C9 Motorcycle and Rider Kinematics in Low Speed Rear-End Collisions

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After attending this presentation, attendees will understand the appropriate parameters for car to motorcycle rear-end accidents, which can be applied in reconstruction and biomechanical analysis of such accidents.

This presentation will impact the forensic community by offering insight to the motorcycle and rider kinematics in an increasingly more common accident type that has not been previously addressed in the literature.

The results of a series of automobile to motorcycle rear-end impacts using an instrumented motorcycle with an instrumented live human rider in low speed impacts is presented. The unique kinematic patterns associated with rear-end impacts to motorcycles are demonstrated and their usefulness in support of an analysis of a particular motorcycle rear- end accident is shown by example through a case study. In addition, the post-impact drag of the motorcycle with the fender folded in above the rear wheel demonstrated in instrumented tests is also presented.

In response to higher fuel costs there are increasing numbers of commuters choosing to ride motorcycles and scooters.(1) As a natural consequence, a corresponding increase in collisions involving motorcycles can be expected. Thus, the occurrence of a relatively uncommon collision type, a car rear-ending a motorcycle, can be expected to become more common. A review of the literature did not reveal any previous demonstrations of motorcycle or rider kinematics in low speed rear-end collisions.

Figure 1: A BMW R1100RT on the left that was rear-ended by a Ford Crown Victoria shown on the right.

The BMW rider described seeing the approaching Ford, picking up his feet, and then his BMW was pushed forward perhaps 5 or 6 feet while the fender was tucked under against the wheel. His hands did not come off the handle bars.

The Ford's driver described rolling slowly forward while looking away and then hard braking upon the realization that the BMW was stopped. The Ford bumped the BMW at no more than 2 mph and the rider was jostled and did not lose grip of the handlebars. Afterward the vehicles were separated by the distance of an arm's length.

A BMW R1200RT motorcycle was used for both the drag tests and the rear-end impacts. A rider wearing a helmet, riding jacket and boots was on the BMW during both test series. A Mazda 929 was used as the striking vehicle in the rear-end impacts.

The rollout distance indicated by the witnesses was correlated to the BMW's post-impact speed by estimating the BMW's drag. The drag force was measured with a load cell attached to the BMW's forks. The drag was measured to be 12 pounds with the BMW free rolling and balanced by the rider, and the drag was measured to be 36 pounds while the fender/mud flap was tucked against and rubbing on wheel.

Accounting for the combined weight of the motorcycle and rider, the corresponding deceleration of the BMW while free rolling and with the fender/mud flap rubbing against the rear tire were 0.015 g's and 0.05 g's, respectively.

Using the latter deceleration, the account of approximately 3 feet of post-impact rollout of the BMW corresponds to a post-impact speed of about 2 mph, while the account of about 5 or 6 feet of post-impact movement corresponds to a post-impact speed of the BMW of 3 mph. Therefore, the witness accounts of the BMW's movement after impact corresponds to a post-impact speed generally within the approximate 2 to 3 mph range.

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Next, a series of automobile to motorcycle impacts were conducted. The additional weight of the data acquisition equipment roughly offset the weight of the BMW's rear fender/mud flap and saddle bags, which were removed to prevent damage to those structures.

The Mazda's speed was measured and recorded using a Racelogic VBOXIII which collects speed data accurate within 0.06 mph at 100 Hz using the Doppler shift of GPS satellite signals. The acceleration of the BMW, rider's head, upper thorax and lower torso were measured by triaxial accelerometers that were affixed to a level portion of the BMW's tank, the front of the rider's helmet, as well as the rider's upper thorax at the approximate forward projection of T1 and the lower torso at the approximate location of L5-S1. The acceleration data was recorded with a Diversified TDAS rack with two signal input modules strapped to the luggage rack. The acceleration data was collected at 10,000 Hz and SAE J211 sign conventions were observed.

Using a CAS weight scale, which has a 10,000 per wheel capacity in 5 pound increments, the test weight of the BMW was measured to be 585 pounds. Thus, the total weight of the BMW with the rider was about 800 pounds. Similarly, the Mazda 929's test weight was measured to be 3680 pounds.

The time of contact was signaled to the data collection equipment via a tape switch mounted across the front bumper of the Mazda and across the rear wheel of the BMW. The contact closure also activated a flash affixed to the Mazda's hood to provide a visual signal of time zero.

The BMW rider was about 5 feet, 7½ inches tall and weighed approximately 200 pounds. The rider wore boots, a riding jacket, and a helmet. The rider was aware of the testing protocol and was aware of the impending impact since the approaching car was visible in the BMW's rear view mirrors.

A series of 7 impacts were conducted with contact speeds ranging from 1.1 to 4.6 mph. In no test did the rider loose his grip on the handlebars.

