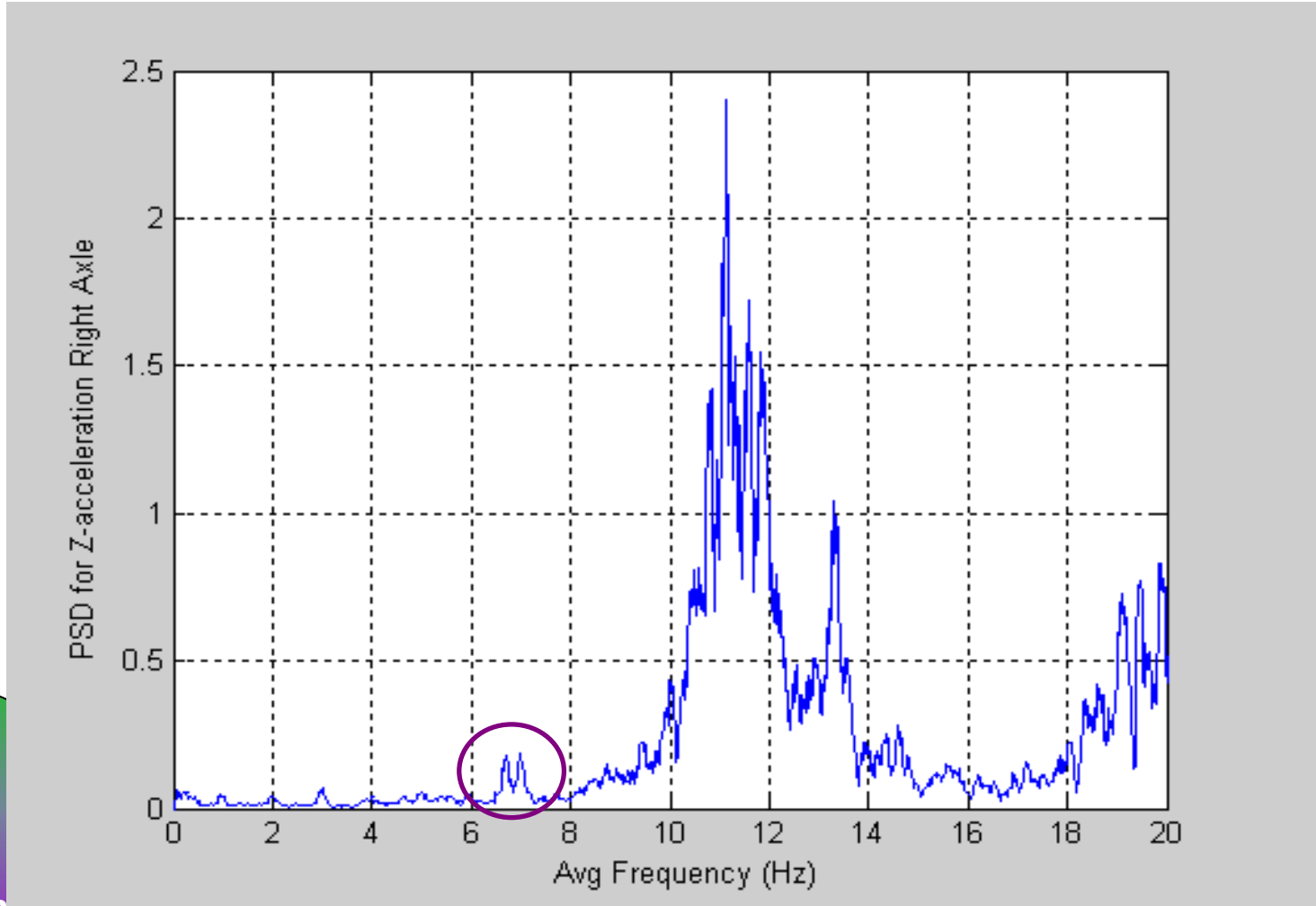
Field Testing

Trailer Loading

Field Testing

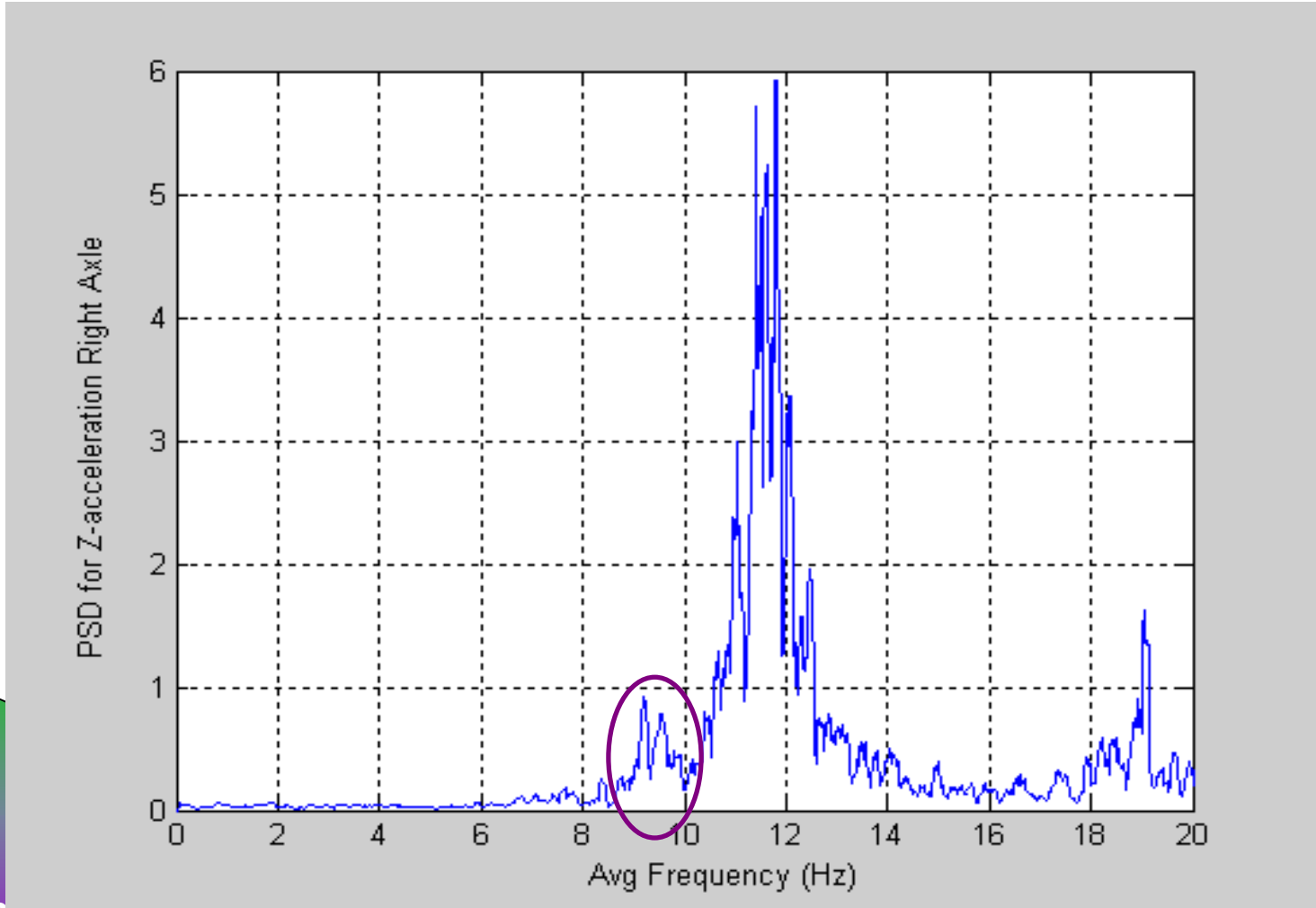
Field Testing

60km/h



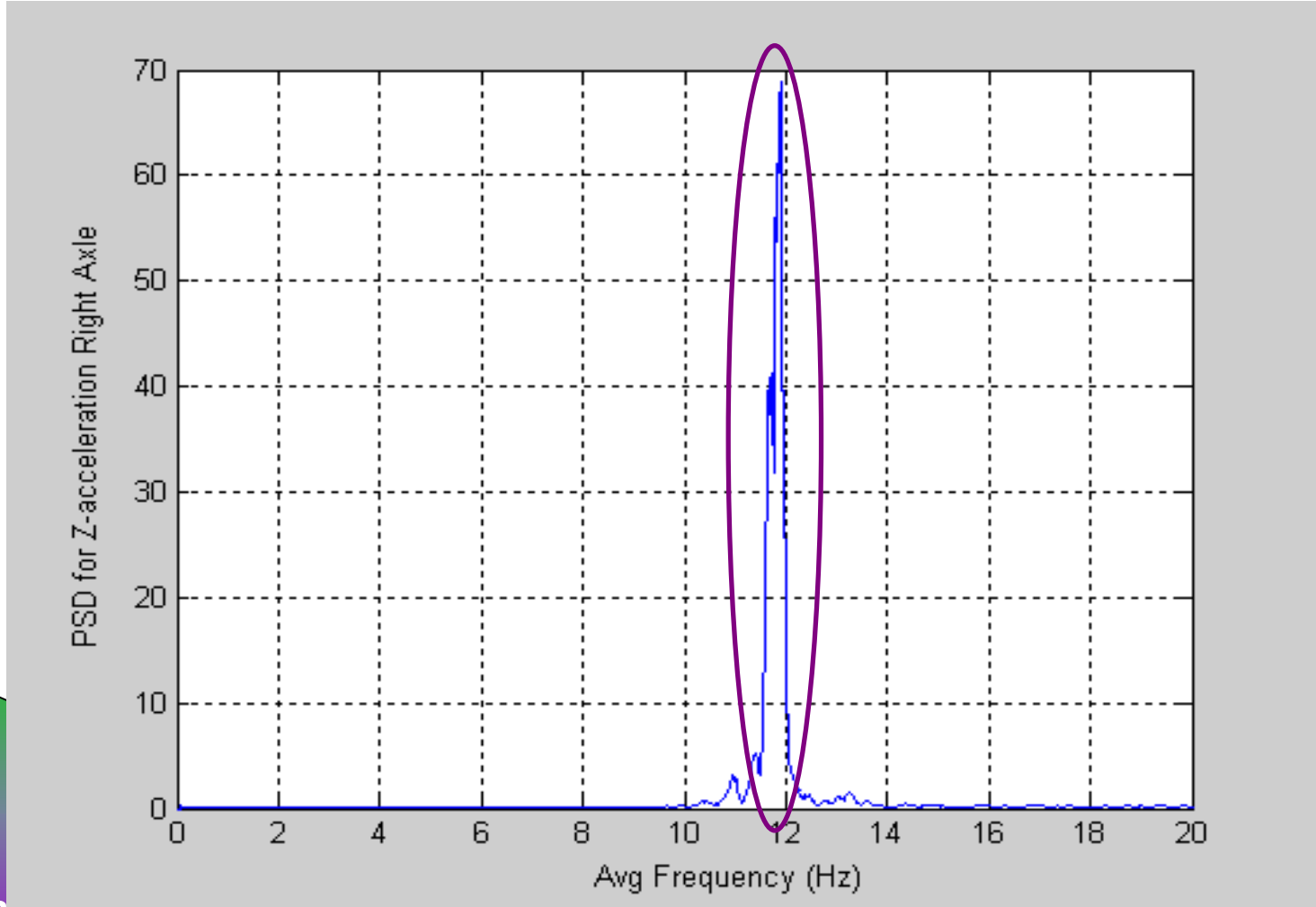
Field Testing

80km/h

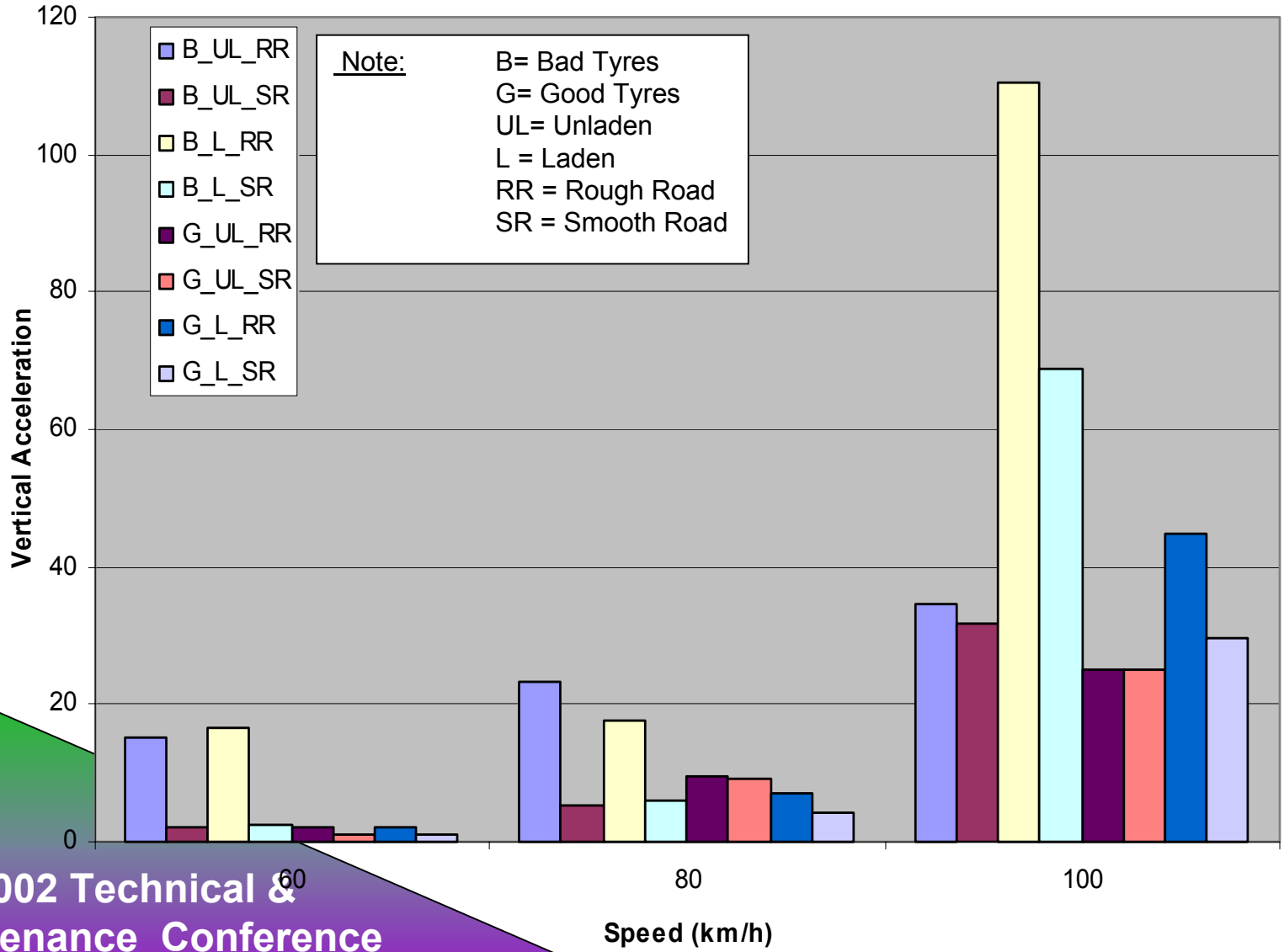


Field Testing

100km/h



Field Testing



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

Computer 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

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Radial Force Variation

In Truck Wheel and Tyre Assemblies

Alan Sutton

National Customer Engineering Manager
Goodyear & Dunlop Tyres

Radial Stiffness Variation

As shown previously when measured in different positions, all tyres have radial stiffness variation when measured around the tyre.

