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Design of an Integrated Steering-Suspension Corner Module

Lyu Haoyang, LIU Jianyuan, WANG Jingran, WANG Kaipeng

JIANG Hongyuan, ZOU Zihong, ZHEN Zhouyi, HU Mingyan, TIAN Mengjian*

Shenzhen Technology University, College of Urban Transportation and Logistics
No. 3002, Lantian Road, Pingshan District, Shenzhen City, Guangdong Province,518118, China(E-mail:tianmengjian@sztu.edu.cn)

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With the development of electric vehicles and intelligent driving technologies, corner modules integrating driving, braking, steering, and suspension have attracted increasing attention. However, existing designs still face challenges such as high-speed shimmy, limited structural compactness, large unsprung mass, and high system integration complexity. In particular, in-wheel motor solutions improve integration but significantly increase unsprung mass, thereby degrading handling stability and ride comfort. Meanwhile, steering system design involves a trade-off between high-speed stability and low-speed maneuverability, which conventional single-kingpin configurations cannot effectively satisfy. To address these issues, this paper proposes a two-stage steering corner module with a dual-kingpin configuration and a sprung-mounted powertrain. The powertrain is arranged above the structure, and torque is transmitted via a short driveshaft and constant-velocity joints, achieving high integration while effectively reducing unsprung mass and improving overall vehicle performance.

The suspension–steering system adopts a dual-kingpin, two-stage steering configuration. The first-stage steering uses a four-bar linkage driven by a steering motor, providing approximately 35° of steering angle and ensuring high-speed stability through a small kingpin offset. The second-stage steering employs a crank–rocker mechanism as a supplement for large-angle maneuvers, enabling a maximum steering angle of up to 90° with a larger kingpin offset. A self-locking crank–rocker mechanism keeps the second kingpin locked under normal driving conditions and only engages at large steering angles, thereby reducing drivetrain loads and improving reliability. In addition, the system integrates a multi-link suspension with a sprung-mounted motor layout, where torque is transmitted via a short driveshaft and constant-velocity joints. This configuration reduces unsprung mass, lowers steering inertia, improves motor operating conditions, and enhances steering response and overall vehicle performance.

To verify the engineering feasibility of the proposed sprung-mounted powertrain layout, the axial plunge of the short drive shaft under coupled suspension and steering motions was analyzed through simulation. A full-vehicle suspension and steering model was established in Adams/Car. The axial displacement of the drive shaft was calculated under combined conditions with wheel travel ranging from −50 mm to +50 mm and steering angles from −35° to +35°. The simulation results indicate that the axial plunge of the drive shaft varies from −9 mm to +3 mm, with a total travel of approximately 12 mm, as shown in Fig. 2. Considering that the typical operating plunge range of a constant-velocity (CV) joint is approximately 15–30 mm, the predicted displacement is well within the allowable limit. This demonstrates that the proposed sprung-mounted powertrain and short drive shaft configuration can effectively accommodate the geometric variations induced by suspension travel and steering motion without exceeding the allowable axial travel, thereby confirming the engineering feasibility of the proposed design.

This study addresses the challenges of high-speed stability, low-speed maneuverability, and unsprung mass in existing corner modules. A two-stage steering corner module with a dual-kingpin configuration and a sprung-mounted powertrain is proposed. By optimizing the spatial layout, the design enables large steering angles and compatibility with wide tires. The powertrain is positioned above the supporting structure, with torque transmitted to the wheel end via a short drive shaft and constant-velocity joints, effectively reducing the unsprung mass.

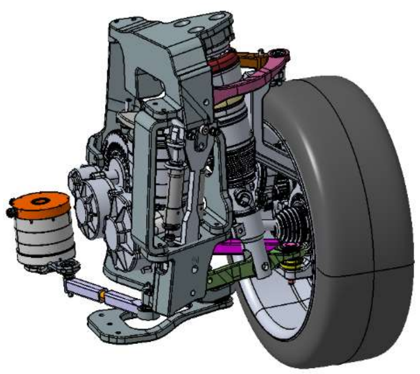

Fig.1 Corner Module Structure

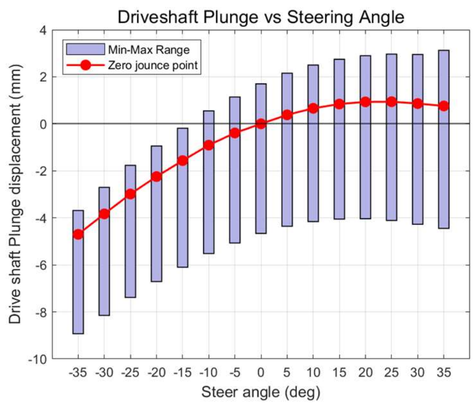

Fig.2 Drive shaft Plunge displacement