How Smooth is Smooth Enough?

September 28, 2011

Steve Karamihas

Introduction

- We don’t know.
- We must consider:
  - Cost
  - Roughness progression
  - Other quality considerations
  - Human perception of ride quality
  - Other sources of vehicle disturbance
  - Other vehicle responses

Outline

- Automobile ride quality
- Tire imbalance
- Truck dynamic loads
- Conclusions

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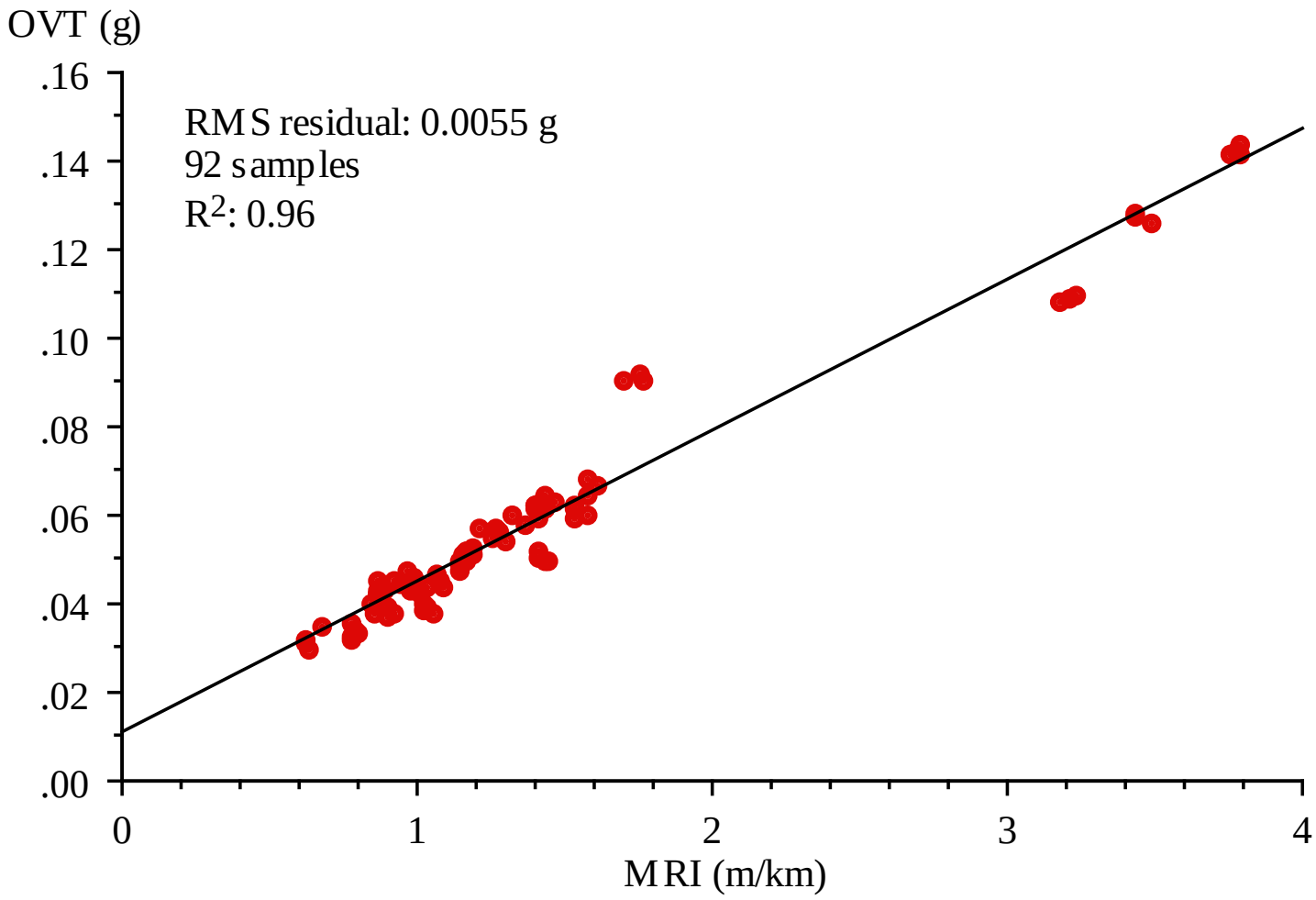
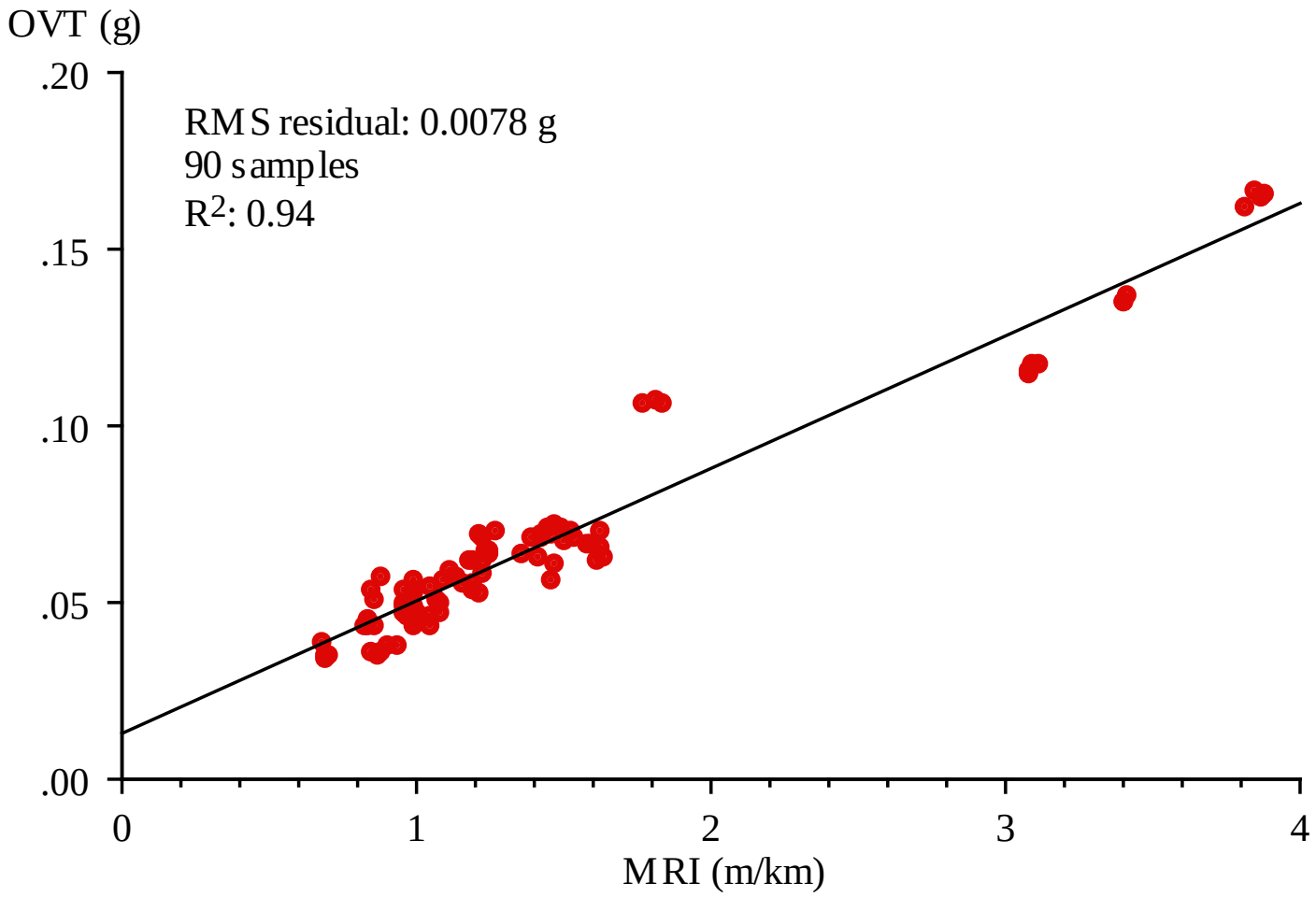
Ride Quality: 2003 Altima

