

Investigation of Impact Behavior of Electric Scooter Riders Struck Head-on by Bonnet-type Automobiles

Ryo Oga^{1,2)}, Toshiaki Sakurai³⁾, Ryotaro Otomo⁴⁾, Hiroki Kami⁵⁾, Akihiro Kido⁶⁾

1) Japan Safe Driving Center, 3-6, Kioicho, Chiyoda, Tokyo, 102-0094, Japan

2) · 3) · 4) Tokyo City University, 1-28-1, Tamatsutsumi, Setagaya, Tokyo, 158-8557, Japan (E-mail: oga@tcu.ac.jp)

5) Tokyo City University Graduate Division, 1-28-1, Tamatsutsumi, Setagaya, Tokyo, 158-8557, Japan

6) National Research Institute of Police Science, 6-3-1, Kashiwa no ha, Kashiwa, Chiba, 277-0882, Japan

KEY WORDS: Safety, Protection for vulnerable road users, Injury mechanism, Electric scooter, Simulation [C1]

1. Introduction

With the enforcement of the revised Road Traffic Act in 2023 in Japan, standing-type electric scooters have joined vulnerable road users like as bicycles. While our previous studies have addressed side-impact collisions. However, head-on collisions remain under-investigated. The primary cause of fatal and severe injuries for vulnerable road users often involves the secondary impact of the head against the road surface after the first impact with the vehicle. This study aims to clarify the impact kinematics of electric scooter riders in head-on collisions with bonnet-type automobiles, specifically focusing on the influence of impact speed.

2. Methodology

A combination of real-world crash tests and Computer-Aided Engineering (CAE) analysis with simulations was employed to evaluate rider kinematics.

Crash Tests: Head-on collision tests were conducted using stationary electric scooters and moving bonnet-type automobiles. Three scooter models and Anthropomorphic Test Dummies (ATDs: AF05 and AM50) were utilized. Target impact speeds were 15 km/h and 30 km/h. High-speed cameras captured the post-impact behavior.

CAE Analysis: Using PC-Crash 12, multi-body system models were developed and validated against the crash test results. Parameter studies were then conducted in 5 km/h increments to extrapolate impact speeds up to 45 km/h.

3. Results and Discussion

Low-Speed Impact (≤ 30 km/h): The rider predominantly exhibited a Wrap trajectory, remaining relatively close to the vehicle's front profile, similar to typical pedestrian impacts⁽¹⁾, as shown in Fig. 1.

High-Speed Impact (> 30 km/h): The kinematics transitioned to Somersault or Roof Vault trajectories. This inversion of the body posture significantly elevates the risk of the rider falling head-first onto the road surface.

Additionally, structural failures were observed at 30 km/h, where the steering stem fractured in most tests. Meanwhile, at 15 km/h, the scooter tended to rotate forward around the front wheel.

4. Conclusion

The collision kinematics of electric scooter riders were similar to those observed in typical pedestrian accidents; at speeds of 30 km/h or lower, a "wrap trajectory" occurred. CAE analysis revealed that at speeds exceeding 30 km/h, the riders exhibited flipping motions, such as "somersault" or "roof vault" patterns. Interaction between the rider and the handlebar caused the scooter to flip forward. In some cases at 30 km/h, the steering stem fractured, causing the scooter to be pushed forward rather than flipping over.

Reference

- (1) Y. Han, Q. Li, W. He, and F. Wan et al. : Analysis of Vulnerable Road User Kinematics Before During After Vehicle Collisions Based on Video, IRCOB Conference, IRC-17-26, 151-165, 2017.

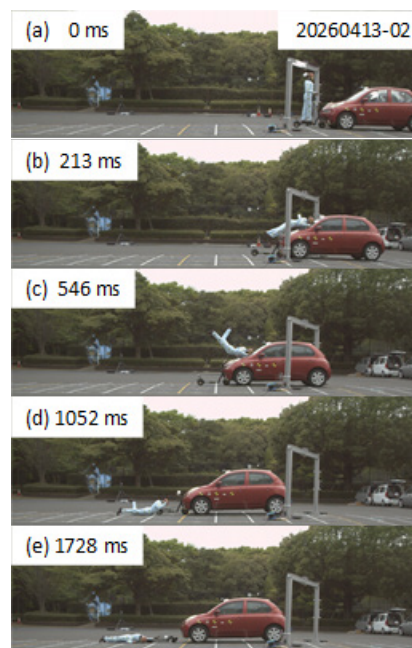


Fig.1 Video images in a real-world crash test at about 30 km/h