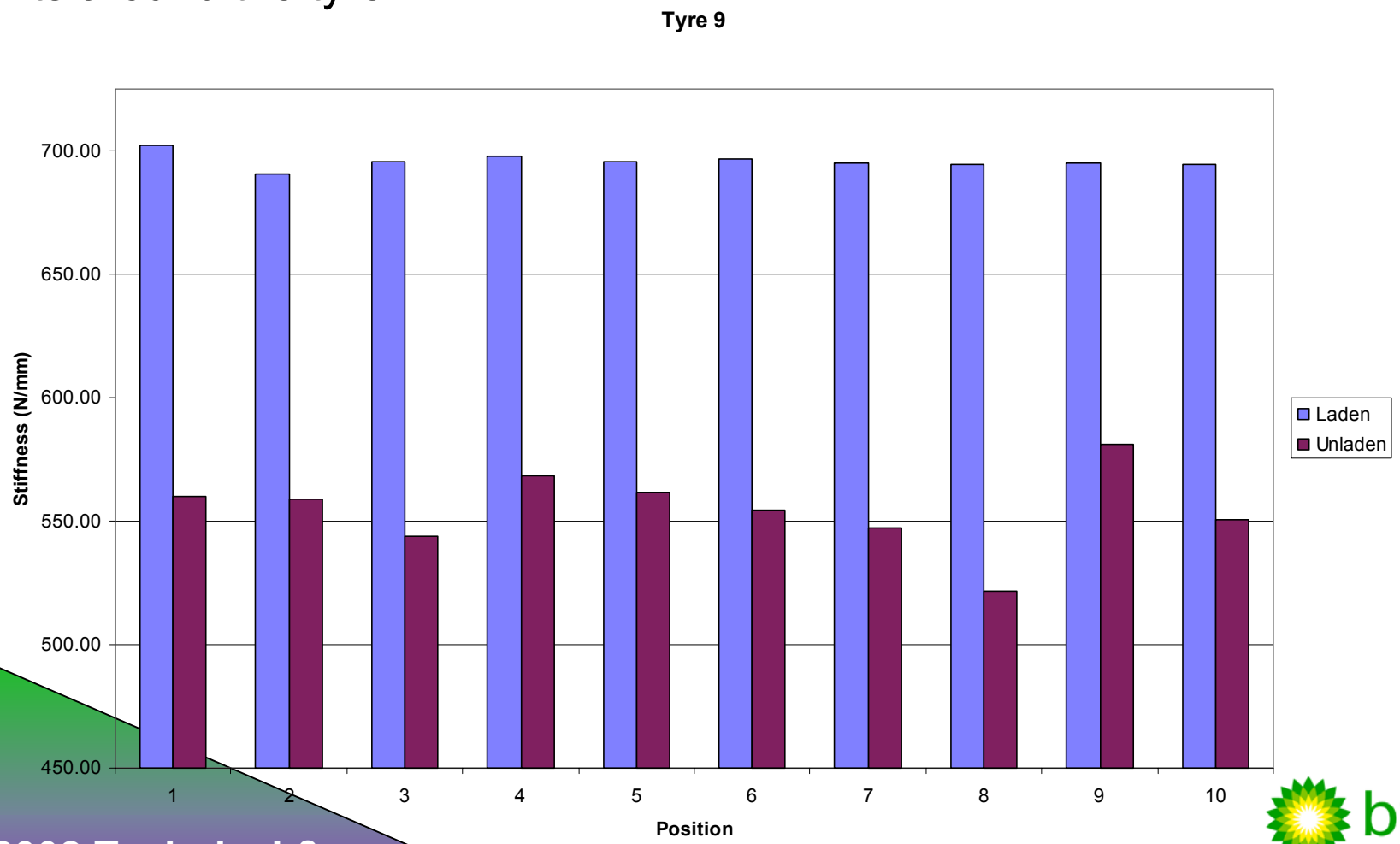
This is due to...

- the composite nature of tyres (made from rubber / steel / fabric)
- the fact tyres shrink around 2% from when they are first moulded to when they have stabilised and cooled to room temperature
- after curing, rubber is elastomeric but still retains some of its previous thermoset characteristics

Measuring “Radial Force” Variation on a Uniformity M/c

contd...

From the RMIT presentation the stiffness was measured statically at 10 points around the tyre.

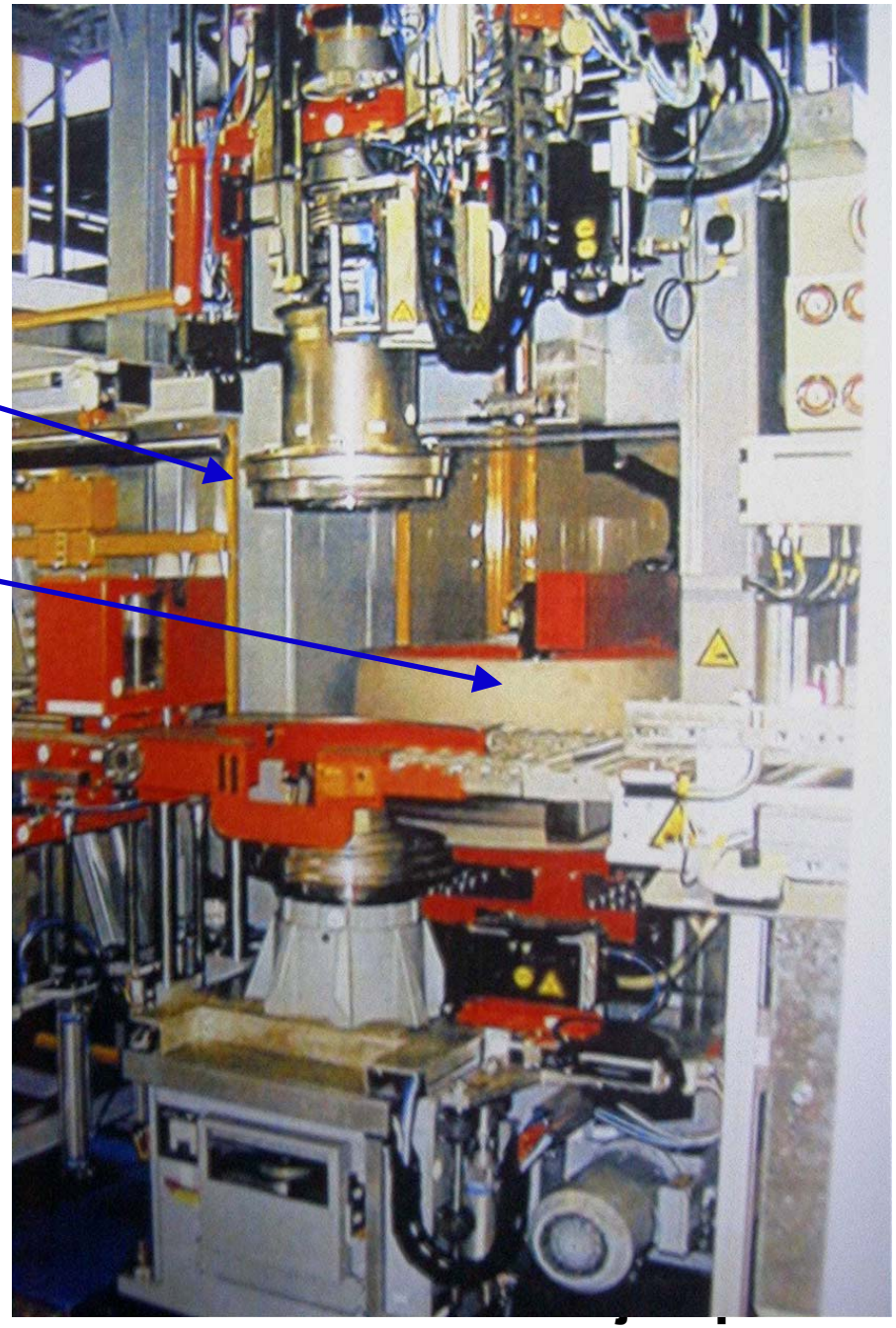


Radial Force Variation contd...

