9/10/2020

EICHER | TRUCKS AND BUSES

Development of Ride Comfort Model for 4x2 Tractor Trailer using MATLAB Simulink.

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VE COMMERCIAL VEHICLES
A VOLVO GROUP AND EICHER MOTORS JOINT VENTURE

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Ride Comfort Evaluation- ISO 2631

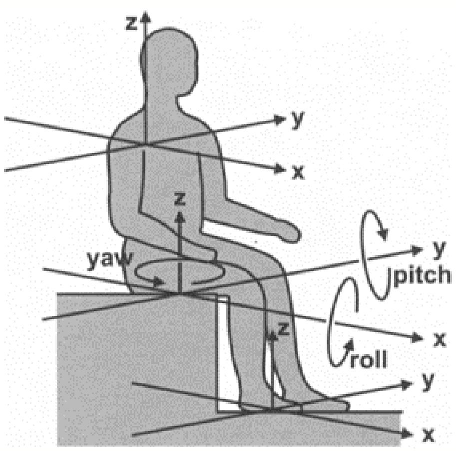
This defines methods for the measurement of periodic, random and transient whole body vibration.

• Frequency range:

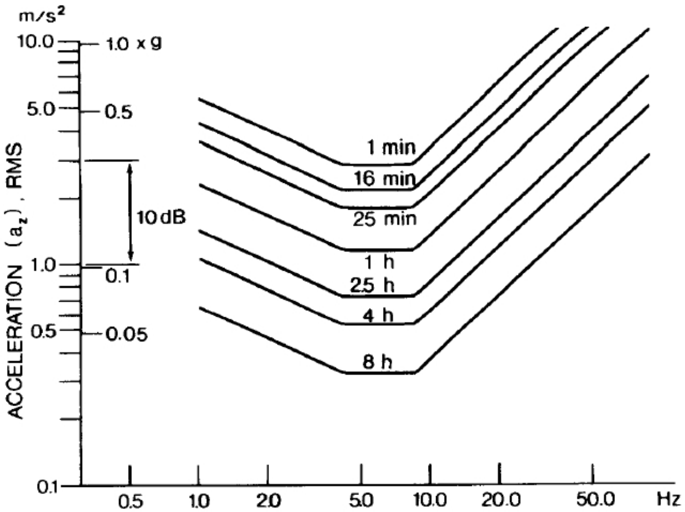
– 0.5 Hz to 80 Hz for health, comfort and perception

– 0.1 Hz to 0.5Hz for motion sickness

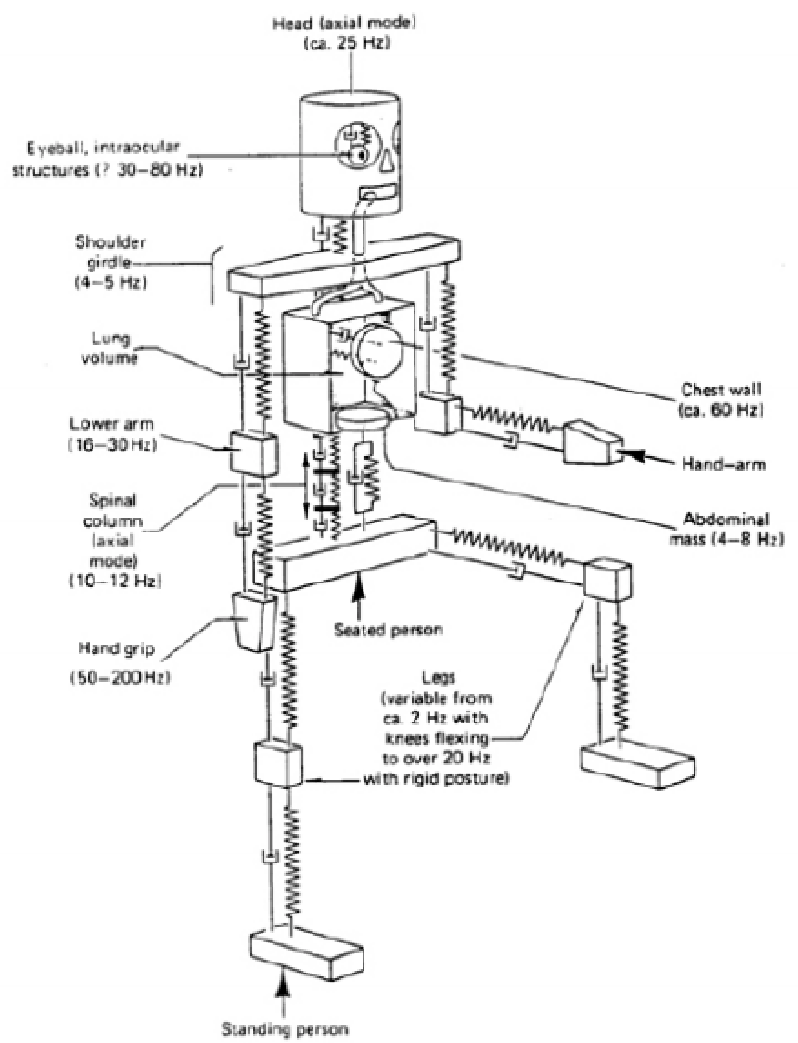
• Bi-centric Axes: ISO 2631 is applicable to motions transmitted to human body through supporting surfaces: the feet of standing person, the buttocks, back and feet of seated person and supporting area of recumbent person.



Measured Vibration (m/s^2)	Level of Comfort
Less than 0.315	Not Uncomfortable
0.315 to 0.63	A Little Comfortable
0.5 to 1	Fairly Uncomfortable
0.8 to 1.6	Uncomfortable
1.25 to 2.5	Very Uncomfortable
Greater than 2	Extremely Uncomfortable

