Vehicle Dynamics Model With Non Linear Bush Model and Tire Filter for Ride Comfort Analysis

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Abstract

There are many non-linear factors affecting ride comfort. In this study, various nonlinear factors affecting vehicle vertical dynamics are modeled to ensure robustness in the analysis of ride comfort performance.
Another factor that affected the interpretation of ride comfort performance is road model. To simulate driving situation of vehicle, a Tire Filter Model is presented.
Conclusion In this paper, the robustness of vehicle dynamics model with nonlinear elements and ride comfort performance analysis model is secured through Tire Filter Model.

Keywords: Vehicle Dynamics Model, Ride Comfort, Non-Linear Bush Model, Hydro Mount

1 Introduction

Nonlinear dynamic factors affecting vehicle's ride comfort performance are as follows. Engine Mount, Spring, and Damper. In this study, we constructed Vehicle Dynamics Model, including these nonlinear dynamic factors, and analyzed how it affected the ride comfort analysis.
Also, use Tire Filter to calculate Drive Signal used in 4-post simulation. Tire Filter calculates effective road profile that affects Vehicle by considering the deformation of Tires.
Using Vehicle Dynamics Model and Tire Filter, which contain the above nonlinear dynamics, the ride comfort analysis improves accuracy.

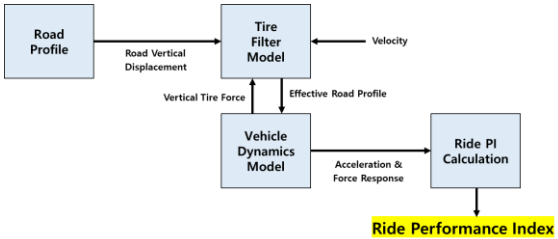

Figure 1. Ride Comfort Analysis Process

2 Vehicle Dynamics Model

Nonlinear dynamic factors such as Engine Mount, Spring, and Damper influence analysis of ride comfort performance. Therefore, Vehicle Dynamics Model was modeled to reflect the above nonlinear dynamic factors.

2.1 Engine Model

Engine Model is a 1D model based on Torque Map.

2.1.1 Engine Mount Model

Engine Mount Model used Hydro Mount Model. Hydro Mount Model reflects mass and rotational inertia values of fluid and calculates time response and stiffness of the translational /rotational direction.

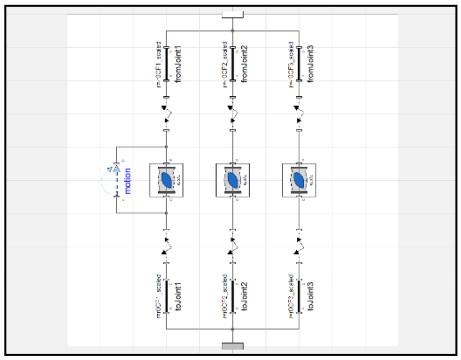

Figure 2. Hydro Engine Mount Model

2.2 Suspension Model

Suspension Model used TEKS Model.

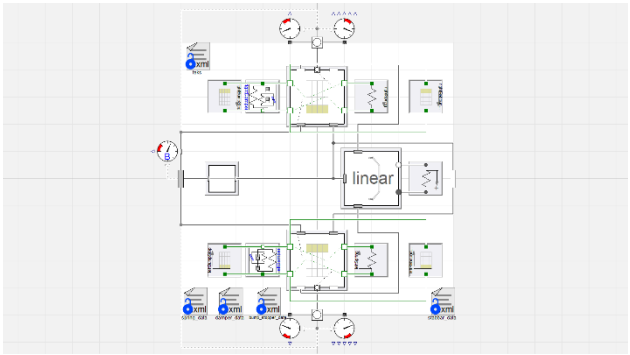

Figure 3. TEKS Model

2.2.1 Spring / Damper Model

Spring models used linear models. On the other hand, Damper Model used Spencer Bouc Wen Model.

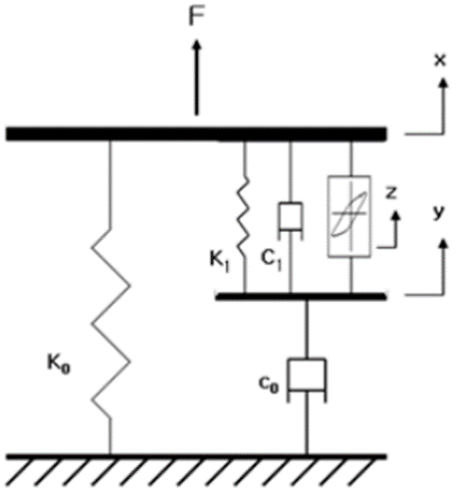

Figure 4. Spencer Bouc Wen Model

Figure 4 illustrates the concept of Spencer Bouc Wen Model. The models modeled through Modelica are shown in Figure 5.
Using the Spencer Bouc Wen Model, we can accurately predict the Hystersis phenomenon of Damper, thereby improving the accuracy of the Ride Comfort analysis.