In the tyre industry we mount the tyre on chucks)...

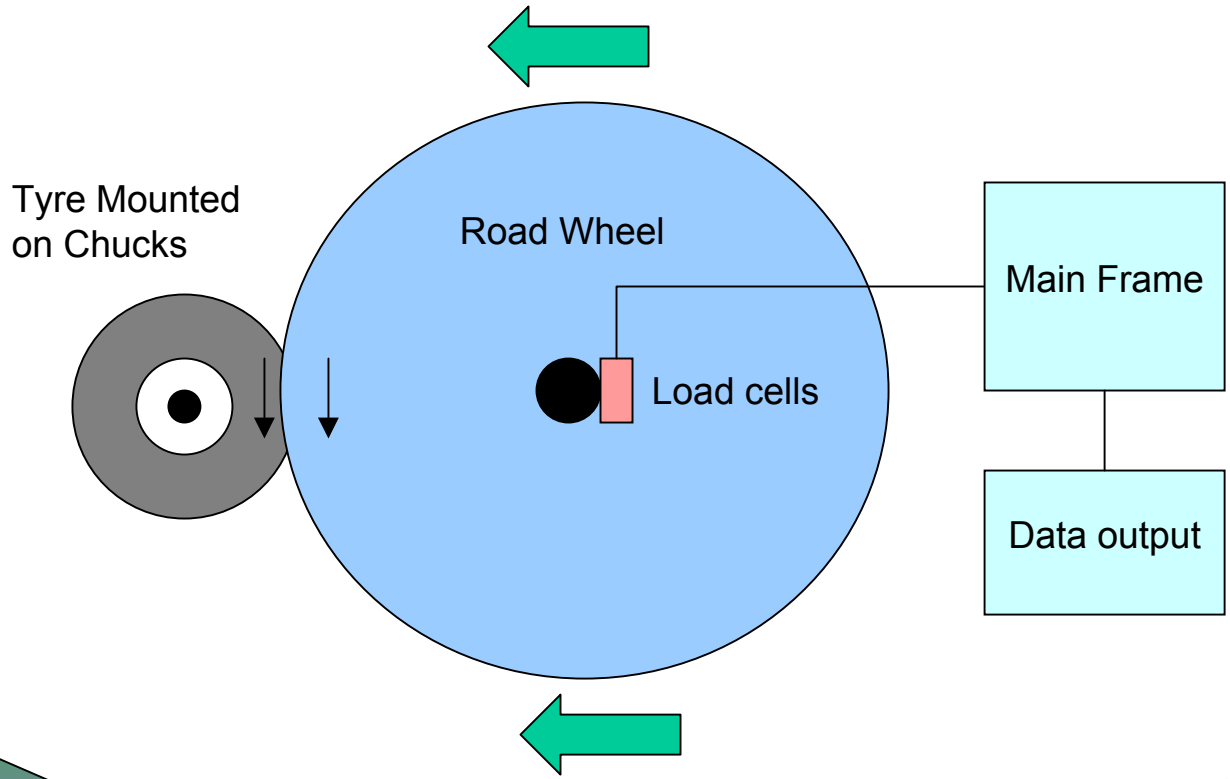
then press a rotating road wheel against the tyre and measure the resistance around the tyre

This is called the
“Radial Force Variation (RFV)”



Measuring Radial Force Variation on a Uniformity M/c

Load cells attached to the road wheel axle measure the lateral and radial forces the tyre exerts on the wheel as it rotates



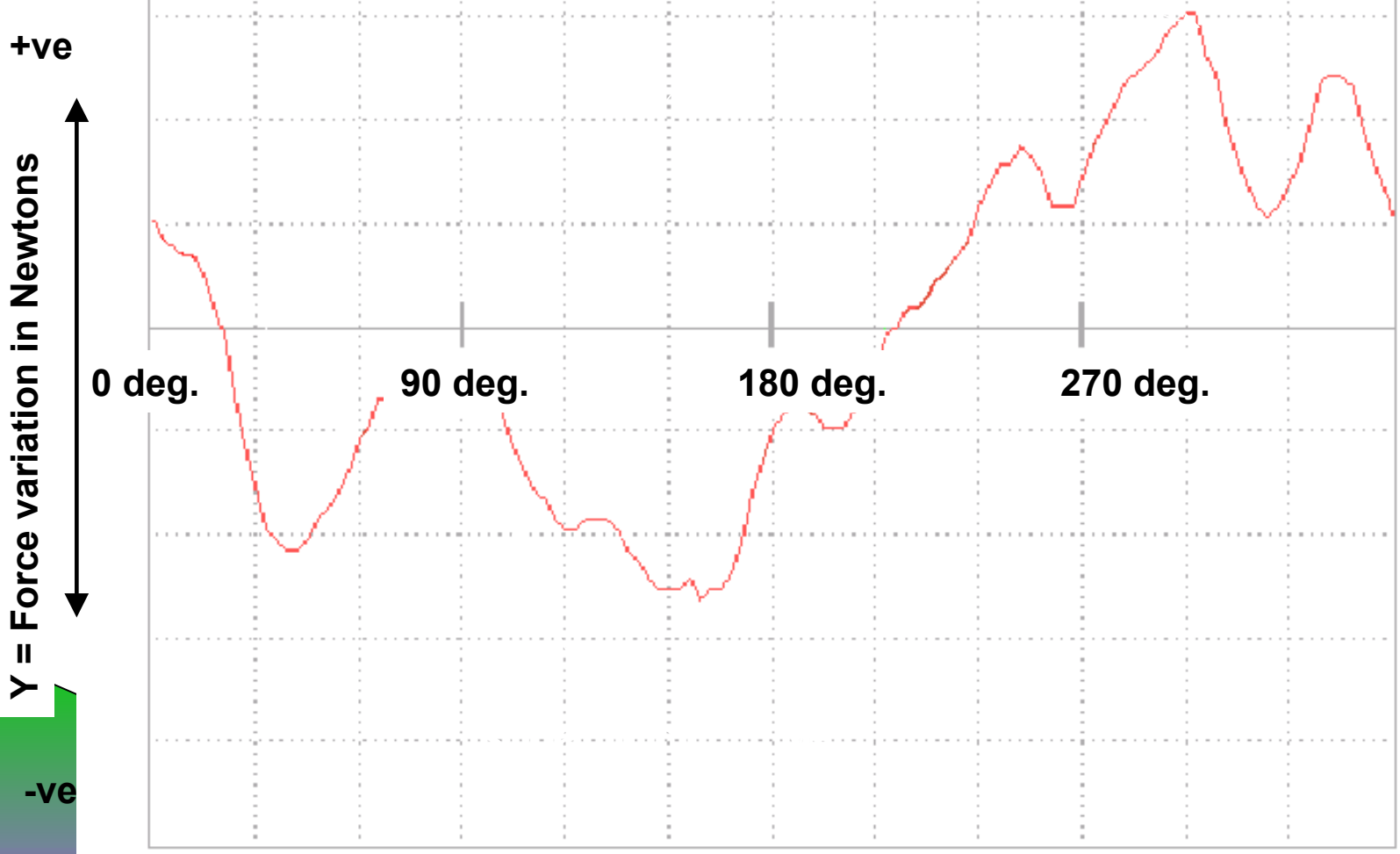
Measuring Radial Force Variation on a Uniformity M/c contd...