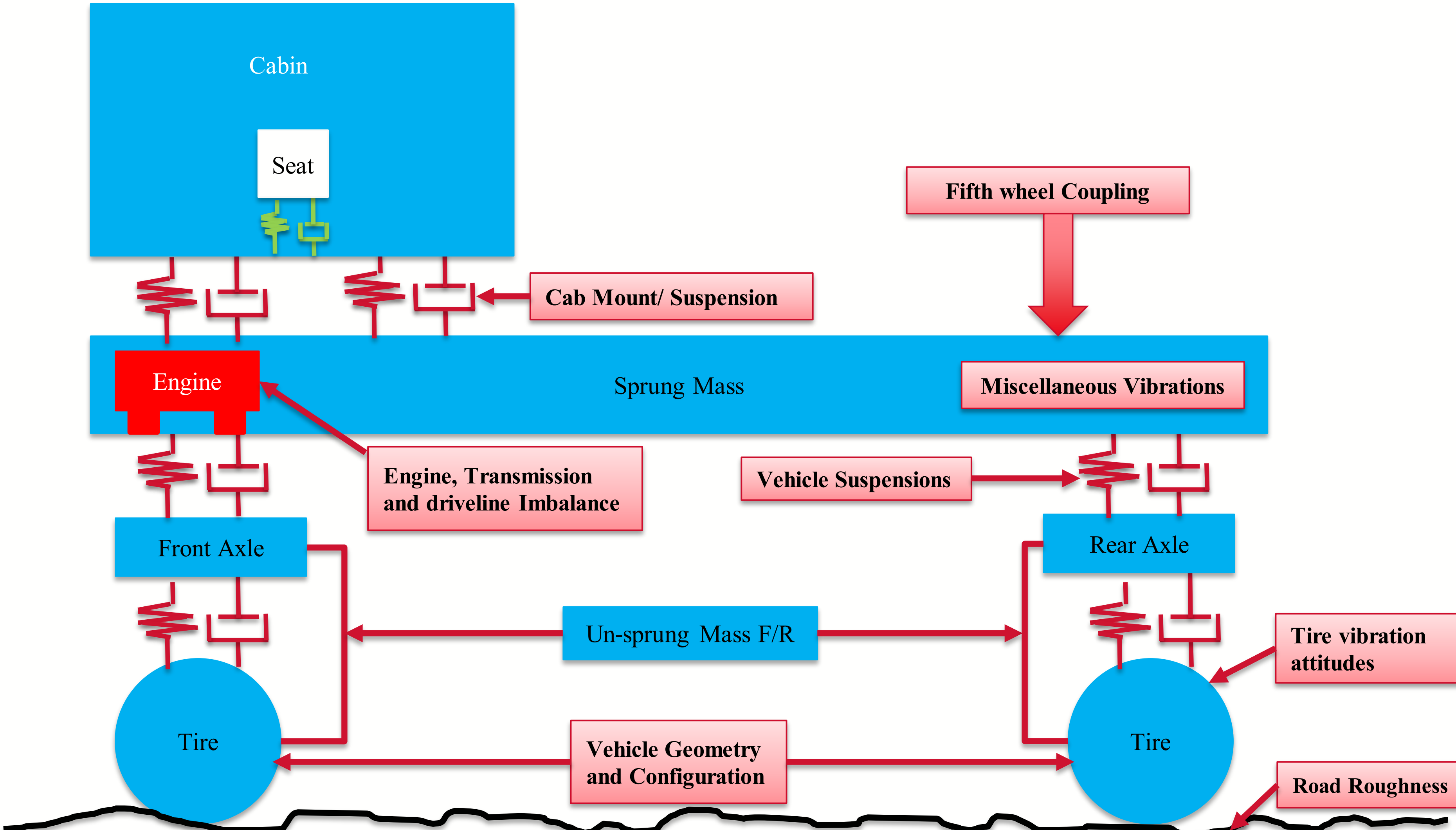


Whole Body Vibration



Frequency [Hz]	Effect
1-2	Dyspnoea (longitudinal vibration)
2	Head resonance for horizontal vibration
1-3	Max sensitiveness for respiratory apparatus
2-3	Resonance of shoulder – head
2-6	Resonance of the whole seated body
3-4	Abdominal problems
4-6	Resonance of thorax and abdomen
4-10	Progressive decrease of visual acuity
4-10	Changing in voice
6-10	Changing in arterial pressure, cardiac frequency and oxygen consumption
10-12	Sleepiness
13-15	Resonance of pharynx
13-20	Head resonance and augment of muscular tone
20-30	Max resonance of whole body with decrease of visual acuity
30-40	Vascular problems
30-90	Resonance of ocular globes
40-600	Resonance of skull
100-200	Resonance of jaw

Parameters Affecting Vibrations in Vehicle



Vehicle Details- 4x2TT

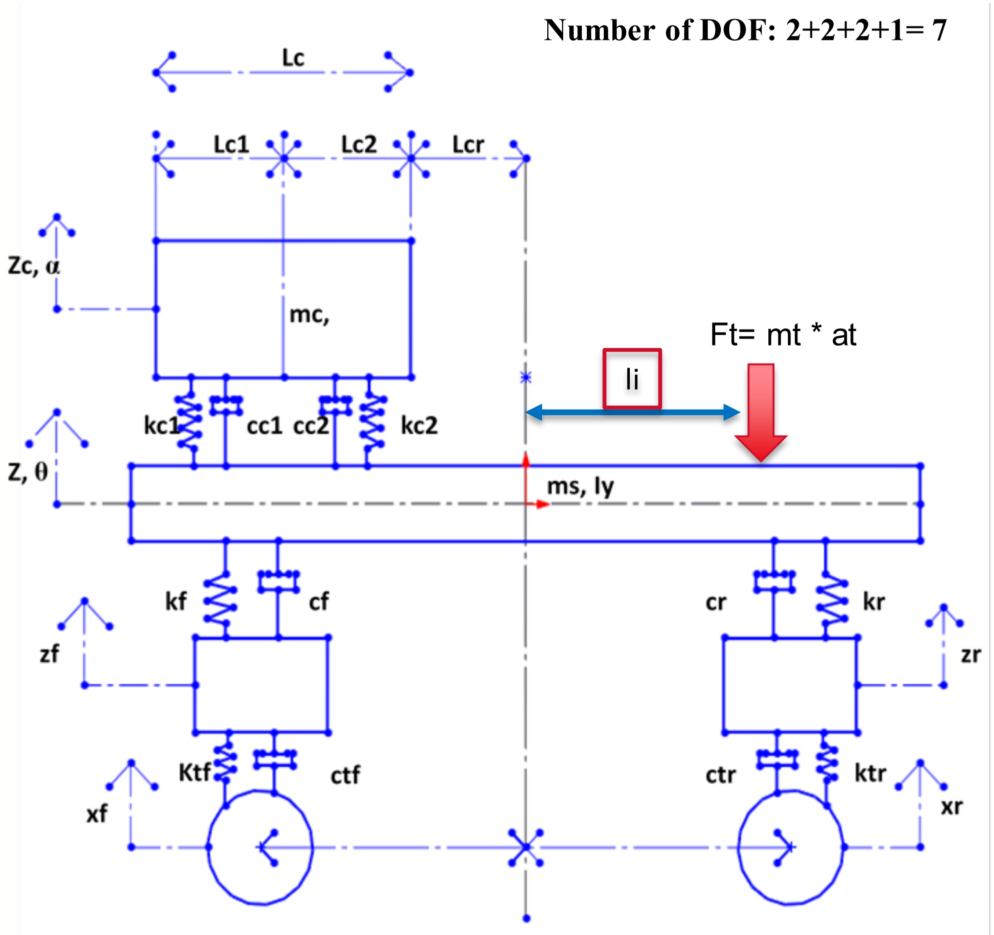
Inputs

SYMBOL	NAME	Units
ms	Sprung Mass	kg
mf	FA Unsprung Mass	kg
mr	RA Unsprung Mass	kg
mc	Cabin Mass	kg
L1	Distance of CG of Sprung mass from FA	m
L2	Distance of CG of Sprung mass from RA	m
Lc1	Distance of Cabin CG from Front cabin mounting	m
Lc2	Distance of Cabin CG from Rear cabin mounting	m
Lcr	Distance of Rear Cabin Mount from Sprung mass CG	m
Iy	Moment of Inertia of Sprung Mass	kg-m^2
Ic	Moment of Inertia of Cabin	kg-m^2
kf	Front Spring Stiffness	N/m
kr	Rear Spring Stiffness	N/m
ktf	Front Tyre Radial Stiffness	N/m
ktr	Rear Tyre Radial Stiffness	N/m
kc1	Front Cabin Mount Stiffness	N/m
kc2	Rear Cabin Mount Stiffness	N/m
cf	Front Damping	N-s/m
cr	Rear Damping	N-s/m
ctf	Front Tyre Damping	N-s/m
ctr	Rear Tyre Damping	N-s/m
cc1	Front Cabin Mount Damping	N-s/m
cc2	Rear Cabin Mount Damping	N-s/m
xrf	FA Excitation	m or m/s^2
xrr	RA Excitation	m or m/s^2

