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Influence of Suspension Ball Joints on Driver Steering Characteristics Evaluation

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1. Introduction:In recent vehicle development, achieving both high handling performance and good driver feel is important, especially under high lateral acceleration conditions such as circuit driving. Suspension components, including ball joints (BJ), influence vehicle dynamics through compliance and alignment changes. However, their nonlinear characteristics under actual installation conditions are not fully understood.This study focuses on the effect of BJ stiffness characteristics on vehicle behavior and driver evaluation using a high-stiffness suspension test vehicle.

2. Method :A modified compact sports vehicle with high suspension stiffness (large negative camber, reduced toe-in, stiff springs, and pillow-ball mounts) was used. Two BJ specifications were compared:

・Original specification (nonlinear stiffness)
・Linearized stiffness specification (LS)

Vehicle behavior was evaluated subjectively on a circuit and objectively

・Steering robot tests (objective response)
・Driver model-based evaluation usingτ_L(Lane-change and circular turning tests)

In addition, a new evaluation index, circular τ_L, was introduced to assess driver workload under sustained high lateral acceleration.

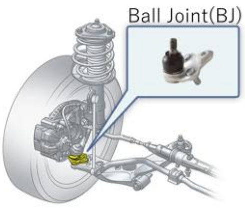


Fig.1 Ball Joint(BJ)

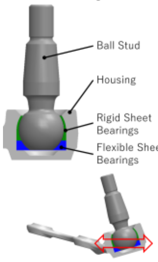


Fig.2 Original

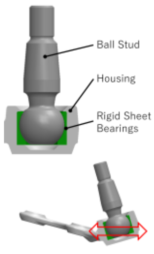
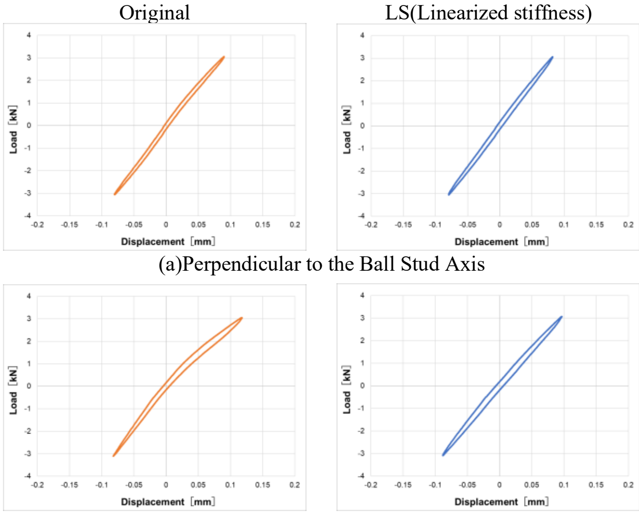


Fig.3 Linearized Stiffness



(a)Perpendicular to the Ball Stud Axis

(b)Vehicle Installation-Representative Angle

Fig.4 Load–deflection characteristics

Fig.5 Experimental Vehicle

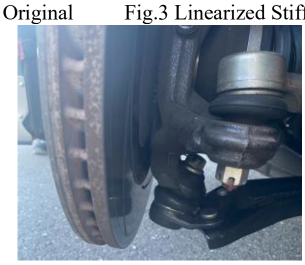


Fig.6 BJ Installation

Table 2 Subjective evaluation results of Circuit Test (FISCO)

Item	Original BJ	LS(Linearized stiffness) BJ
Handling stability	Requires corrective steering throughout the corner	Reduced corrective steering and improved line-tracing performance.
Steering response	Good steering response.	Improved direct steering feel compared to the conventional BJ.
US/OS characteristics	Limited response to additional steering under understeer conditions.	Good turning response to additional steering input.

3. Results:The LS specification showed:

・Smaller τ_L in lane-change maneuvers
・Larger τ_L in steady-state cornering

This indicates that vehicle evaluation depends on driving conditions. In high lateral acceleration conditions, the original BJ shows nonlinear load–deflection behavior, causing non-uniform alignment changes. This leads to response variability and corrective steering.

In contrast, the LS specification stabilizes alignment behavior due to linearized stiffness, improving response consistency and steering margin. This improvement appears as an increase in τ_L.

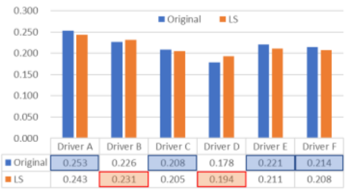


Fig.7 τ_L Results for Lane Change

Fig.8 τ_L Results for Circular Turning

4. Conclusion:

This study clarified that BJ stiffness characteristics significantly affect vehicle dynamics and driver evaluation. A consistent evaluation framework from component-level characteristics to vehicle behavior using τ_L was established.The proposed circular τ_L is effective for the evaluation of high lateral acceleration conditions. Future work includes applying this approach to normal vehicles and studying friction effects in the BJ.

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