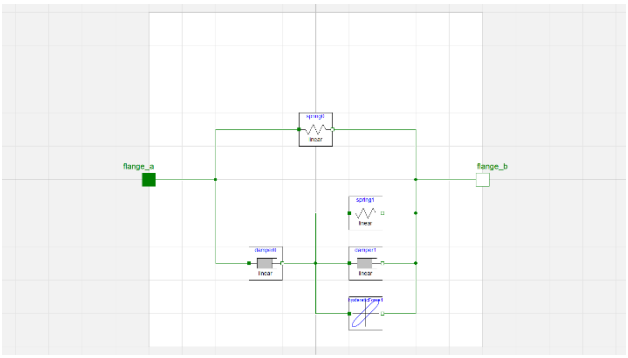

Figure 5. Spencer Bouc Wen Modelica Model

3 Tire Filter Model

Actual Road Profile is different from the input to the vehicle. Therefore, the Ride Comfort performance analysis should be performed using the Road Profile that is delivered to the actual vehicle.
To evaluate the ride comfort of an irregular road surface, Tire Filter model predicts deformation by considering the characteristics of Tire and calculates Effective Road Profile that affects actual vehicle.

3.1 Tire Enveloping Model

Based on the vertical load, speed and road profile of the tyre, Wheel Vertical position is predicted.

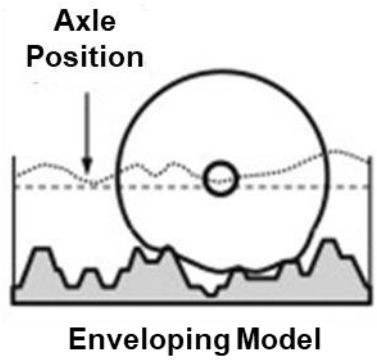

Figure 6. Tire Enveloping Model

3.2 Road Perception Model

Calculate required road profile that can be utilized in the analytical model for wheel specific position predicted by Tire upgrade model.

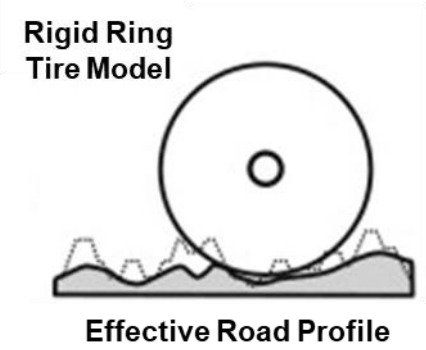

Figure 7. Road Perception Model

Effective road height is determined by Formula (1).

$$-W_e(X) = \frac{Z_f(X_f) + Z_r(X_r)}{2} - b_e \quad (1)$$

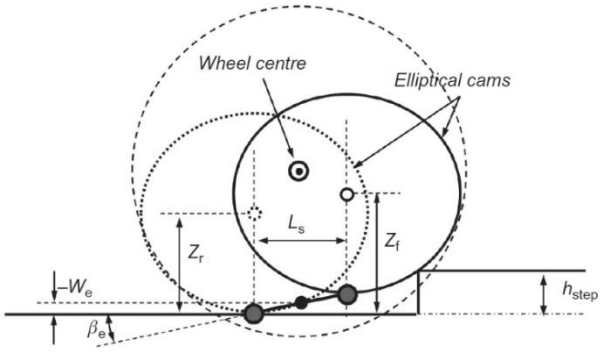

Figure 8. Effective Road Height Calculation

3.3 Tire Filter Result

Using Tire Filter to calculate the Road Profile, the results are as shown in Figure 9. This results can be used for 4-post simulation.

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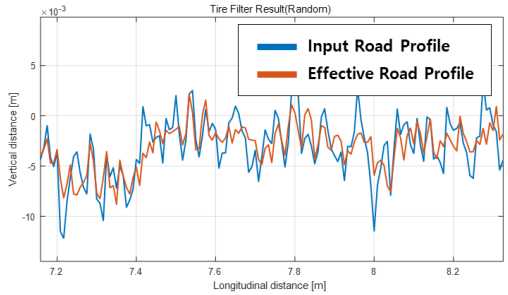

Figure 9. Tire Filter Result

4 Simulation

4.1 Performance Index

Ride comfort Performance Index is defined as the commonly used Bounce, Wheel Hopping, Choppy, and the Ride Filter where values are calculated by weighting the acceleration signals at each location.