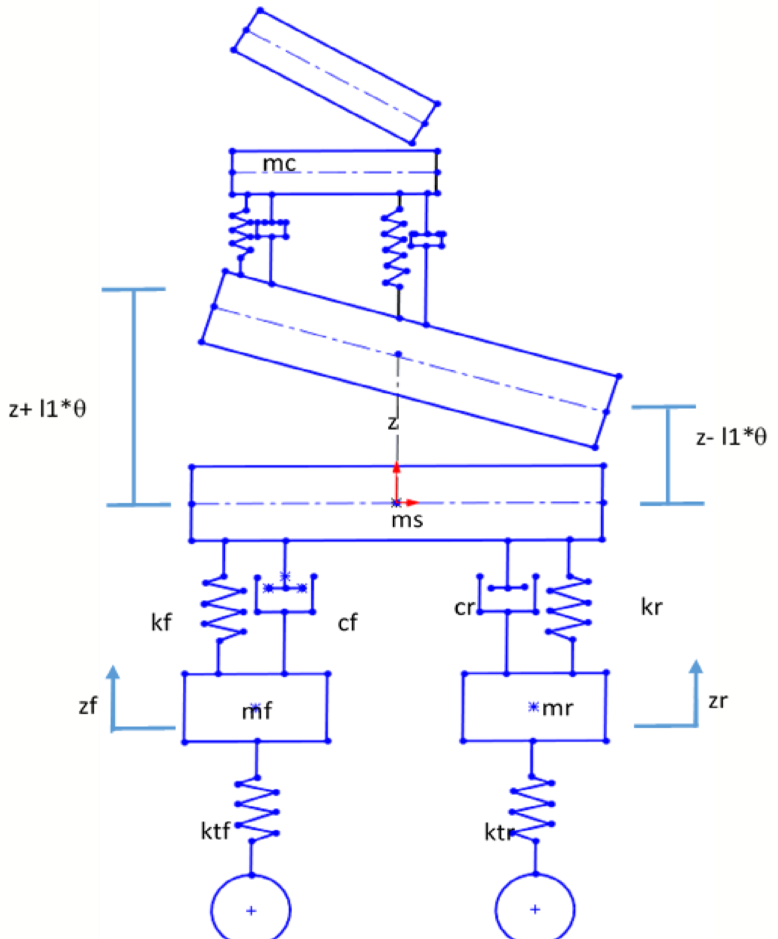
Outputs

Symbol	Name	Units
z	Sprung Mass Bounce	m
$\ddot{z}$	Sprung Mass Bounce Acceleration	m/s^2
θ	Sprung Mass Pitch	rad/ deg
$\ddot{\theta}$	Sprung Mass Pitch Acceleration	m/s^2
zc	Cabin Bounce	m
$\ddot{z}c$	Cabin Bounce Acceleration	m/s^2
α	Cabin Pitch	rad/ deg
$\ddot{\alpha}$	Cabin Pitch Acceleration	m/s^2
f	Sprung Mass Bounce Frequency	Hz
fc	Cabin Bounce Frequency	Hz