Tyres are measured…

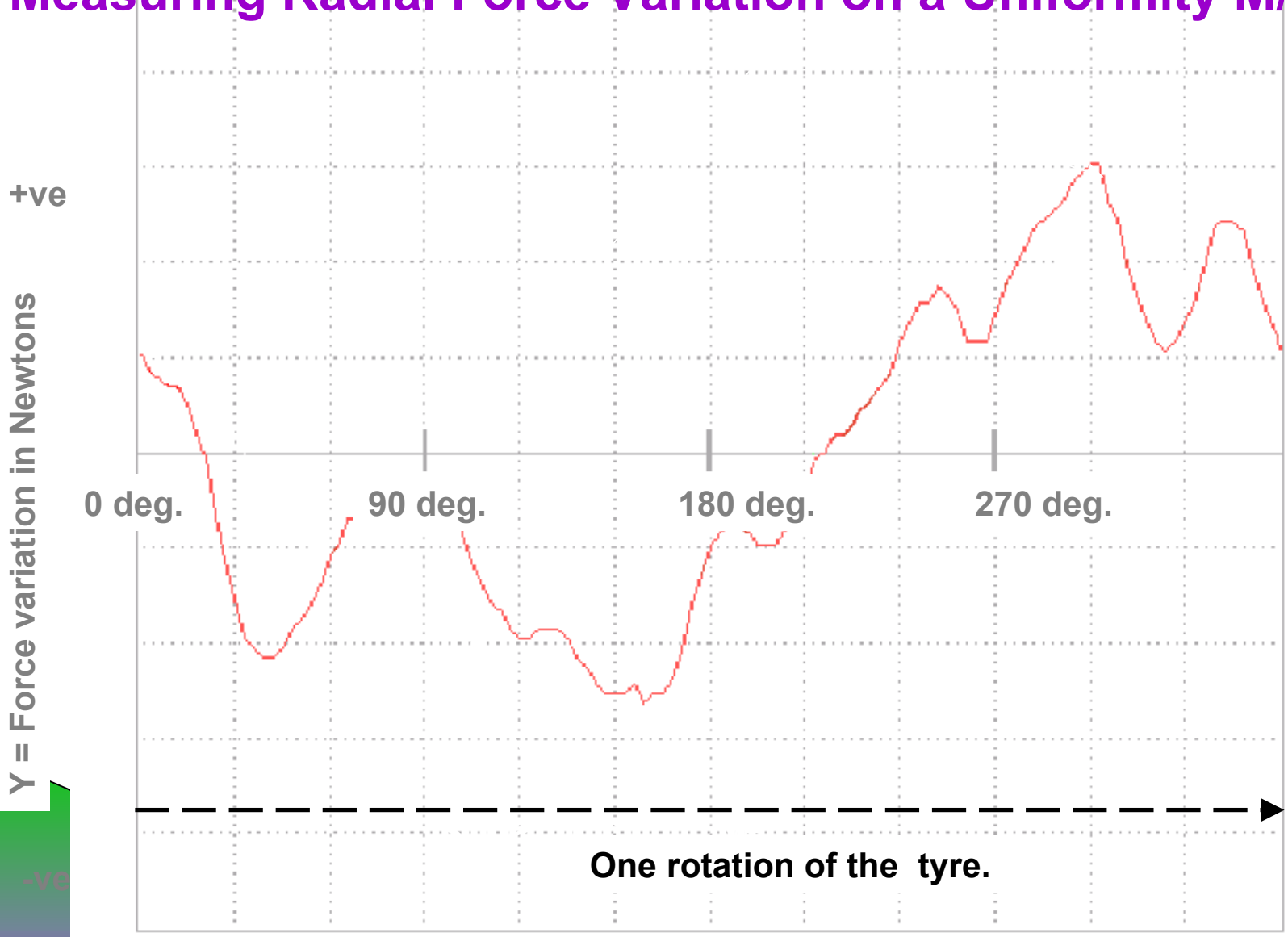
- dynamically in both directions of tyre rotation
- for both radial and lateral “force” (stiffness) variation
- with the tyre loaded to approximately 60% of its rated load
- with the tyre inflated to approximately 75% of the inflation pressure for the maximum rated load

Measuring Radial Force Variation on a Uniformity M/c contd...

So we get a typical radial force trace that looks like this…

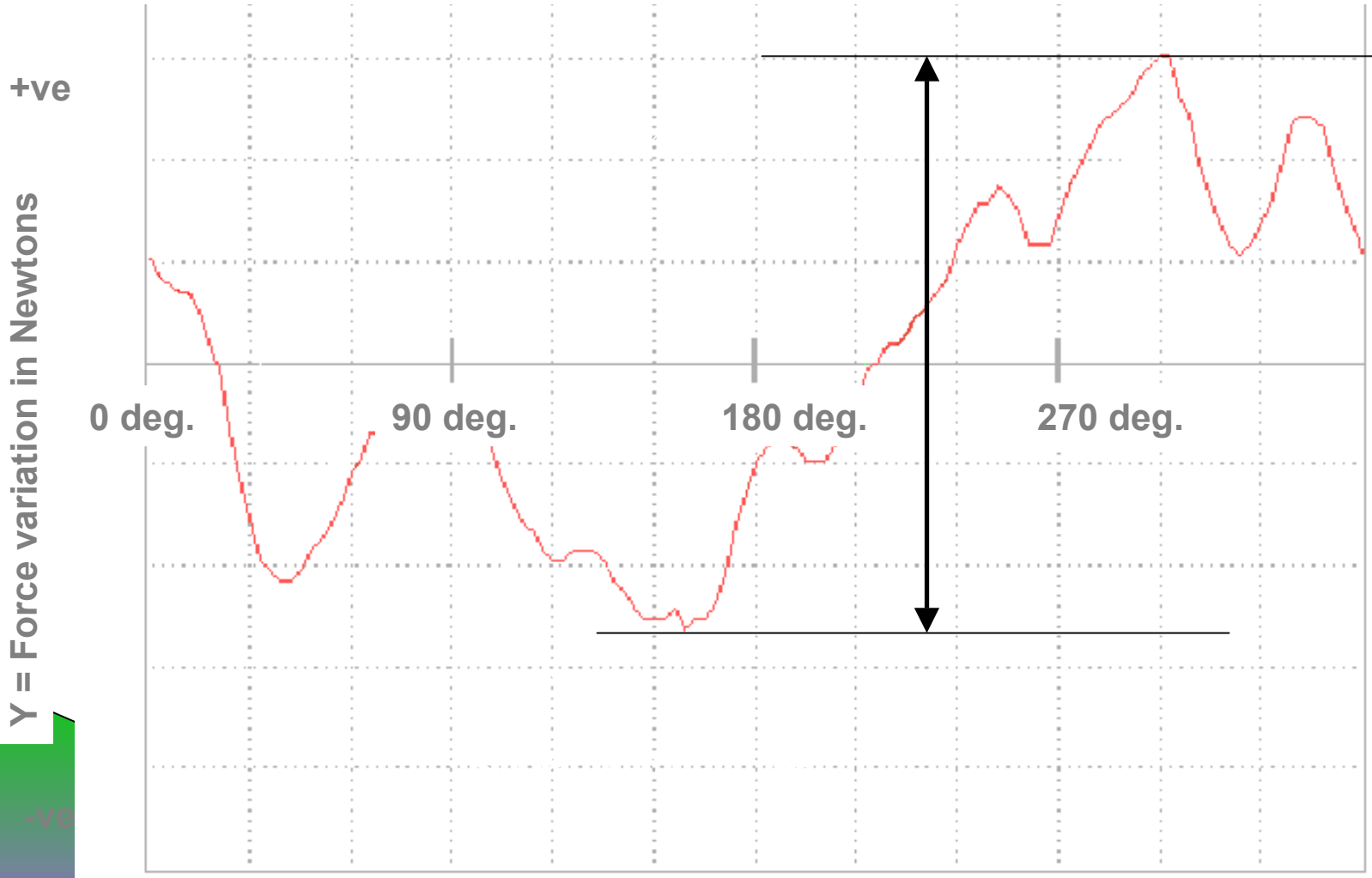


Measuring Radial Force Variation on a Uniformity M/c contd...



