MBD Week3 Problem3 Report: Vehicle Suspension System

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Introduction

This example shows how to model a simplified half-car model that includes an independent front and rear vertical suspension. The model also includes body pitch and bounce degrees of freedom. The example provides a description of the model to show how simulation can be used to investigate ride characteristics. You can use this model in conjunction with a powertrain simulation to investigate longitudinal shuffle resulting from changes in throttle setting.

This report is about modelling a Vehicle Suspension system using Simulink, demonstrating some Simulink skills on this model and showing various test cases.

Equations

To model the Simulink design for the Vehicle Suspension system, it is important to look into the mathematical equations which represents the system.

$F_f = 2K_f$ (Lf theta - (z + h)) + 2Cf(Lf theta -z)

where:

Ff,Fr = upward force on body from front/rear suspension

Kf, Kr = front and rear suspension spring constant

Cf, Cr = front and rear suspension damping rate

Lf, Lr = horizontal distance from gravity center to front/rear suspension

theta, \dot{\theta} = pitch (rotational) angle and its rate of change

z = bounce (vertical) distance and its rate of change

h = road height

Equations 2 describe pitch moments due to the suspension.

$Mf = -LfFf$

$Fr = -2Kr (Lr\theta + (z + h)) -2Cr (Lr \dot{\theta} + \dot{z})$

$Mr = Lr\ Fr$

where:

Mf, Mr= Pitch moment due to front/rear suspension

Equations 3 resolves the forces and moments result in body motion, according to Newton's Second Law:

$Mbd\ \dot{z} = Ff + Fr - mb\ g$

$Iyy\ \ddot{\theta} = Mf + Mr + My$

where:

mb = body mass

My = pitch moment induced by vehicle acceleration

Iyy = body moment of inertia about gravity center

Simulink Model

- Vehicle Suspension System

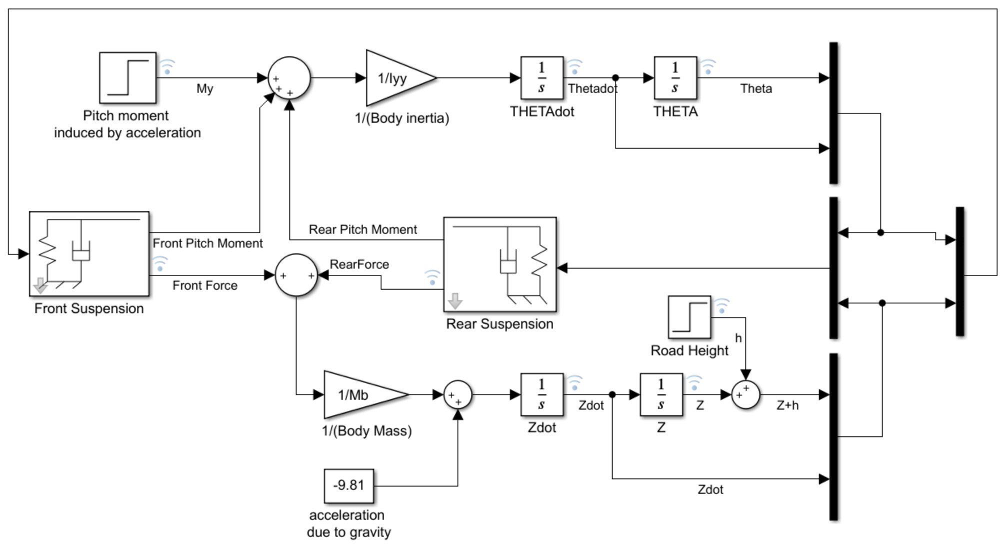
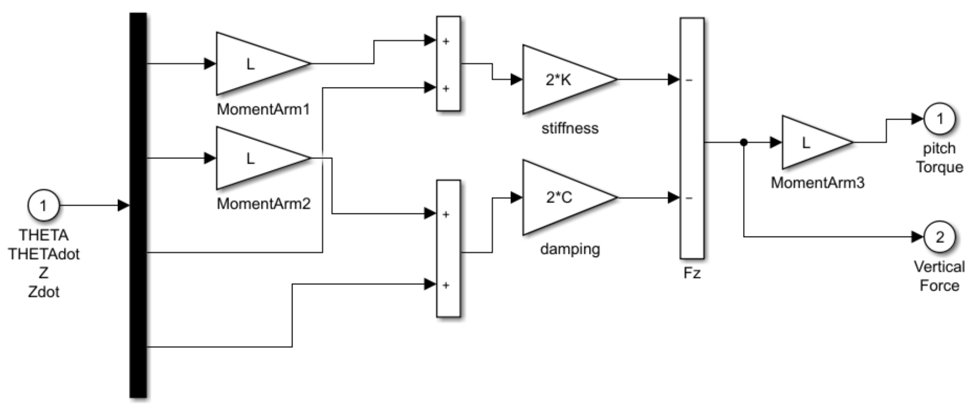