Mathematical Modelling of 4x2 Tractor

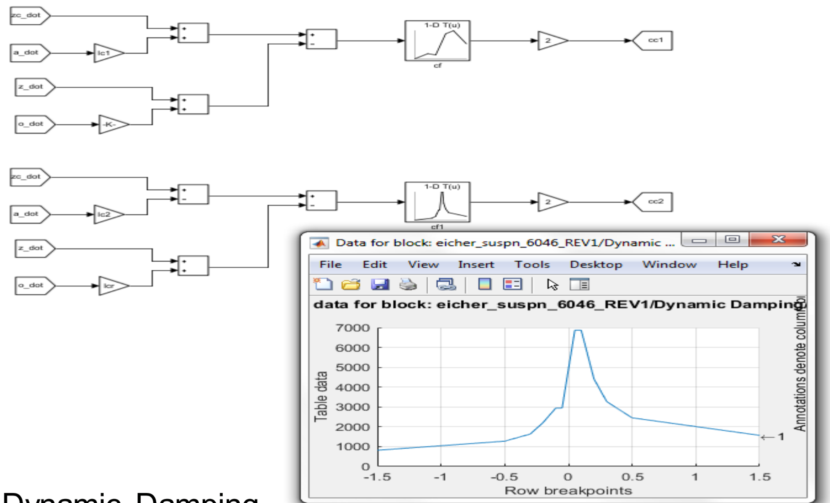


Static Condition

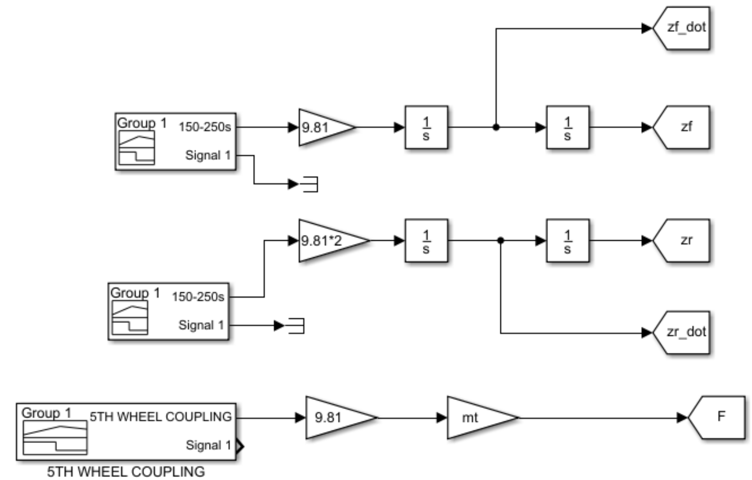


Dynamic Condition

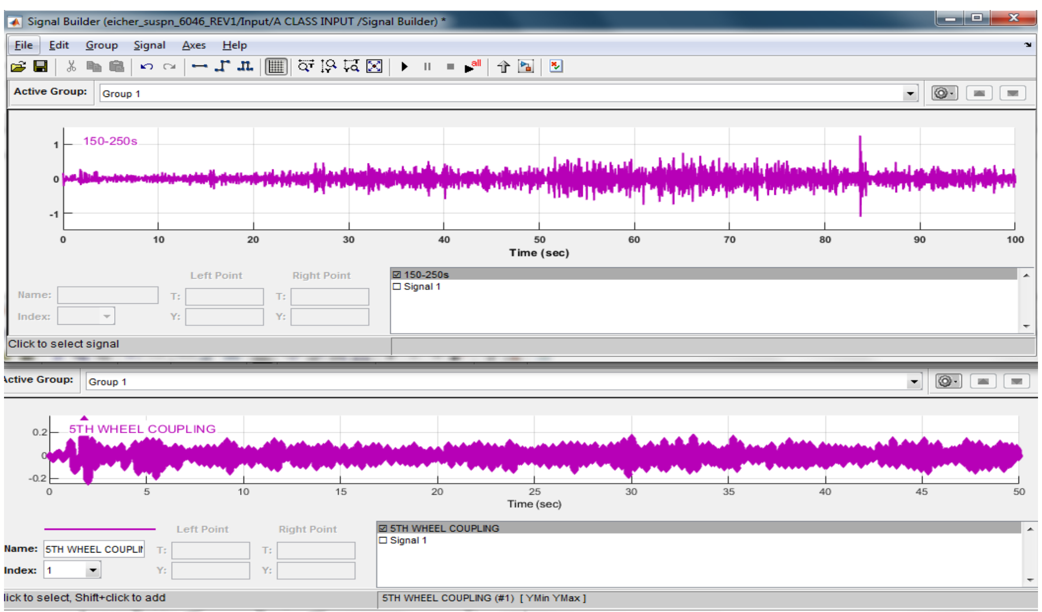
Input Parameters



Dynamic Damping



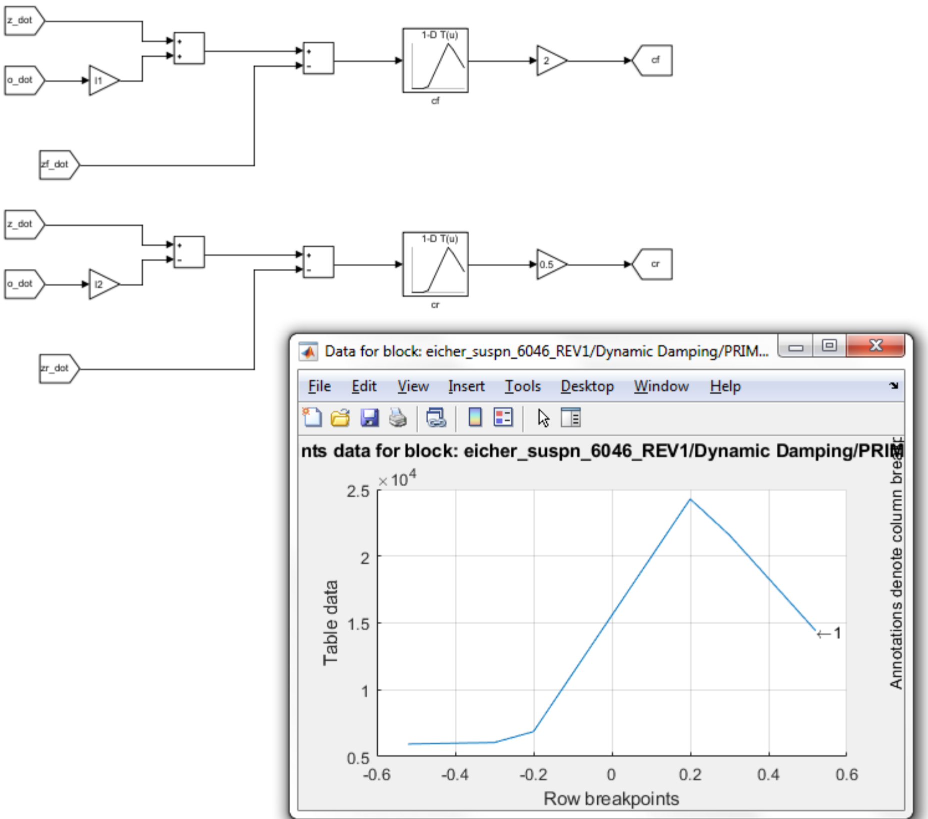
Input conditions for Cement Road



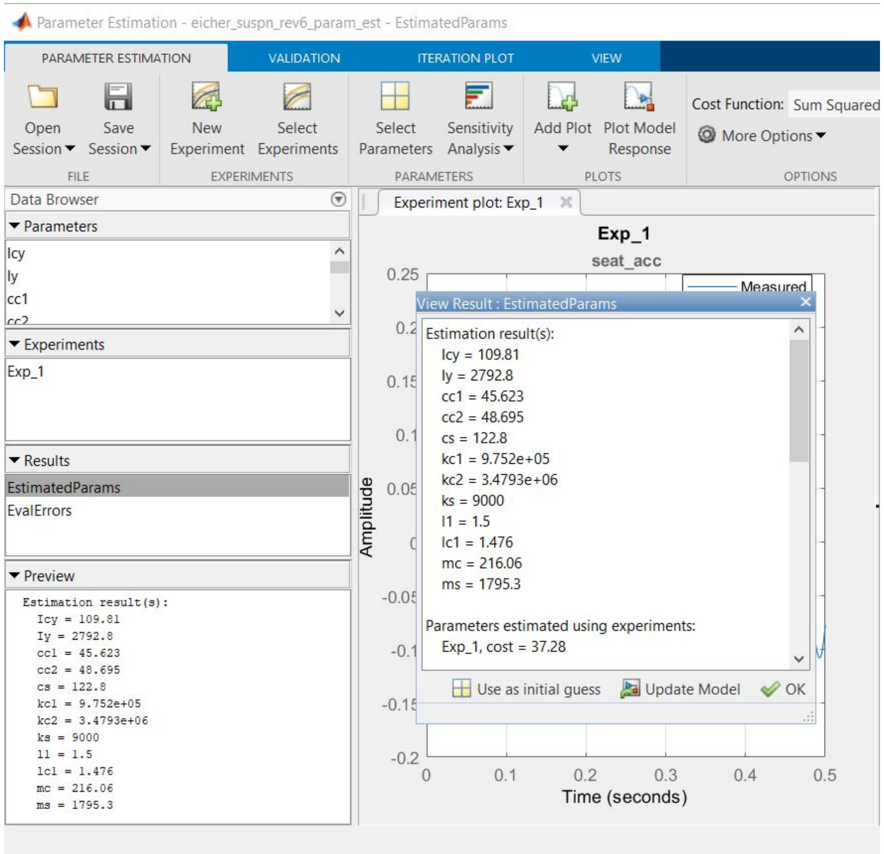
Road Input from A Class Road & 5th Wheel Coupling

Sensor Mtg. Location	No. of Sensors
Front Axle	2 (LH+RH)
Rear Axle	2 (LH+RH)
Chassis- Above Front Suspension	2 (LH+RH)
Chassis- Above Rear Suspension	2 (LH+RH)
Fifth Wheel Coupling	1
Cabin Floor	1 (Below Driver Seat)
Driver Seat	2 (Driver+ Co Driver)