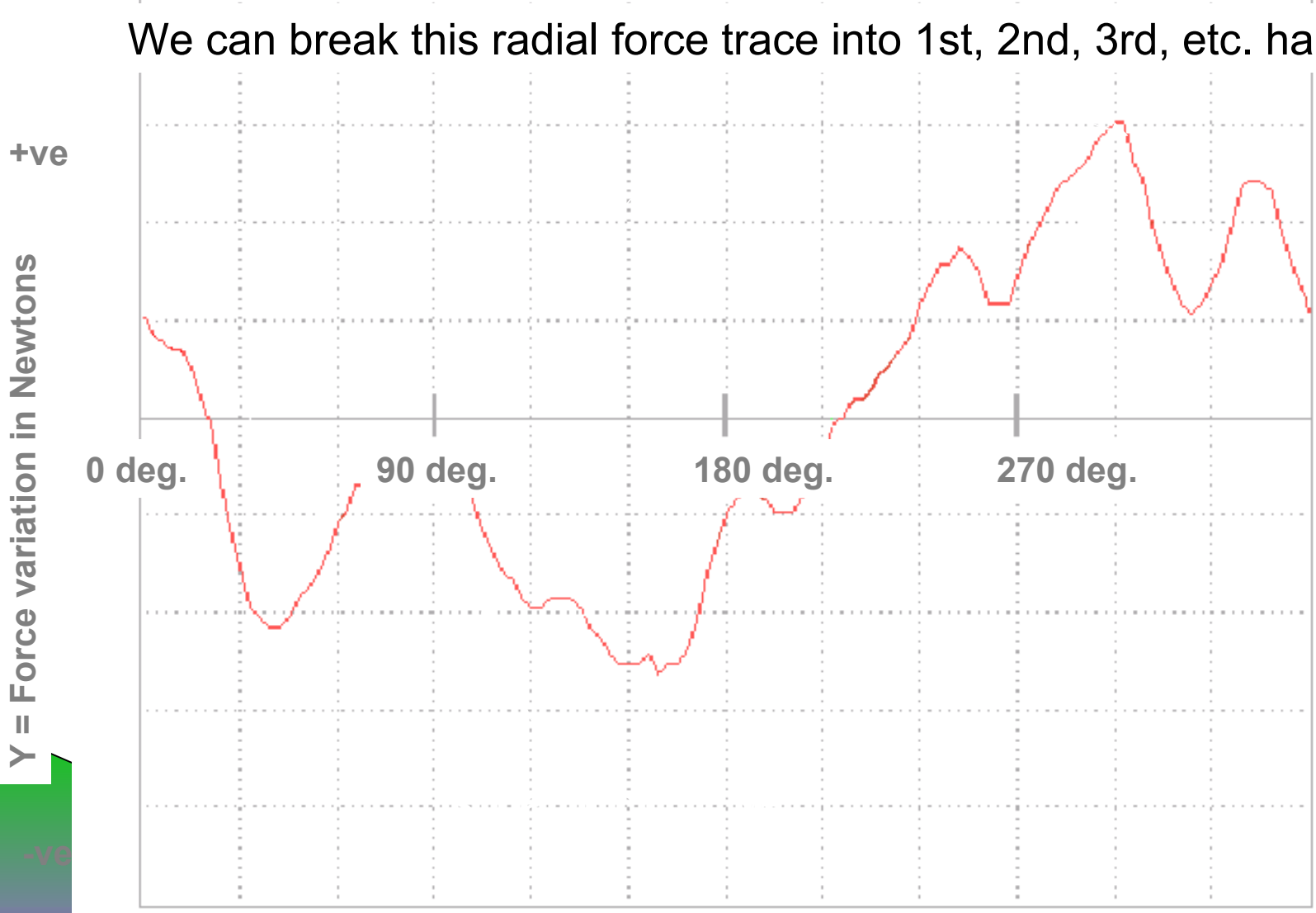
Measuring Radial Force Variation on a Uniformity M/c contd...

The radial force variation of the tyre is the “peak to peak” value…



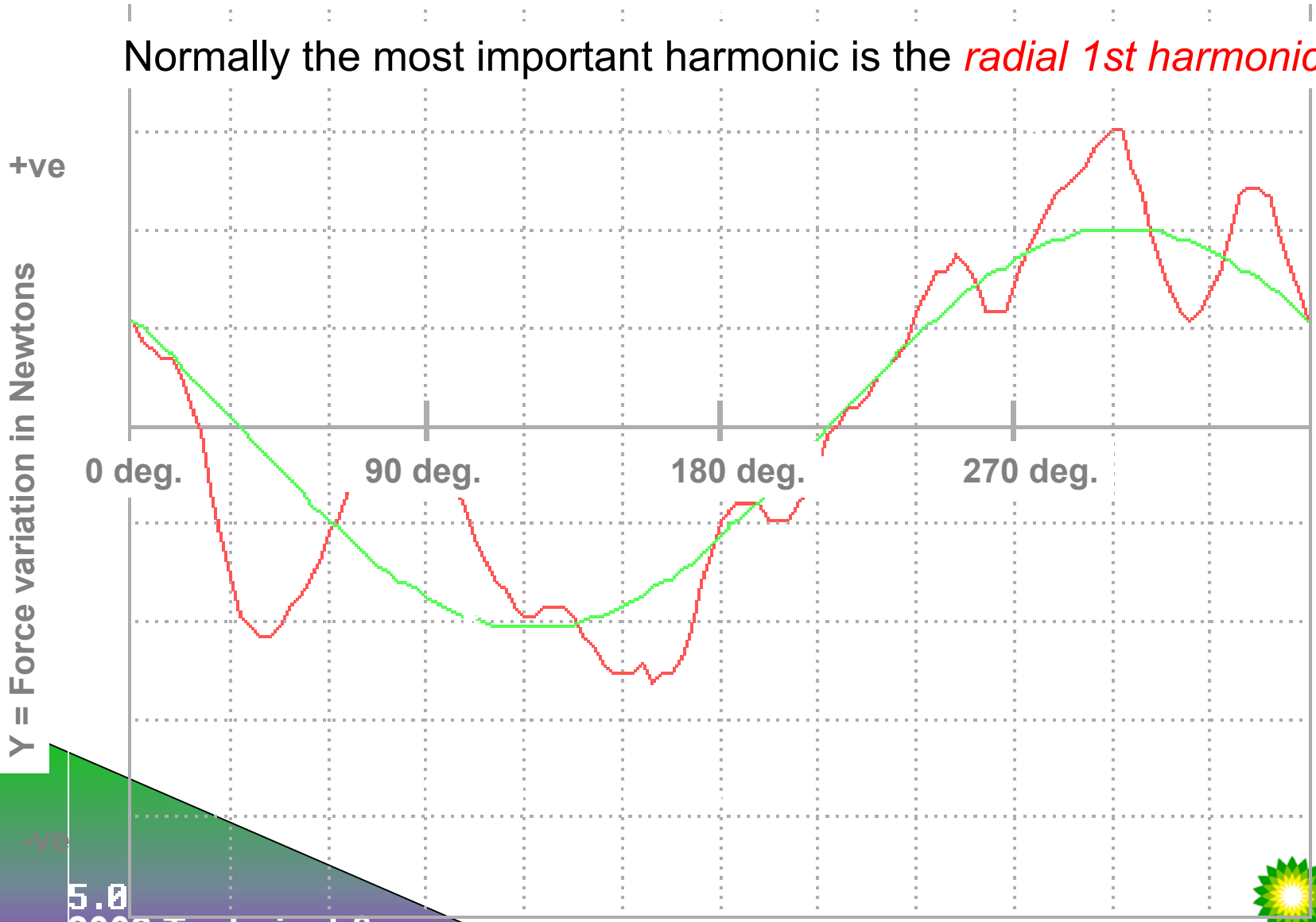
Measuring Radial Force Variation on a Uniformity M/c contd...