Figure 1: Vehicle Suspension Simulink Model

- Front Suspension Subsystem



- Rear Suspension Subsystem

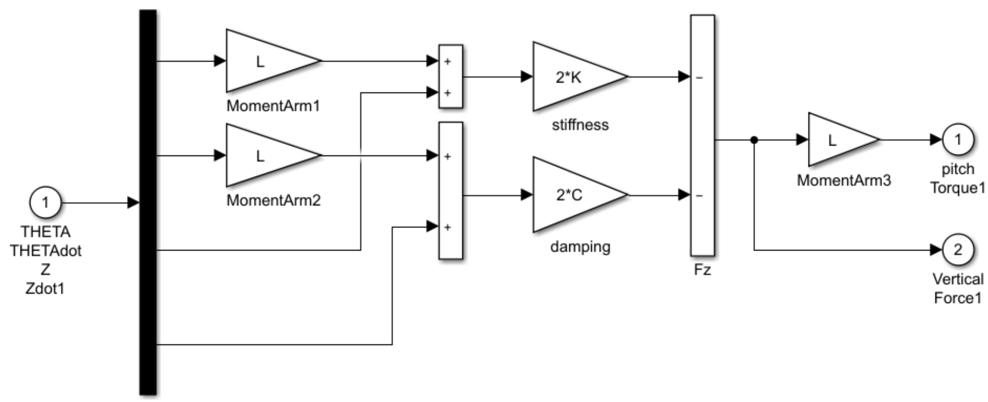


Figure 2: Subsystem Model block: Front and Rear Suspension

Skill sets to demonstrate

- Callbacks:

  Callback code is added to initialize the variables at the initialization phase of the model. This can be edited or other callbacks can be included through Property Inspector -> Callbacks. The code entered:

```
Iyy = 2100;
Lf = 0.9;
Lr = 1.2;
Mb = 1200;
cf = 2500;
cr = 2000;
kf = 28000;
kr = 21000;
x0 = [-4.3357883287291038E-18;-0.1201224489795918;6.4623485355705287E-27;-1.0339757656912851E-25];
```

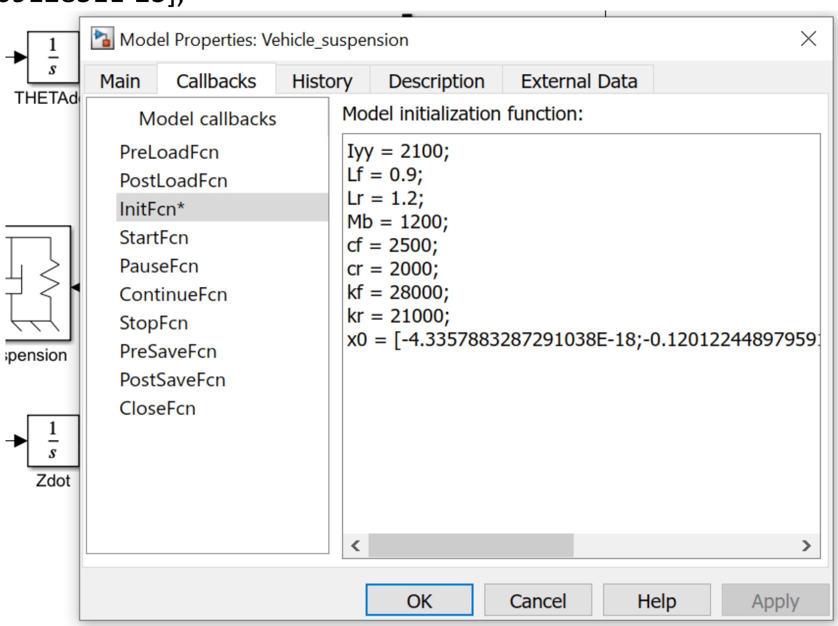


Figure 3: Callback function

- ## Data Inspector:

  By enabling data logging, we can view and inspect the signals for each run using data inspector. The data inspector reports are included in this project repository.