Parameter Estimation & Look-up Tables for Dynamic Input

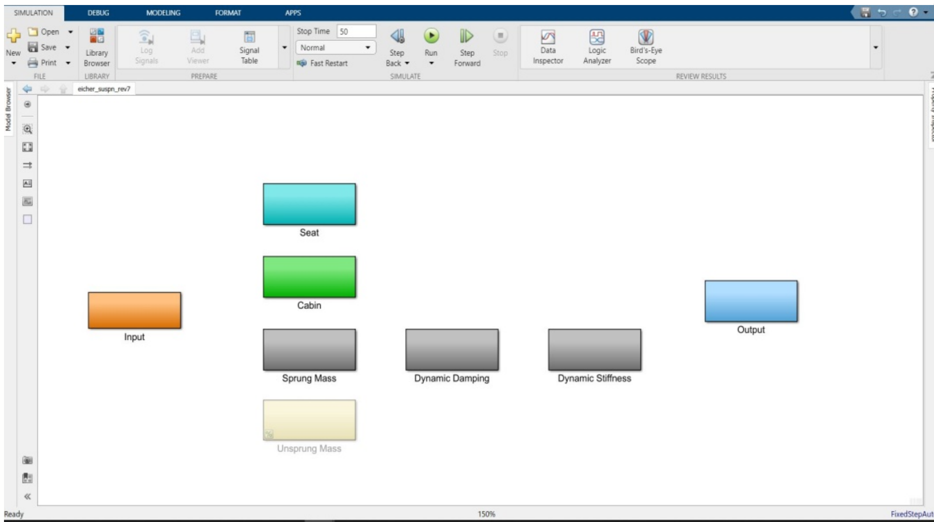


Damper properties of Main Suspension

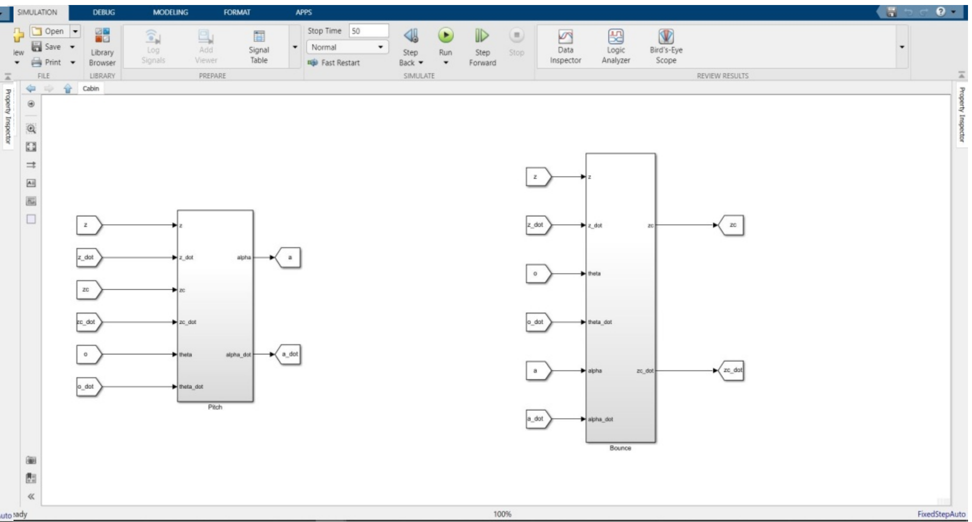


Parameter Estimation Tool

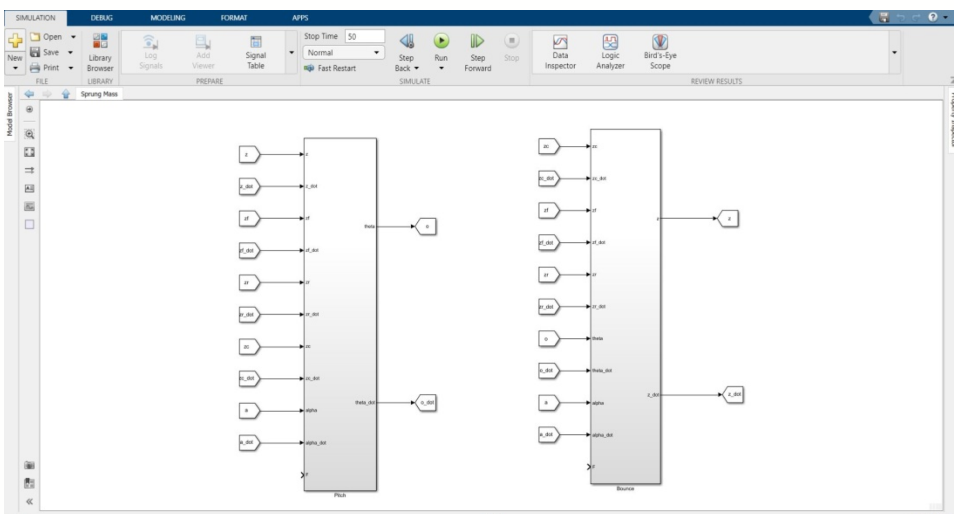
Mathematical Modeling of Differential Equations in Simulink