We can break this radial force trace into 1st, 2nd, 3rd, etc. harmonics…



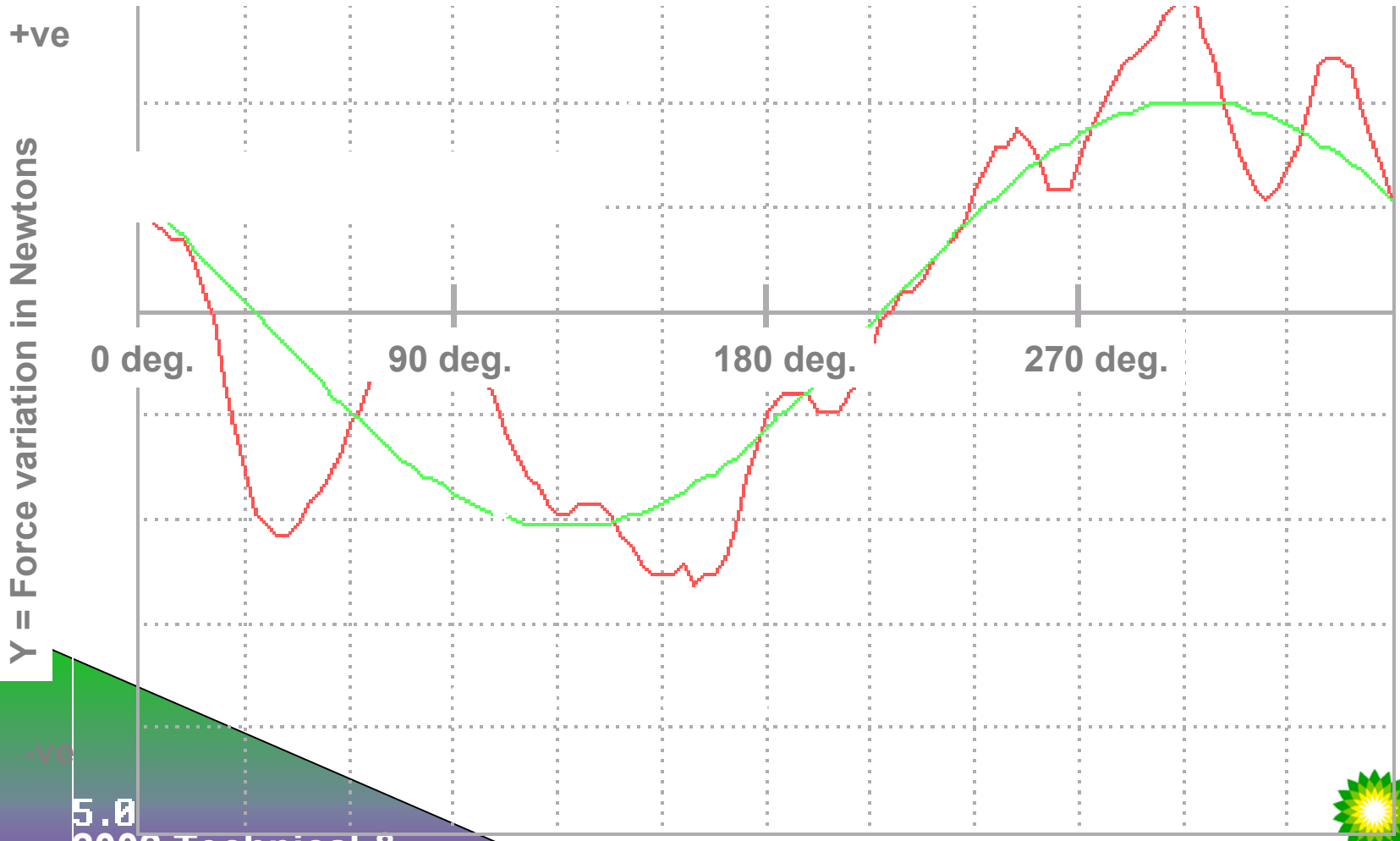
1st Harmonic of Radial Force Variation

Normally the most important harmonic is the *radial 1st harmonic…*



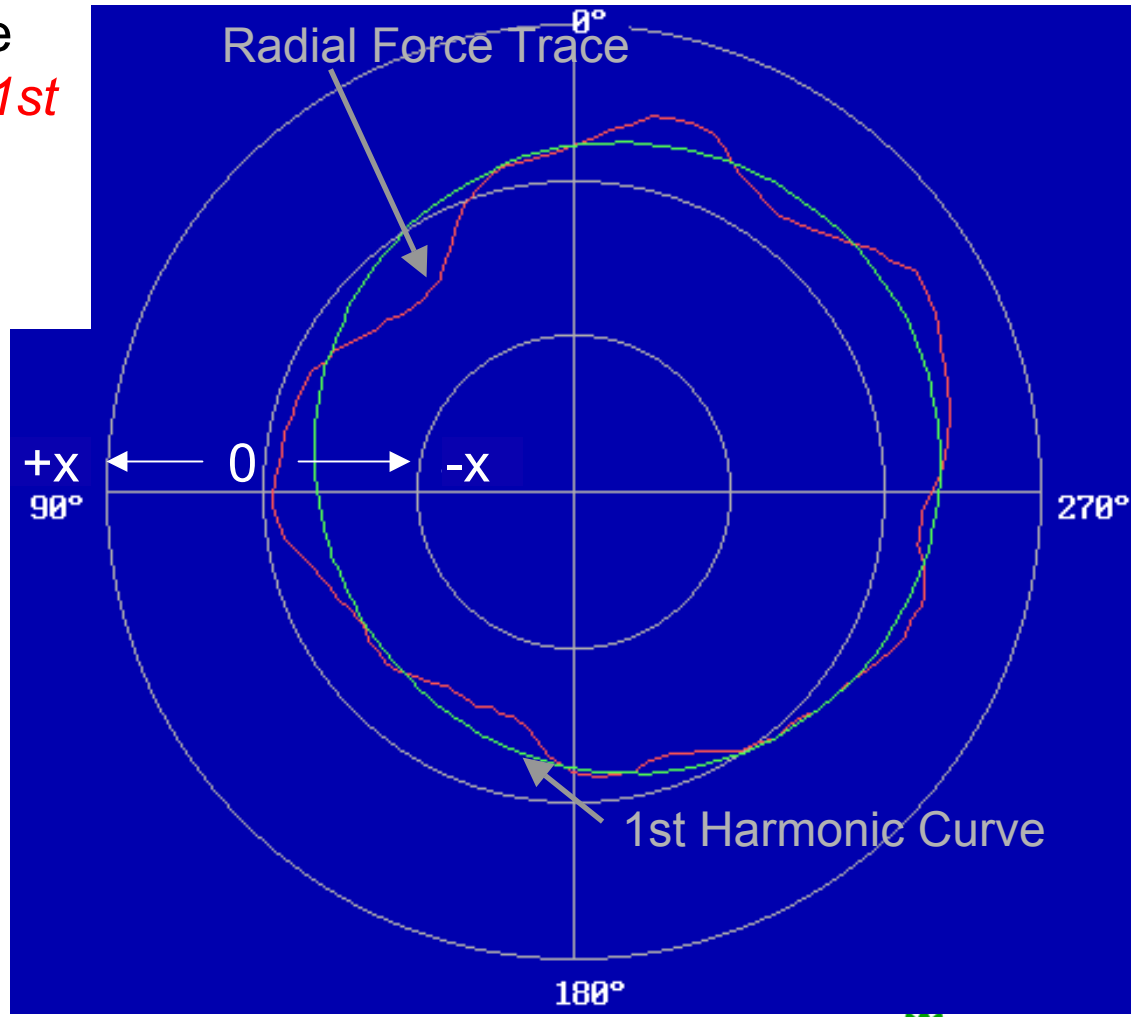
1st Harmonic of Radial Force Variation contd...