Seat/Buttock and Seat/Back

Relationship to the IRI, 60-65 mph



Relationship to the IRI, 70-75 mph



Quarter-Car Model

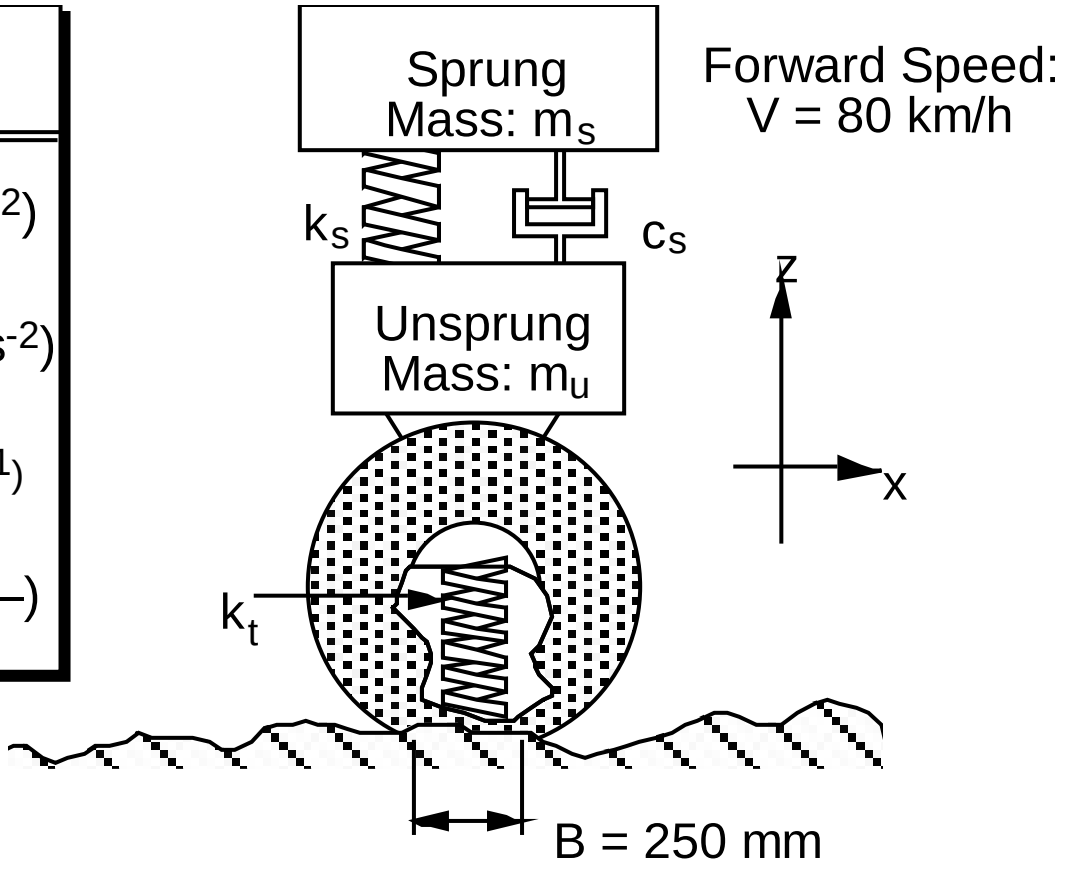
Golden Car Parameters

$\frac{k_t}{m_s} = k_1 = 653\ (s^{-2})$

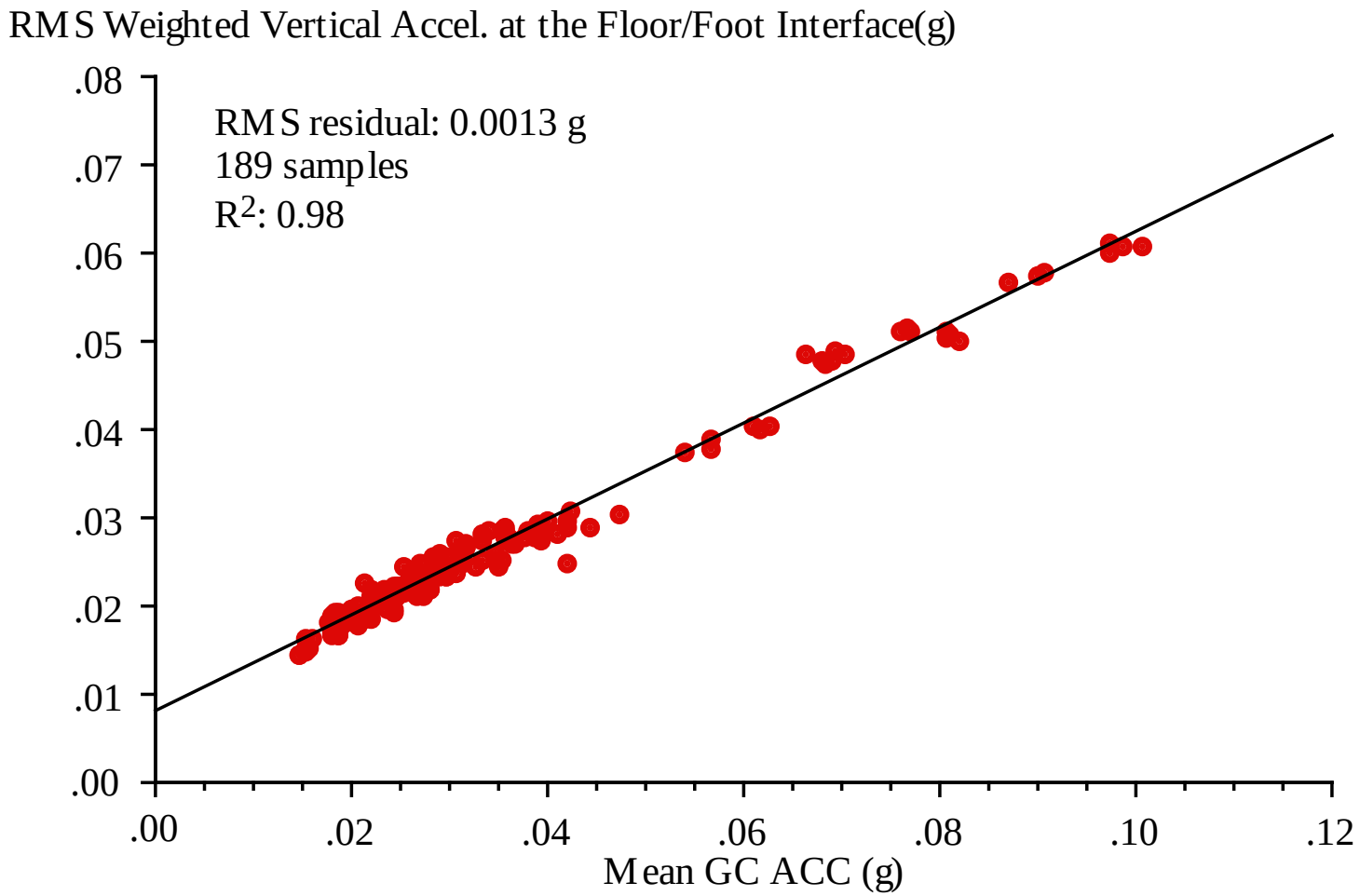
$\frac{k_s}{m_s} = k_2 = 63.3\ (s^{-2})$

$\frac{c_s}{m_s} = c_2 = 6.0\ (s^{-1})$

$\frac{m_u}{m_s} = \mu = 0.15\ (—)$



Relationship to “Golden Car”



Human Reaction

Likely Reaction	Midsize vehicle		Luxury SUV	
