LOW SPEED BRAKING TESTS OF A FLY-7 ELECTRIC LIMITED USE MOTORCYCLE AND OTHER VEHICLES

By Richard Hermance

BACKGROUND

Micromobility Vehicles such as Electronic Limited use Motorcycles/Mopeds, E-Bikes, and electronic scooters are becoming more and more popular and it follows that there are now many more accidents involving these types of vehicles. Many occur at speeds less than 20 mph. Although many of the machines, especially the limited use motorcycles, are street legal and can be registered, many are not. Their range, ease of charging, lack of needing fuel, relatively simple mechanical construction, abilty to carry a passenger, ease of parking, ease of storage, ability to navigate in tight spaces, abilty to register as street legal, and relatively low price as compared to other legal forms of transportation are reasons these vehicles are so popular.

Injuries caused by electric scooters are an emerging phenomenon, despite existing regulations. There are many studies that analyzed the injuries sustained in these accidents. [Ref. 1-3] When these vehicles collide with cars and trucks, the injuries are often life-threatening or fatal. Most injuries in such accidents are severe and preventable.

Investigation of accidents involving light vehicles can be tricky. Even determining which laws apply to an incident may not be clear cut. For example, researching between the Laws of the State of New York and the Laws of the City of New York, reveals a lack of organization relative to classifications, definitions, and laws. [Ref. 4] As you spread out the conversation about these vehicles across the country, abroad, across various governmental agencies and user groups, the confusion in terminology increases appreciably.

Many start-up companies manufacturing these Limited Electric Motorcycles and micromobility vehicles that are not certified, have no VIN, oftan are illegal to drive on the road. Some of these vehicles are homemade and do not even come with an owners manual.

Visibility, braking, riding location, and lack of safety in many urban areas are potential problems with these vehicles since they are often driven in between stopped and slow moving traffic, sometimes by children. A common accident scenario is when one of these vehicles is approaching a red traffic signal passing in between rows of other vehicles stopped for the traffic signal. In addition, many of these vehicles are not street legal and are not something motorists are expecting to encounter. Conspicuity issues with these small-profile vehicles also come into play.

With many of these accidents occuring at low speed, there is the need to conduct lower speed testing of effective braking drag factors as well as acceleration factors in reconstructing the vehicle dynamics of a case. Unfortunately, there is very little information on these parameters with regard to these vehicles.

The purpose of this article is to share data from recently conducted braking and acceleration tests of these small vehicles.

TEST METHODOLOGY

The main vehicle utilized in the testing was a Fly-7 Electric Limited Use Motorcycle with no modifications. This particular type of vehicle has a 1500 watt brushless electric motor and is historically described more as a Moped. This, along with stand-up e-scooters are two of the most popular types of micromobility vehicles readily seen on urban streets. The stand-up E-Scooters are commonly operated by children.

This Fly-7 vehicle had disc brakes front and rear. Brakes were hand operated, one on each handlebar. It also had rear foot pegs for a rear passenger, a maximum payload capacity of 350lbs, a maximum speed of 30mph, 10X3" new tires, and can be purchased with lead-acid or lithium ion batteries. The vehicle was weighed with a EZ Weigh Scale and found it to be 166lbs. The unit had 3 gears to choose from when riding.

This vehicle also is street legal and had brakes lights, directionals, rear view mirrors, and crash bars all around. Its range is approx. 20-25 miles with a 60V/20Ah Lead-acid battery, 55-65 miles with a 60V/50Ah Lithium-ion battery, and approx. 60-70 miles with a 60V/55AH Lithium-ion battery. The vehicle is shown in Figure 1.

Other light vehicles brake tested were the Jetson LX-10 E-Scooter (Figure 2) and the 2019 CanAm 70cc ATV (Figure 3).

For comparative purposes, additional hard braking tests were performed on a

Figure 1. Fly-7 Electric Limited Use Motorcycle

Figure 2. Exemplar Jetson LX-10 E-Scooter

2023 GMC Sierra (Figure 4), a 2018 Jeep Wrangler (Figure 5) and a 2016 EZ-GO S4 golf cart (Figure 6).

All of the vehicles tested had excellent tires and brakes.