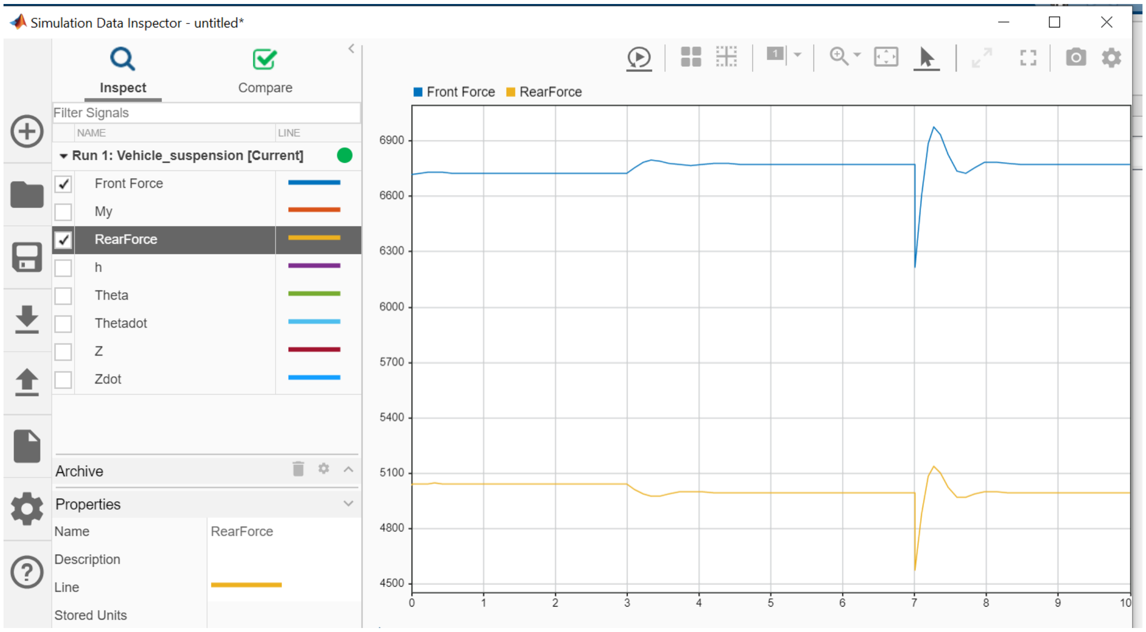


Figure 4: Data inspector

- ## Solver Selection:
  The solver selected for this system is Variable-step type and ode45 for better results.

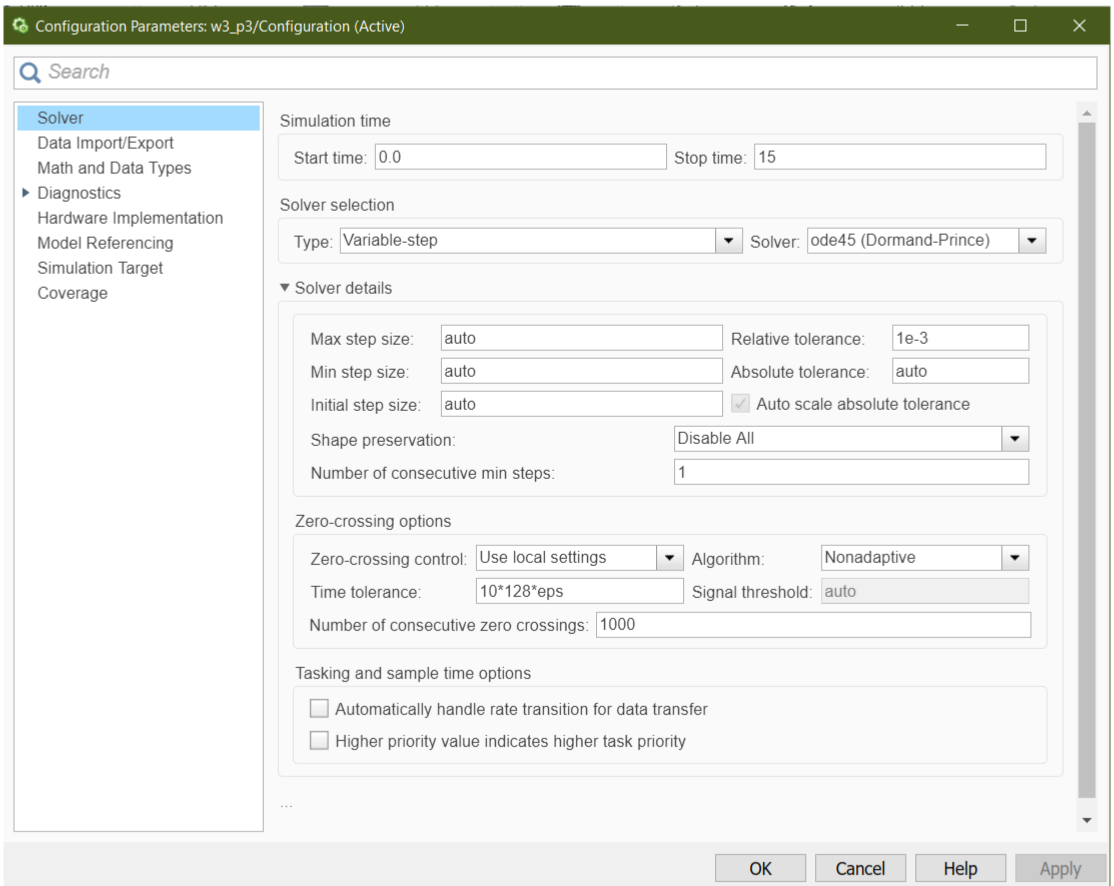


Figure 5: Solver selection

Conclusion

In this project, the design of Vehicle Suspension System was designed. This model allows to simulate the effects of changing the suspension damping and stiffness, thereby investigating the tradeoff between comfort and performance. In general, racing cars have very stiff springs with a high damping factor, whereas passenger vehicles have softer springs and a more oscillatory response

References

[1] https://in.mathworks.com/help/simulink/slref/automotive-suspension.html
[2] https://en.wikipedia.org/wiki/Automotive_suspension_design_process