	60-65 mph	70-75 mph	60-65 mph	70-75 mph
not uncomfortable	< 39	< 33	< 44	< 44
a little uncomfortable	39 – 99	33 – 87	44 – 122	44 – 122
fairly uncomfortable	75 – 169	65 – 151	90 – 214	90 – 212
uncomfortable	131 – 283	116 – 254	165 – 364	163 – 359
very uncomfortable	217 – 454	194 – 409	276 – 587	273 – 579
extremley uncomfortable	> 359	> 323	> 463	> 457

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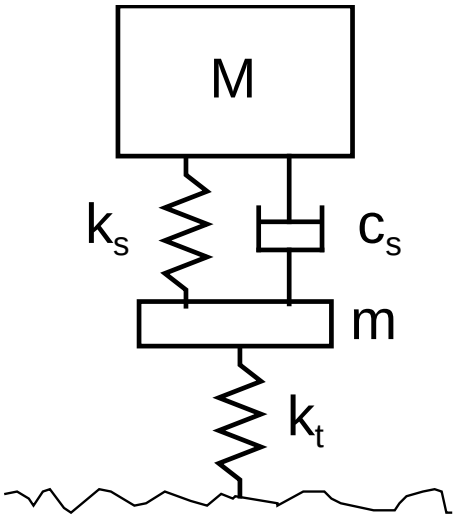
Tire Imbalance

