

Numerical simulation on the effect of body stiffness on vehicle dynamic behavior considering detailed tire model

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The objective of this study is to elucidate the influence of body stiffness on vehicle behavior during transient cornering using vehicle dynamics simulations based on a four-wheel model that incorporates a detailed tire model. Although vehicle motion simulations generally assume the body to be a perfectly rigid body, it is known that body stiffness significantly affects vehicle behavior during limit cornering. In particular, by focusing on torsional stiffness—which is related to the difference in roll angles between the front and rear wheels—and lateral bending stiffness—which results from tire friction and centrifugal forces during cornering—we quantitatively clarified whether changes in tire attitude and vertical loads caused by body deformation lead to a deterioration in vehicle dynamic performance. Specifically, by focusing on slalom driving and analyzing and evaluating the frequency response of the yaw rate to periodic steering inputs, we elucidated the effects of the body's lateral bending stiffness and torsional stiffness on vehicle behavior.

As shown in Figure 1, we assumed that during cornering, lateral bending deformation occurs in the body due to the friction forces generated by the tires and the centrifugal forces acting on the body. We applied finite element method (FEM) analysis to the body of our university's FSAE vehicle to calculate the body's lateral displacement. Based on these results, we determined the body's lateral bending spring constant (lateral bending stiffness) and solved the equations of motion governing the body's lateral bending deformation. We evaluated the effect of the body's lateral bending stiffness on vehicle behavior by reflecting the change in tire toe angle caused by the body's lateral bending deformation in the slip angle of each wheel.

To verify improvements in slalom handling performance, we compared the behavior of the FY2025 and FY2026 models. Compared to the previous model year, the FY2026 model features a 7.2% increase in lateral bending stiffness, and the ratio of front-to-rear lateral bending deformation has been brought closer to 1:1. Figure 2 shows the change in yaw rate over time, and Figure 3 shows the vehicle's trajectory. The solid red line represents the measured values for the 2025 model year vehicle, the solid blue line represents the measured values for the 2026 model year vehicle, and the dashed blue line shows a comparison with the results of the lateral bending simulation. In the simulation, the vehicle's lateral bending stiffness was taken into account, and the steering input was set directly based on data recorded during actual slalom driving. Figure 2 shows that the fiscal year 2026 vehicle consistently maintains a higher yaw rate amplitude compared to the fiscal year 2025 vehicle. The vehicle trajectories in Figure 3 also indicate that the amplitude of the 2026 model is slightly smaller. Furthermore, it was confirmed that the simulation results shown by the dashed lines in Figures 2 and 3 accurately capture the trends observed in the measured data, demonstrating that the body's lateral bending stiffness has a significant impact on vehicle behavior.

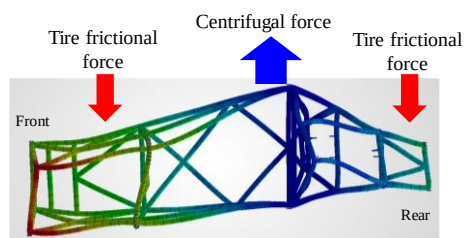


Fig. 1 Bending Deformation of the Body, Conceptual Diagram

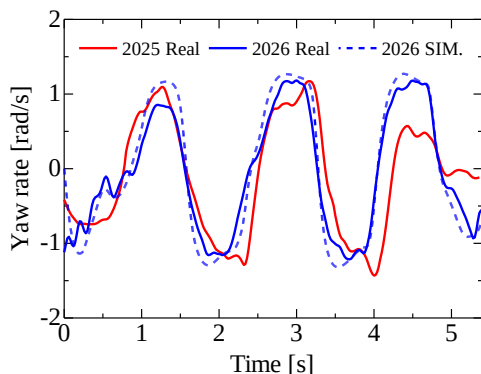


Fig. 2 Yaw rate time variation

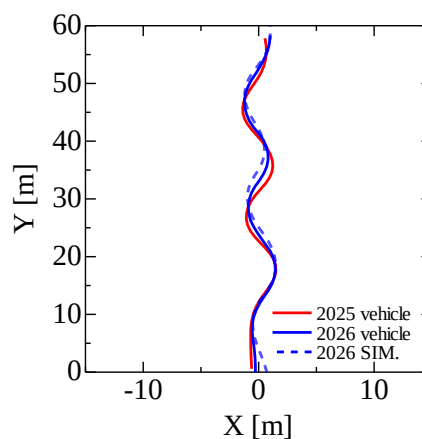


Fig. 3 Vehicle Trajectory in a Slalom