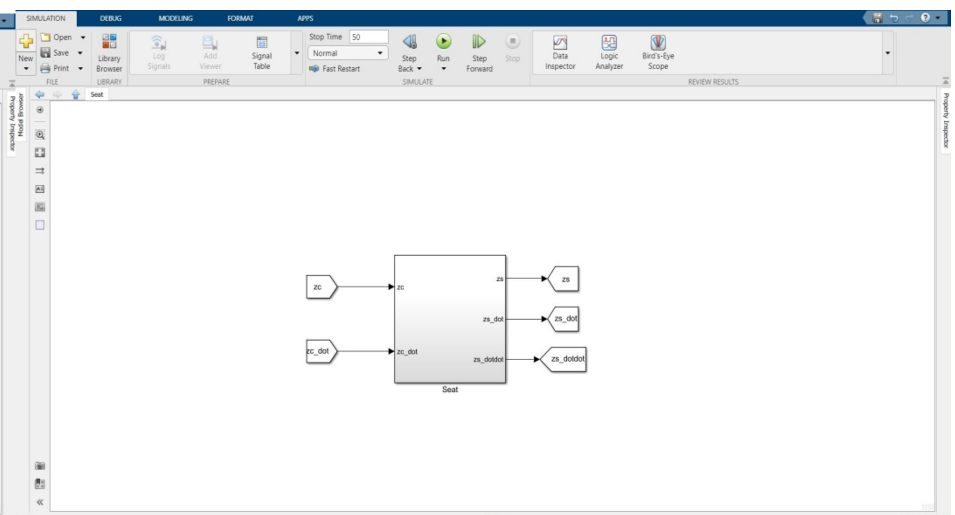
Overview of Mathematical Model



Mathematical Model of Cabin

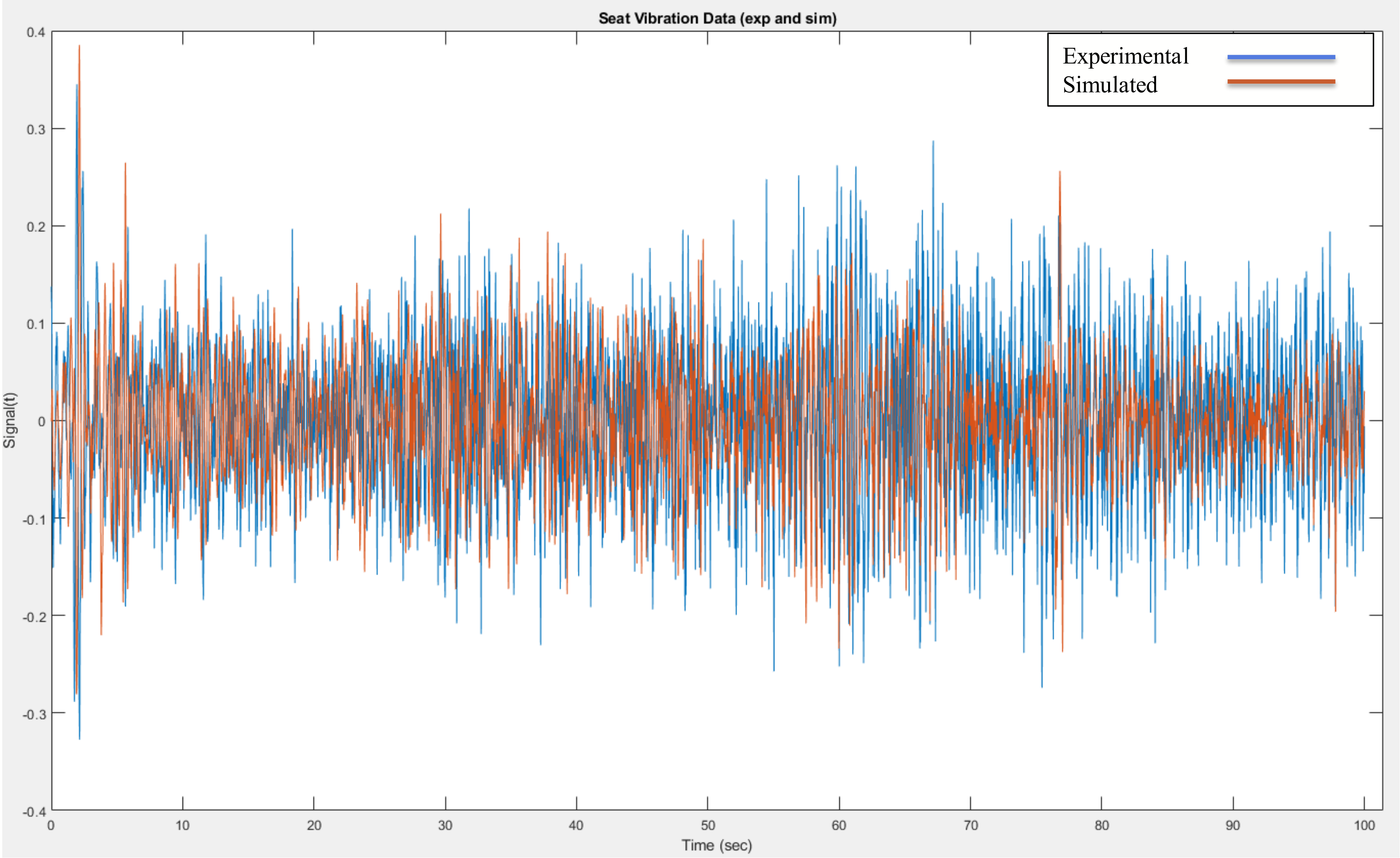


Mathematical Model of Sprung Mass

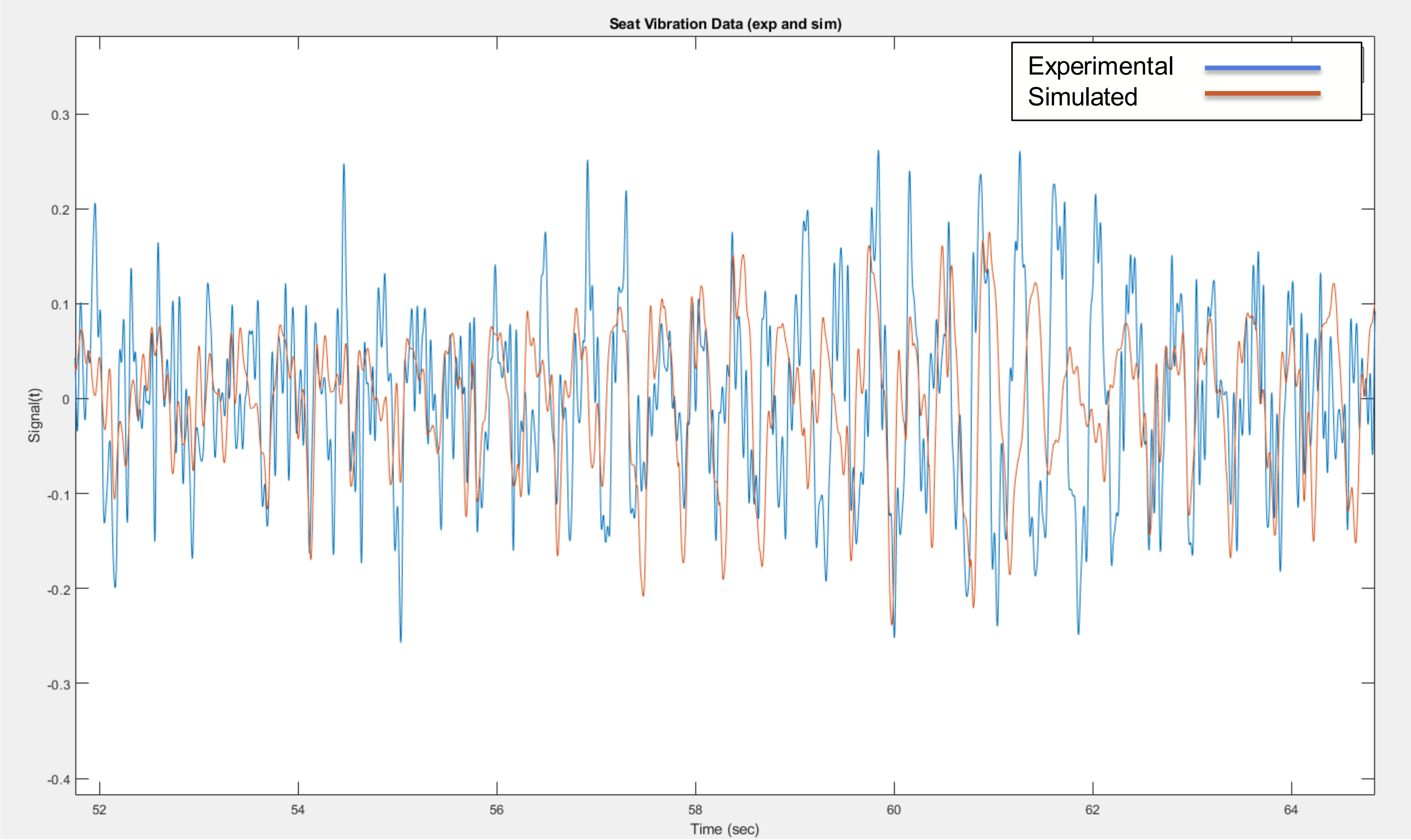


Mathematical Model of Seat

Time Domain Output

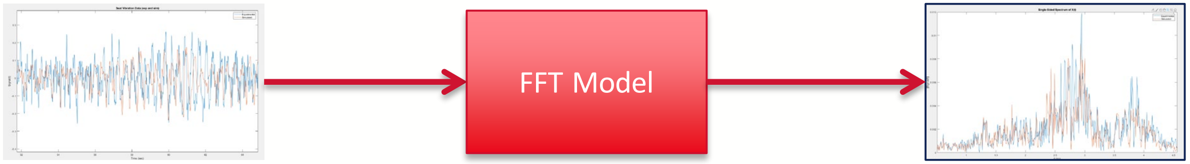


Time Domain Output Visulaization



Following Result shows close trend being followed by Simulation and actual result