The tests were conducted on a dry, straight, and level semi-polished blacktop driveway, a dry and level straight gravel road, and a dry level straight grass field located at Collison Research Ltd. in Tillson, New York.

In addition, six maximum acceleration tests were conducted on Fly-7. The tests were conducted on the level paved surface and three riders operated the vehicle on different runs.

Four test drivers volunteered to assist in the data generation. Test Driver #1 was 4’4” tall and weighed 110lbs. Test Driver #2 was 5’3” tall and weighed 170bs. Test Driver #3 was 5’8” tall and weighed 160lbs, and Test Driver #4 was 5’9” and weighed 350lbs. The author operated the vehicles during the Wrangler and Sierra tests.

A Vericom VC3000 accelerometer to analyze the acceleration and braking capabilities of the vehicles tested: The minute details and parameters that go with the Vericom VC3000 will not be addressed here since most readers here are pretty much familiar with these units.

A Bushnell Radar Gun Model #101911 was utilized to corroborate the speed numbers generated by the Vericom unit.

Figure 3. Exemplar 2019 CanAm 70cc ATV

Figure 4. 2023 GMC Sierra

Figure 5. Exemplar 2018 Jeep Wrangler

Figure 6. EZ-GO S4 Golf Cart

Figure 7. Paved Test Surface.

Figure 8. Test Rider on Grass Surface

TABLE 1. Individual Braking Test Results

Test No.	Vehicle	Veh./Rider Weight (lb)	Braking	Speed (mph)	Avg. g's	Peak g's	Meas. Device	Test Surface
1	Fly-7	166/170	Both @ 100%	9.59	.45	.68	VC3000	Paved
2	Fly-7	166/170	Both @ 100%	10.8	.49	.99	VC3000	Paved
3	Fly-7	166/170	Both @ 100%	11.7	.41	.68	VC3000	Paved
4	Fly-7	166/170	Both @ 100%	10.3	.38	.55	VC3000	Paved
5	Fly-7	166/170	Both @ 100%	13	.48	.89	VC3000	Paved
6	Fly-7	166/170	Rear @ 100%	11.3	.23	.42	VC3000	Gravel
7	Fly-7	166/170	Rear @ 100%	12.4	.33	.65	VC3000	Gravel
8	Fly-7	166/170	Rear @ 100%	9.0	.23.	.51	VC3000	Grass
9	Fly-7	166/170	Rear @ 100%	10.6	.22	.52	VC3000	Grass
10	Fly-7	166/170	Rear @ 100%	10.9	.37	.57	VC3000	Paved
11	Fly-7	166/170	Rear @ 100%	9.0	.21	.51	VC3000	Grass
12	Fly-7	166/170	Rear @ 100%	10.6	.22	.52	VC3000	Grass
13	Fly-7	166/170	Rear @ 100%	11.3	.23	.42	VC3000	Gravel
14	Fly-7	166/170	Rear @ 100%	12.4	.33	.65	VC3000	Gravel
15	Fly-7	166/170	Rear @ 100%	12.5	.38	.70	VC3000	Gravel
16	Fly-7	166/170	Rear @ 100%	11.7	.37	.54	VC3000	Paved
17	Fly-7	166/170	Rear @ 100%	12.8	.38	.53	VC3000	Paved
18	Fly-7	166/170	Rear @ 100%	14.7	.36	.61	VC3000	Paved
19	Fly-7	166/170	Both @ 100%	9.9	.44	.66	VC3000	Paved
20	Fly-7	166/170	Both @ 100%	9.59	.45	.68	VC3000	Paved
21	Fly-7	166/170	Both @ 100%	12.6	.46	.65	VC3000	Paved
22	Fly-7	166/170	Both @ 100%	15.45	.45	.85	VC3000	Paved
23	Fly-7	166/170	Both @ 100%	12.7	.54	.86	VC3000	Paved
24	Fly-7	166/110	Rear @ 100%	8.36	.28	.63	VC3000	Grass
25	Fly-7	166/110	Rear @ 100%	9.1	.26	.60	VC3000	Grass
26	Fly-7	166/110	Rear @ 100%	11.7	.23	.45	VC3000	Gravel
27	Fly-7	166/110	Rear @ 100%	10.0	.32	.57	VC3000	Paved
28	Fly-7	166/110	Rear @ 100%	11.9	.32	.54	VC3000	Paved
29	Fly-7	166/110	Front @ 80%	12.86	.35	.51	VC3000	Paved
30	Fly-7	166/110	Front @ 80%	16.21	.63	.98	VC3000	Gravel
31	Fly-7	166/110	Front @ 80%	6.8	.61	.99	VC3000	Gravel
32	Fly-7	166/350	Front @ 80%	10.7	.27	.51	VC3000	Gravel
33	Fly-7	166/350	Both @ 100%	10.2	.35	.61	VC3000	Gravel
34	Fly-7	166/350	Both @ 100%	10.8	.49	1.0	VC3000	Gravel
35	Fly-7	166/350	Both @ 100%	11.7	.41	.68	VC3000	Paved
36	Fly-7	166/350	Both @ 100%	13.0	.48	.89	VC3000	Paved
37	Fly-7	166/350	Front @ 80%	10.5	.33	.56	VC3000	Gravel
38	Fly-7	166/350	Front @ 80%	12.0	.38	.61	VC3000	Gravel
39	Fly-7	166/350	Front @ 80%	12.1	.36	.6	VC3000	Paved
40	Golf Cart	1101/390	All @ 100%	13.37	.21	.34	VC3000	Paved
41	Golf Cart	1101/390	All @ 100%	16.3	.22	.35	VC3000	Paved
42	Golf Cart	1101/390	All @ 100%	19.3	.25	.34	VC3000	Paved
43	Golf Cart	1101/390	All @ 100%	21.2	.20	.31	VC3000	Paved
44	ATV	290/110	All @ 100%	15.5	.34	.49	VC3000	Paved
45	ATV	290/110	Rear	10.27	.18	.50	VC3000	Paved
46	ATV	290/110	Front	14.3	.25	.48	VC3000	Paved
47	ATV	290/170	All @ 100%	15.0	.20	.52	VC3000	Paved
48	ATV	290/170	Rear	17	.25	51	VC3000	Paved