Run	Impact speed (mph)	Rollout (in)
1	1.1	21
2	1.9	2
3	2.4	5
4	4.2	71
5	DL	19
6	3.8	12
7	4.6	66

Table 1: The test series

The BMW bounced away from the Mazda in the 1.1 mph impact resulting in a rollout of 21 inches. The two subsequent impacts resulted in significantly lesser rollouts due to the interaction between the Mazda front bumper and wheel, which tended to retard the motion of both the motorcycle and the car. This significant restriction to forward movement also occurred at higher speeds in runs 5 and 6. In other runs, the rollout was limited to 5 or 6 feet by rider brake application.

Starting at run 3 through the last run, the Mazda's front wheel notably rode up the BMW's rear wheel. This upward motion continued until the Mazda's hood directly contacted the BMW's exposed rear frame below the luggage rack producing hood denting. In run 7, both the Mazda's front wheels lost contact with the ground.

Throughout the demonstrations, rolling of the BMW's wheel while in contact with the Mazda's bumper also produced abrasions through the paint and into the plastic of the bumper cover. With contacts limited to the BMW's rear wheel and fender frame, the motorcycle was undamaged throughout the test series.

Figure 2: Wheel penetration into bumper and hood to frame contact

As seen in figure 3 below, the motorcycle's crash pulse was longer than a typical bumper-to-bumper impact. Throughout the series, the duration of the BMW's acceleration was measured to be within the 130 to

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270 msec range, and its peak acceleration ranged from 0.5 to 3.75 g's.

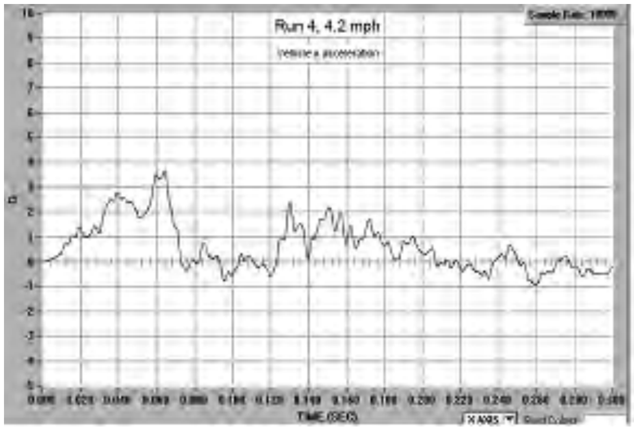

Figure 3: Motorcycle accelerations in Run 4 (4.2 mph)

The longer crash pulse was due to both the softer pole-type contact between the motorcycle wheel and the Mazda bumper, as well as the tendency for the Mazda bumper to ride up onto the BMW's wheel, both of which lengthened the distance over which the BMW was accelerated forward.

In addition to the relatively long duration, high speed video of the final demonstration run reveals that the motorcycle pitched nose-up, further lengthening the distance the rider was accelerated forward.

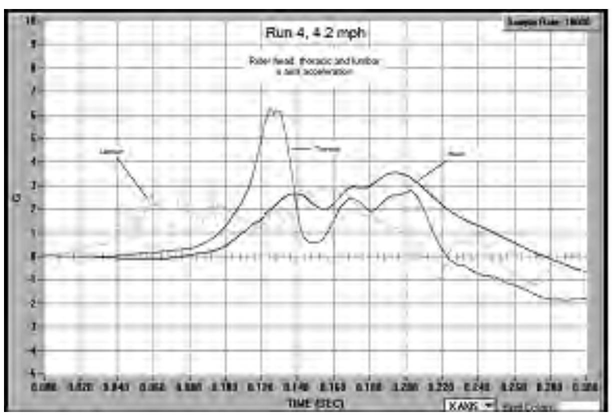

Figure 4: Rider accelerations in Run 4 (4.2 mph)

The rider's buttocks sliding rearward on the seat spread the acceleration of the lower torso over an extended distance, as evident in the long flat lumbar acceleration shown in Figure 4. Also evident is the upper thorax accelerating forward primarily through the rider's arms. The initial peak in the thoracic acceleration corresponds with the rider's arms becoming straight.

Both the sliding of the rider on the seat and the straightening of the arms serve to further lengthen the distance over which the rider as a whole is accelerated forward, thereby reducing the rider's acceleration. The rider's peak head acceleration ranged from 1.2 to 3.6 g's and the average acceleration of the BMW and rider were less than 2 g's throughout the test series. The type of secondary or rebound motion characteristic of car-to-car rear-end impacts was not observed.

Reference:

1 "Cycle Sales Powered by Pricey Gas," William M. Welch, *USA TODAY*, 6/5/2006.

Motorcycle, Rear-End, Kinematics