Post Processing and FFT Analysis using MATLAB Script



Editor - C:\Users\Abhishek\Downloads\compare_peaks.m

compare_peaks.m

This file can be opened as a Live Script. For more information, see Creating Live Scripts.

```
%% Compute FFT of the Ride and Handling data

   data = readmatrix('6046 TT Class A 150-250s.xlsx');
%data = readmatrix('6046 TT Cement 150-250s.xlsx');
T = 0.001;              % Sampling period
Fs = 1/T;               % Sampling frequency
Tspan = 100;             % Time span
L = Tspan/T + 1;        % Length of signal

t = data(:,1);          % Time vector
X = data(:,5);          % Experimental data
%S = data(:,10);         % Simulated data for A Class
S = data(:,8);         % Simulated data for Cement
%% Plot the signal
figure(1)
plot(t,X)
hold on
plot(t,S)
title('Seat Vibration Data (exp and sim)')
xlabel('Time (sec)')
ylabel('Signal(t)')
legend('Experimental','Simulated')

%% Compute the Fourier transform of the signal.
Y = fft(X);
P2 = abs(Y/L);
P1 = P2(1:L/2+1);
P1(2:end-1) = 2*P1(2:end-1);
```

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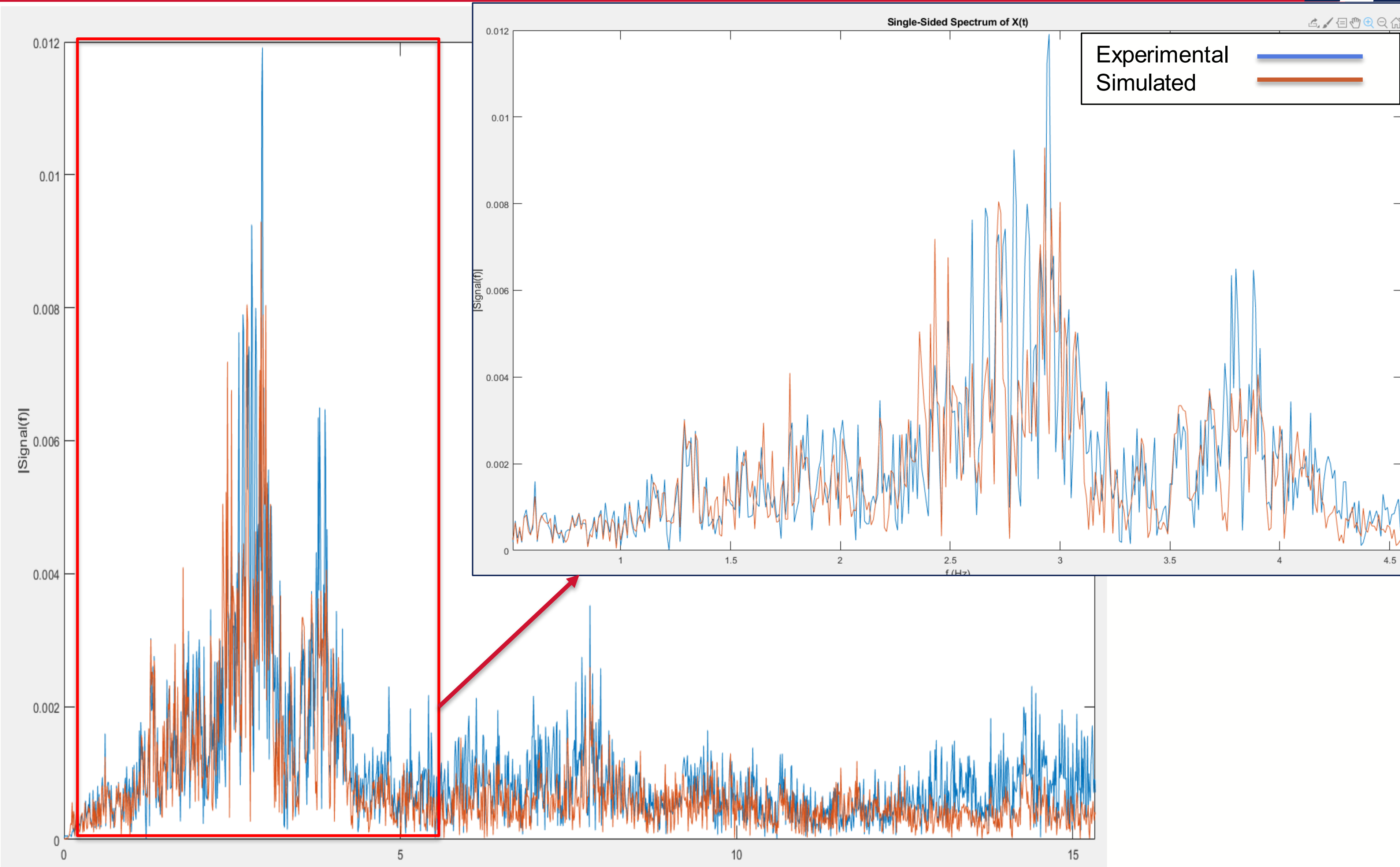
Y = fft(X);
P2 = abs(Y/L);
P1 = P2(1:L/2+1);
P1(2:end-1) = 2*P1(2:end-1);
```