The tyre wheel assembly will give one up and down input per rotation
(Even though **unloaded** the tyre and wheel may be perfectly round)



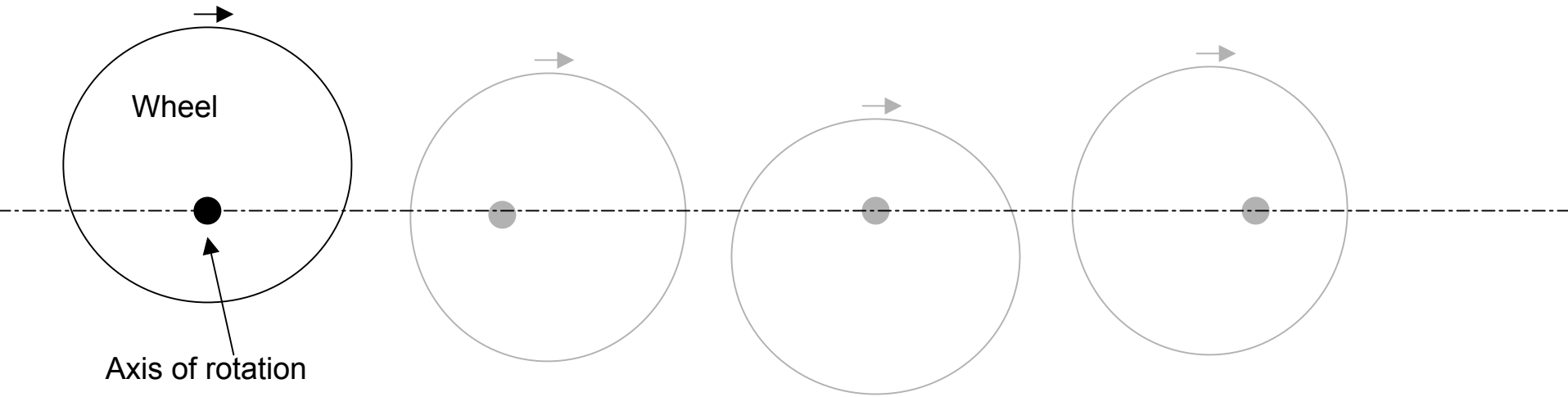
Polar Representation contd...

Another way of looking at the radial force trace and *radial 1st harmonic* *is in polar form*….



Where X is a value in N (Newtons)

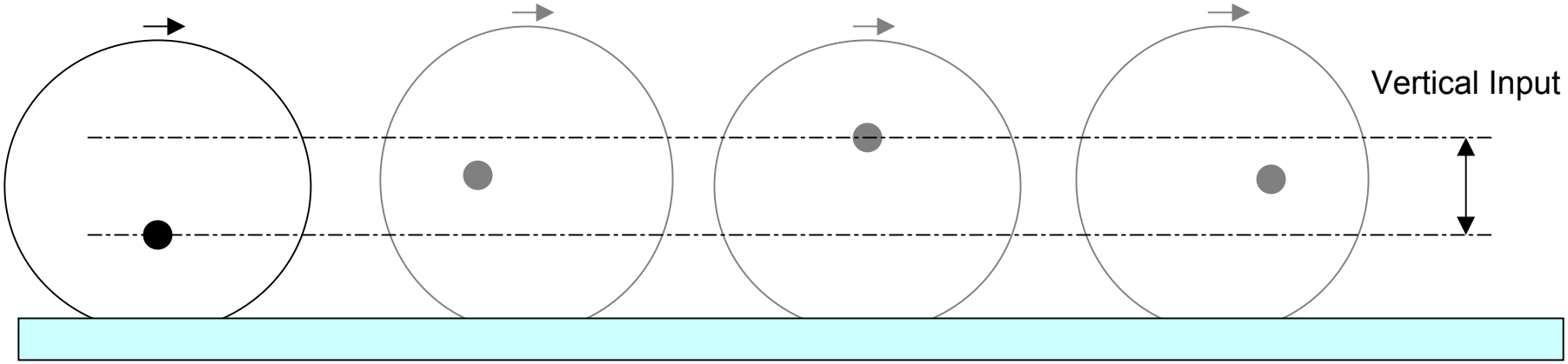
1st Harmonic Inputs contd...



In the previous examples we have looked at tyre variations only

Now consider a wheel and tyre assembly **without any variation** bolted up *non-concentrically.* It will have a radial force trace that is a perfect 1st harmonic curve.

1st Harmonic Inputs contd...



So effectively stiffness variation can be created with a perfect tyre if...

- its mounted on a non concentric wheel and hub
- its mounted on a non concentric spider and rim
- its mounted incorrectly -
  (where the tyres bead is not correctly seated on the rim bead seat)

Can Radial Force Variation be Eliminated / or Reduced In a Wheel and tyre Assembly?

Tyres

All tyres have some non uniformity in them due to the materials and processes used in their manufacture this variation does not normally affect trucks.

However the following actions will assist…

- Keep tyre inflation pressures up as this reduces tyre deflection This reduces variation.
- When fitting tyres they should be dual inflated on rims with an ATMA approved bead lube to ensure beads are seated correctly
- Use tyres from a reputable manufacturer

Can Radial Force Variation be Eliminated / or Reduced In a Wheel and tyre Assembly?

Wheels

Disc wheels with low radial run-out should be used where possible and should be bolted up...

- concentrically
- using the correct tightening pattern
- using a torque wrench

(Spiders / rims inherently more difficult to achieve concentricity)

Brief Summary...

Today's presentations have talked about...

1. Radial stiffness, radial force variation and the radial 1st harmonic component

2. How this effect can be induced by non concentricity of wheel / axle components

3. How these force variations result in vertical inputs to axles

4. At certain speeds this may be contributing to diagonal wipe wear on this size of tyre

What Else Can Be Done to Reduce Diagonal Wear...

1. Shock absorbers should be hot after a decent run as they convert vibration to heat whilst dampening the wheel tyre oscillation
   If they are cool or cold then they are not working but worse the tyre is trying to do that job as well

2. New and worn tyres or different tyre brands should not be used together as duals.
   If duals are mismatched then one tyre carries all the load and the other has a smaller footprint which leads to skipping or drag
   This can lead to rapid or irregular wear
   This also applies to pressure differences

3. Changing to a tyre of different size (outside diameter) will cause it to have a different 1st harmonic frequency at the critical speed
   This may eliminate or reduce the axle tramp induced irregular wear

Thanks for listening !

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