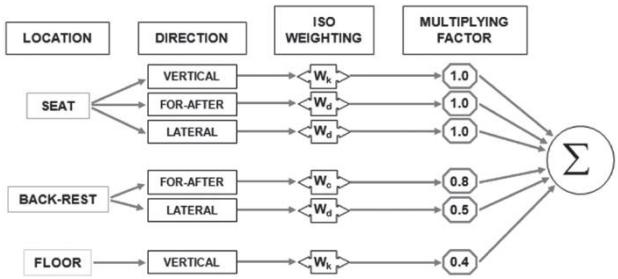

Figure 10. Ride Filter

4.2 Simulation Result

4-post simulation was performed by entering the Random Road Profile as Drive Signal in vehicle. To verify the usefulness of the dynamic features of vehicle, the results of the analysis of ride comfort performance of the vehicle model with the engine mount removed were compared. The comparison result is a picture 11. As shown in , a vehicle model with a dynamic feature has a smaller tolerance to field test compared to a vehicle model that does not.

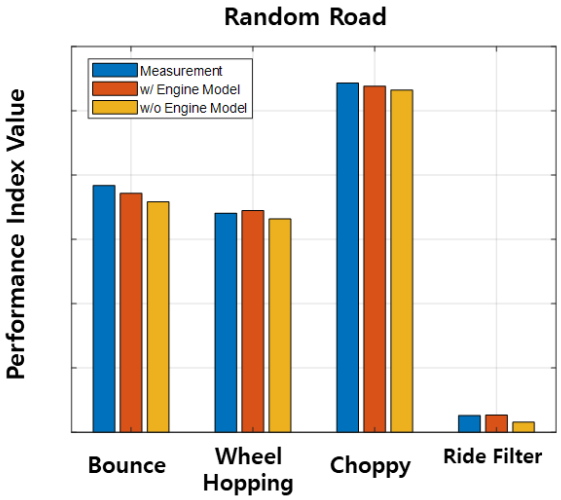

Figure 11. Engine Mount Verification Result

Table 1. Engine Mount Verification Result

Performance Index	With Engine Mount	W/O Engine Mount
Bounce	3.20%	6.65%
Choppy	1.14%	2.66%
Wheel Hopping	0.87%	1.97%
Ride Filter	2.03%	40.29%

Similarly, to verify the usefulness of tire filter, the results of the 4-post simulation using the actual road profile were compared with the results of the 4-post simulation using the efficient road profile calculated through tire filter. The comparison result is a picture 11. While other performance indexes do not have a significant effect on tire filter, for the Ride Filter, we can see that the model used in tire filter is similar to the field test results.

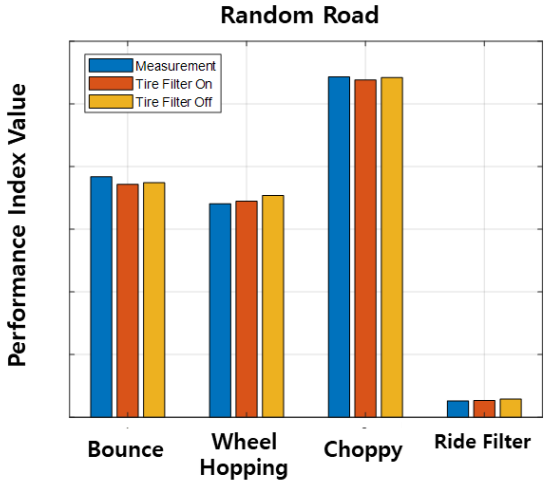

Figure 12. Tire Filter Verification Result

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Table 2. Tire Filter Verification

Performance Index	Tire Filter On	Tier Filter Off
Bounce	3.20%	2.51%
Choppy	1.14%	3.87%
Wheel Hopping	0.87%	0.16%
Ride Filter	2.03%	11.07%

5 Conclusion

In this study, vehicles with modelica based dynamic features were modeled. Dynamic element models are Hydro Engine Mount, Damper (Spencer Bouc Wen Model). In addition, the tire filter was modeled to predict road profile to be delivered to vehicle.
A 4-post simulation was conducted to verify the nonlinear dynamic model and tire filter. Simulation results showed that models with nonlinear dynamics were more similar to field test results. When calculating road profile using tire filter, the results of field test were more similar than those of the other road profile.
Analysis has been achieved through the vehicle dynamic model with non-linear dynamics component model and tire filter model, this will be applicable to the vehicle's design process.

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