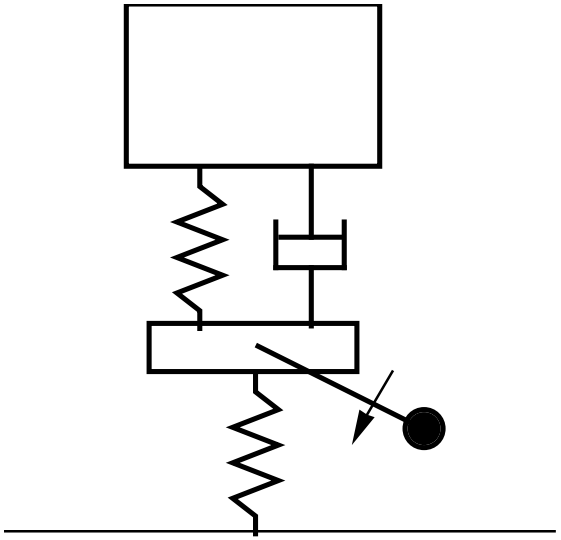


M	body mass
m	axle mass
k_s	suspension stiffness
c_s	suspension damping
k_t	tire stiffness

$$\begin{bmatrix} M & 0 \\ 0 & m \end{bmatrix} \begin{Bmatrix} \ddot{z}_s \\ \ddot{z}_u \end{Bmatrix} + \begin{bmatrix} c_s & -c_s \\ -c_s & c_s \end{bmatrix} \begin{Bmatrix} \dot{z}_s \\ \dot{z}_u \end{Bmatrix} +$$

$$\begin{bmatrix} k_s & -k_s \\ -k_s & k_s + k_t \end{bmatrix} \begin{Bmatrix} \ddot{z}_s \\ \ddot{z}_u \end{Bmatrix} = \begin{Bmatrix} 0 \\ k_t \end{Bmatrix} z_r(t)$$

Tire Imbalance



V	forward speed
R	rolling radius
r	imbalance radius
m_b	imbalance mass

$$\begin{bmatrix} M & 0 \\ 0 & m \end{bmatrix} \begin{Bmatrix} \ddot{z}_s \\ \ddot{z}_u \end{Bmatrix} + \begin{bmatrix} c_s & -c_s \\ -c_s & c_s \end{bmatrix} \begin{Bmatrix} \dot{z}_s \\ \dot{z}_u \end{Bmatrix} +$$

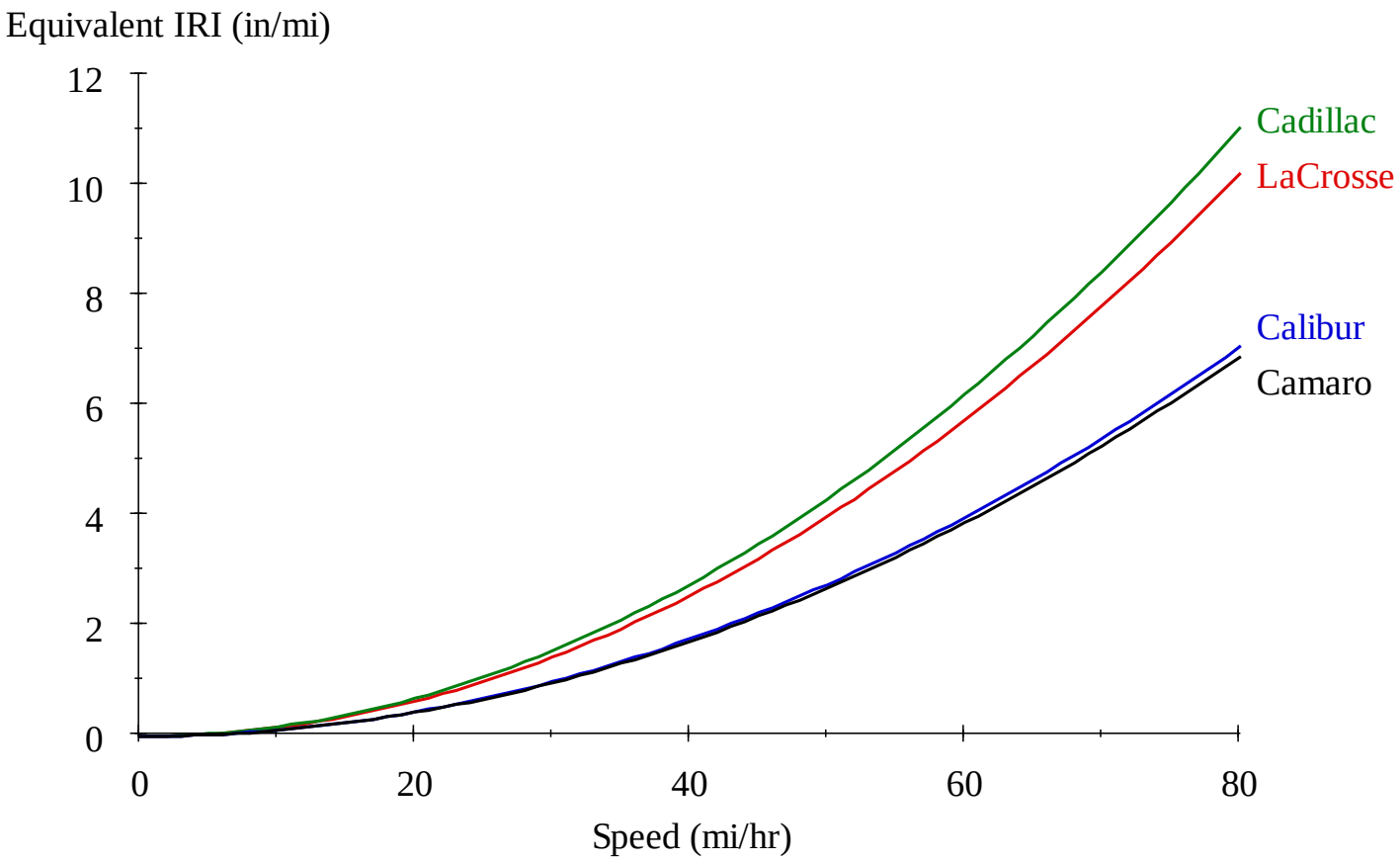
$$\begin{bmatrix} k_s & -k_s \\ -k_s & k_s + k_t \end{bmatrix} \begin{Bmatrix} \ddot{z}_s \\ \ddot{z}_u \end{Bmatrix} = \begin{Bmatrix} 0 \\ m_b \frac{V^2}{R} \frac{r}{R} \sin\left(\frac{V}{R} t\right) \end{Bmatrix}$$