```

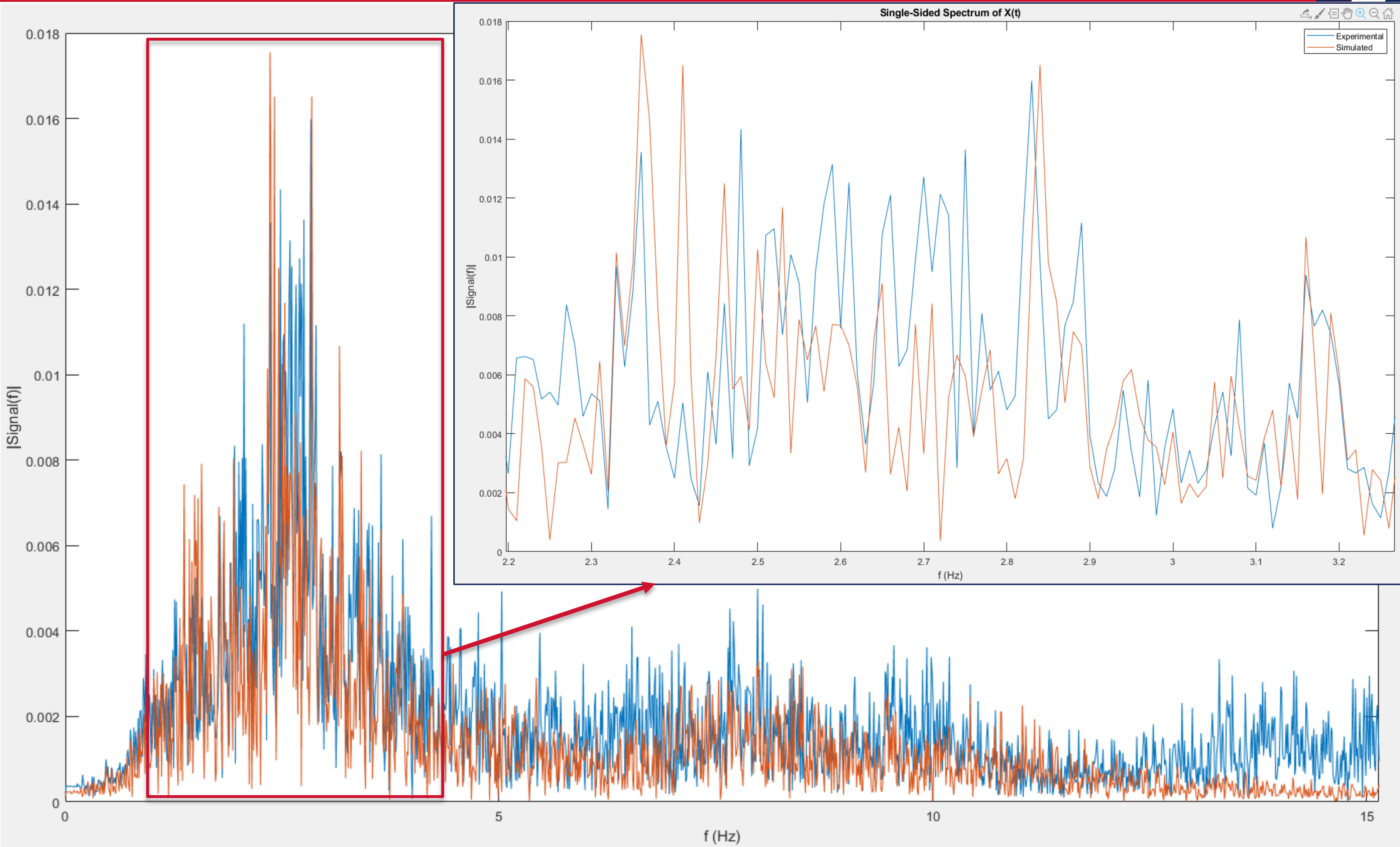
Y = fft(S);
Q2 = abs(Y/L);
Q1 = Q2(1:L/2+1);
Q1(2:end-1) = 2*Q1(2:end-1);

%% Plot the spectrum
f = Fs*(0:(L/2))'/L;
N = 25*round(2*length(f)/Fs);
figure(2)
plot(f(1:N+1),P1(1:N+1))
hold on
plot(f(1:N+1),Q1(1:N+1))
title('Single-Sided Spectrum of X(t)')
xlabel('f (Hz)')
ylabel('|Signal(f)|')
legend('Experimental','Simulated')
```

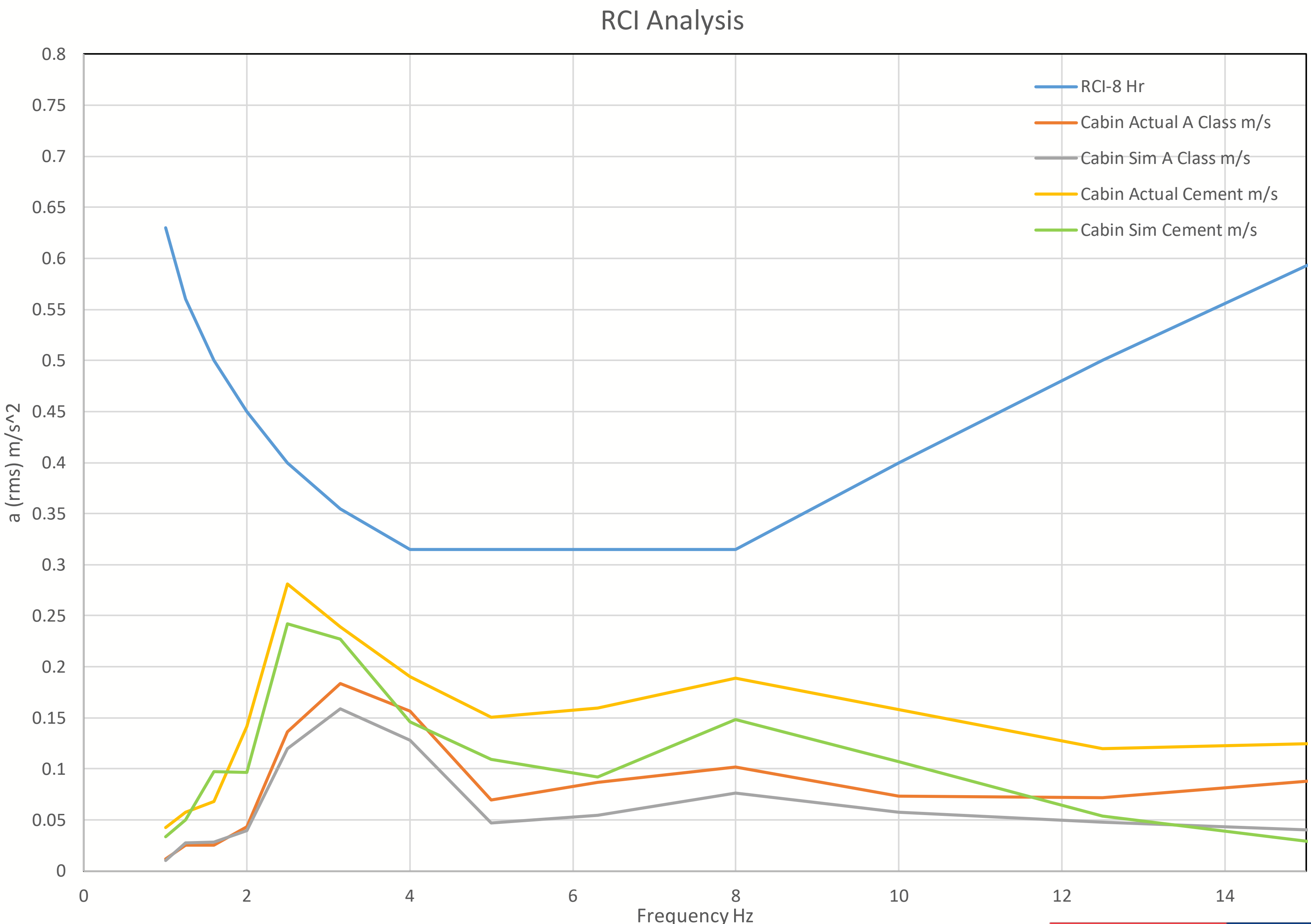
FFT Analysis- A Class Road



FFT Analysis- Cement Road



RCI Analysis



Conclusion & Future Scope

The project features Ride Comfort Establishment of Tractor Semi-Trailer Vehicle in Virtual Environment using MATLAB Simulink R2019b. The following conclusions can be obtained:

- Time Domain Simulation Showcases the model following the Actual Simulation with close proximity
- Frequency domain shows the simulation to follow the actual result between 1-5Hz.

Further Scope

- **Engine Level vibration as input.**
- **Multi Axle Input**
- **Full Car Model Development for Handling Analysis**