Tire Imbalance

$$k_t z_r(t) = m_b \frac{V^2}{R} \frac{r}{R} \sin\left(\frac{V}{R} t\right)$$

$$z_r(x) = \frac{1}{k_t} m_b \frac{V^2}{R} \frac{r}{R} \sin\left(\frac{x}{R}\right)$$

Equivalent IRI



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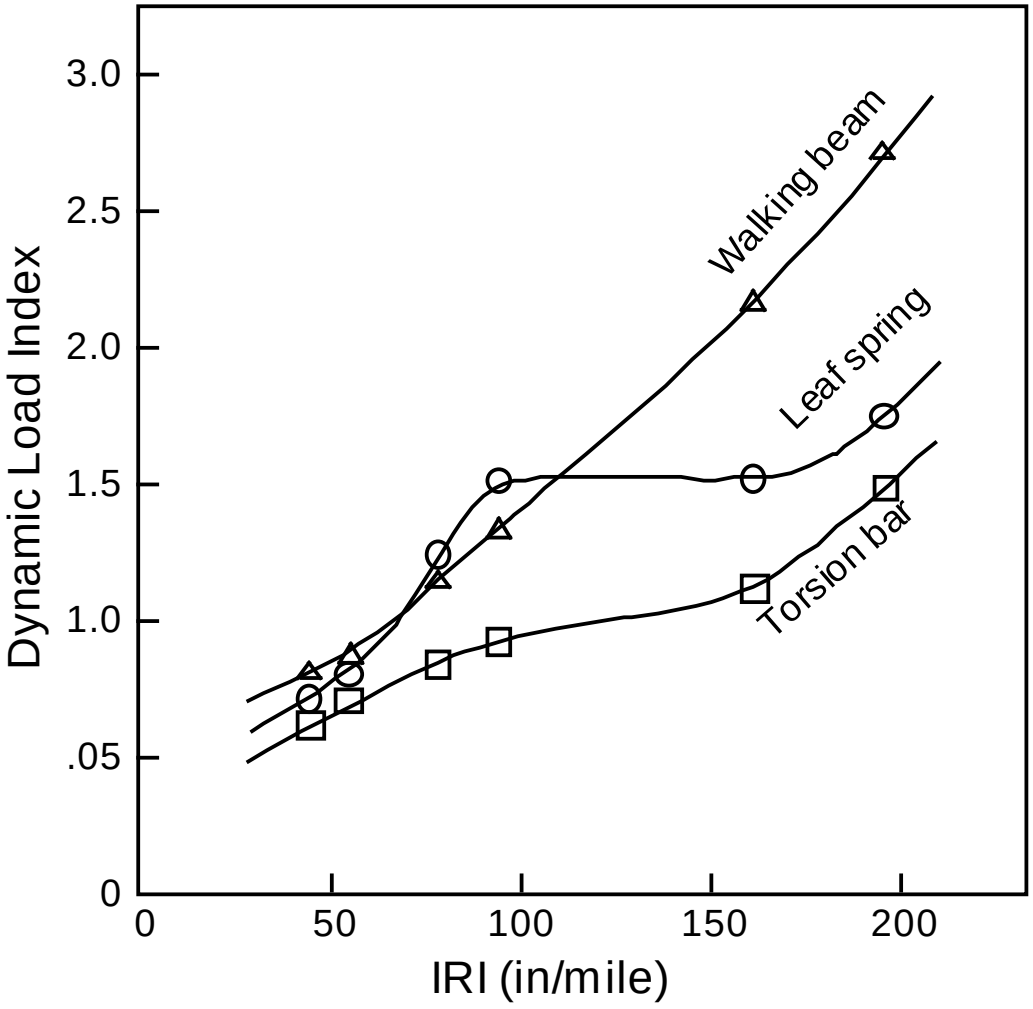
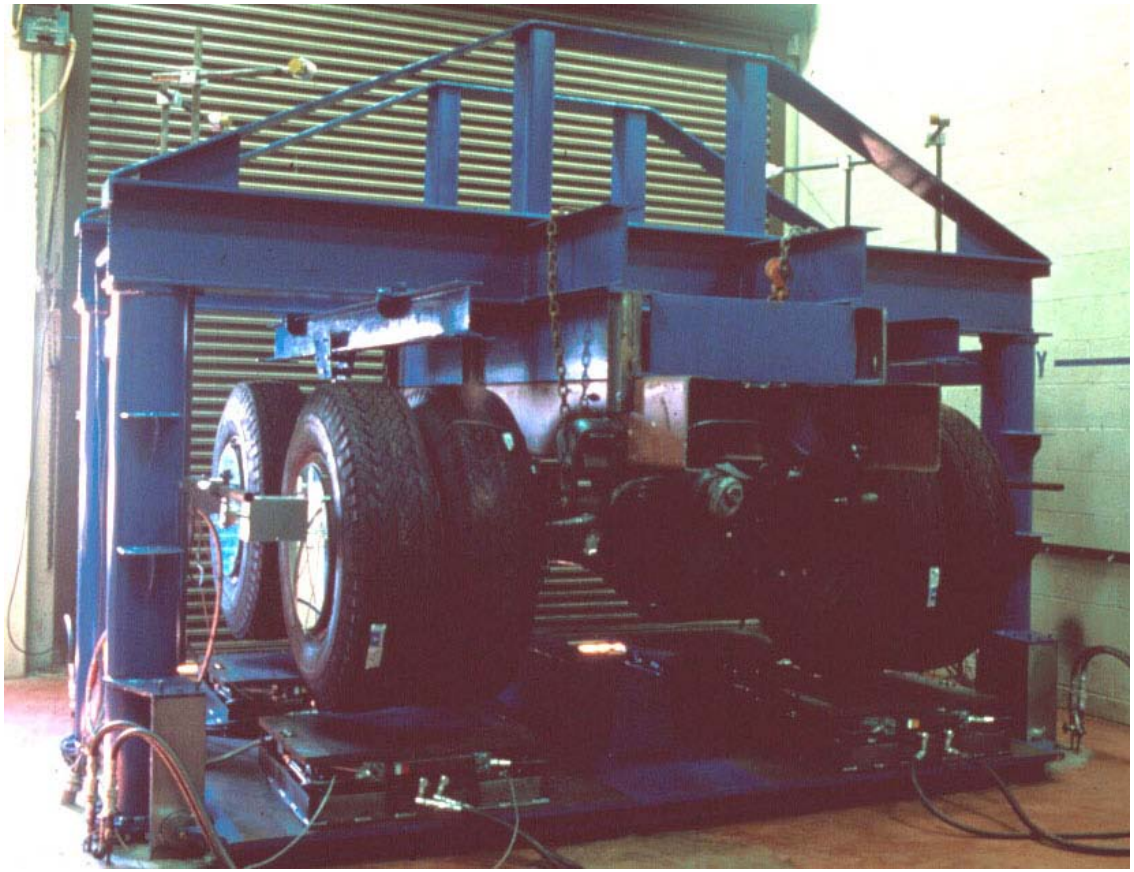
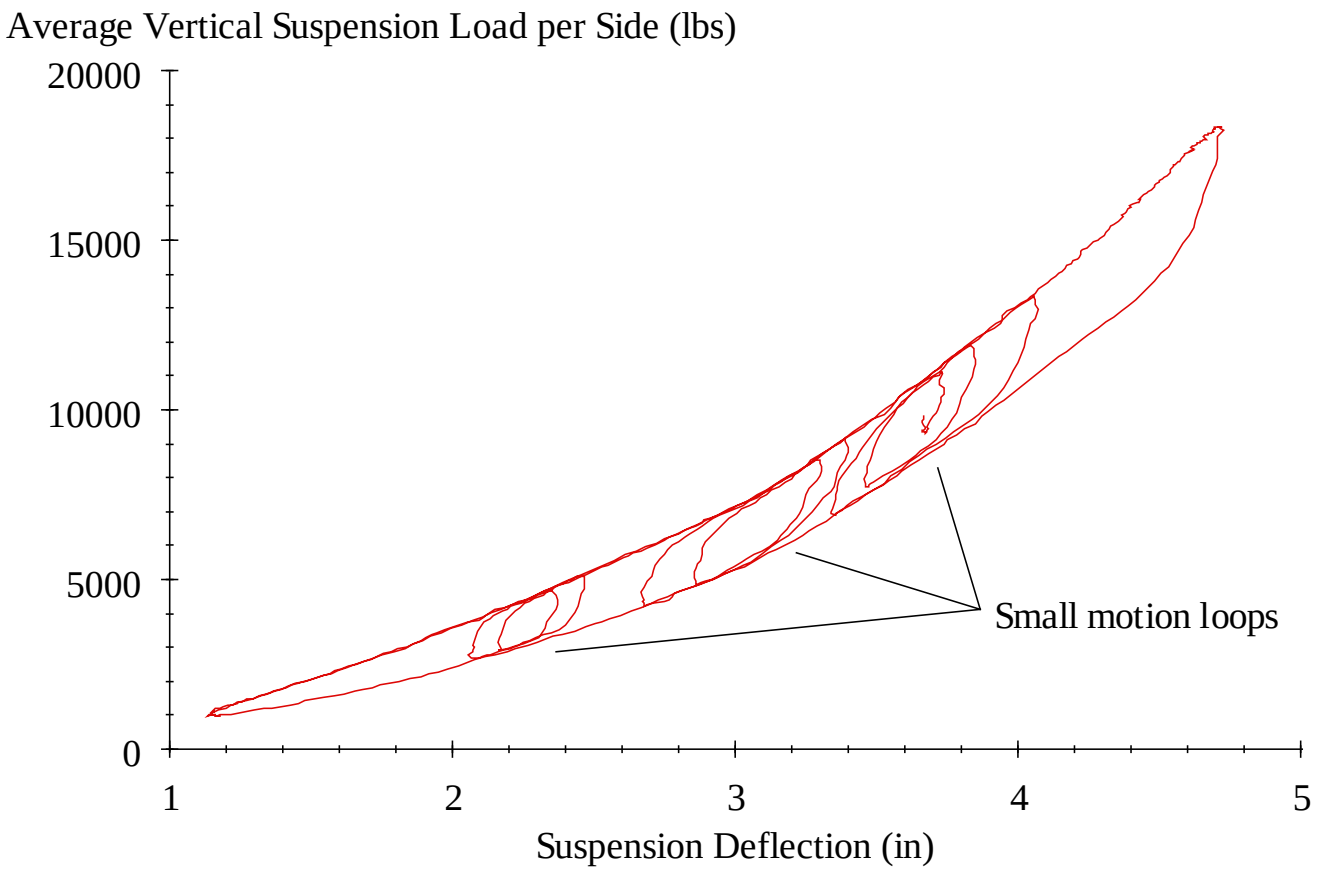
Truck Dynamic Loading



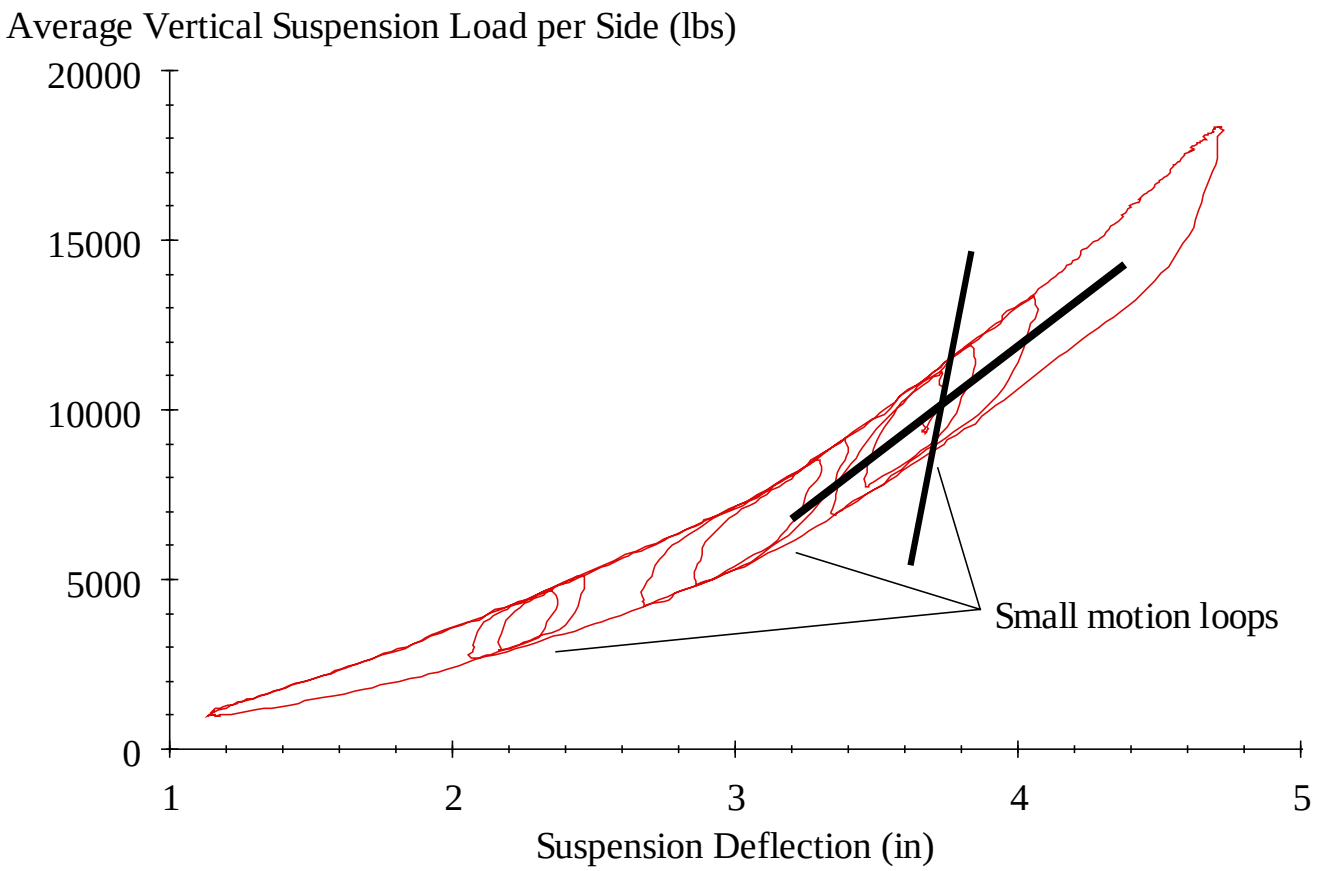
Truck Suspension Testing Rig



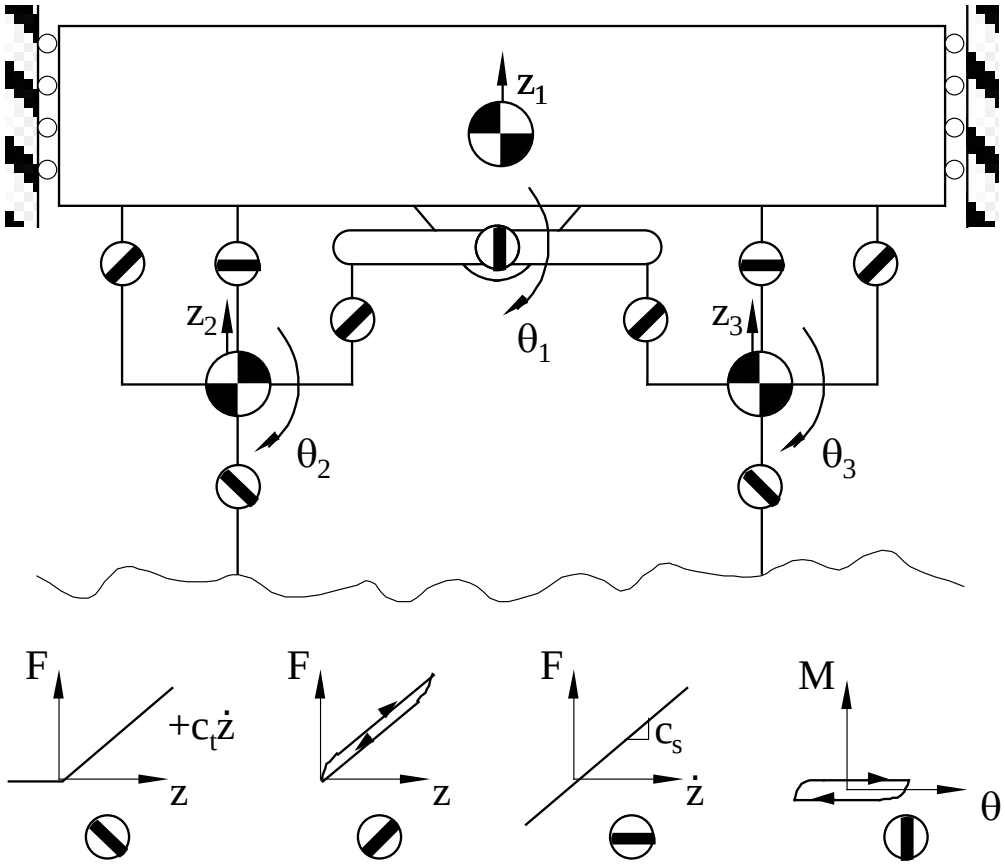
Truck Suspension Stiffness



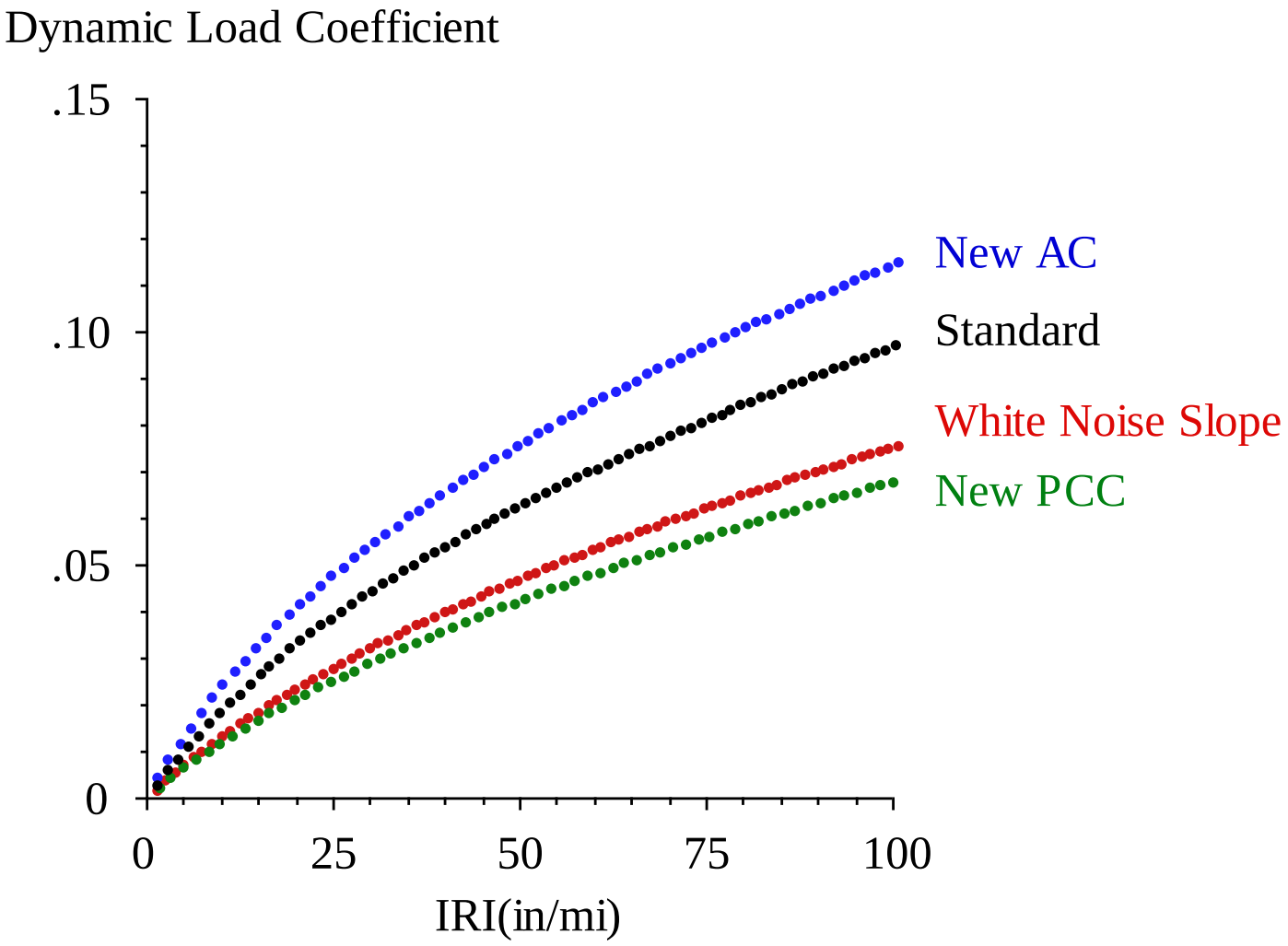
Truck Suspension Stiffness



Tandem Suspension Modeling



Truck Dynamic Loading



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- I don’t know.
- Neither do you.

Thank you.