Figure 9. Sighting device.

RESULTS

A total of 39 hard braking tests were conducted on the Fly-7. Tests were conducted with both brakes fully applied and with only the front or rear brakes applied. Twenty-five tests were conducted on the paved surface, with initial test speeds ranging from 9.59 to 15.45 mph. Thirteen braking tests were conducted on the gravel surface, with initial test speeds ranging from 11.3 to 16.21 mph. Six braking tests were conducted on the grass surface, with initial test speeds ranging from 8.36 to 10.6 mph.

A total of 11 full braking tests were conducted with the Jeep Wrangler. Three tests were conducted on the paved surface, with initial test speeds ranging from 15.4 to 26.1 mph. Three tests were conducted on the gravel surface, with initial test speeds ranging from 17.3 to 24.9 mph. Five braking tests were conducted on the grass surface, with initial test speeds ranging from 7.3 to 34.7 mph.

Additional hard braking tests were conducted on the paved surface. Three were conducted on the Sierra pickup, four on the EZ-GO golf cart, five on the Jetson E-scooter, and six on the Can Am ATV.

Table 1 presents the complete list of braking test runs and the resultant data.

In addition, six standing start maximum acceleration tests were performed on the Fly-7. The results of these tests are presented in Table 2.

DISCUSSION

As is typical with two-wheel vehicles, the test riders observed stability issues with front wheel only braking tests. It is also worthy to note that the smaller wheels of the Fly-7 and the Jetson made braking with the front brake only that much more difficult. Thus most of the front brake only tests were conducted just below full brake application and front wheel lockup.

The average drag factors observed for the Fly-7 were somewhat lower than the resulting average drag factors observed by Phan et al, [Ref. 5] in which a BMW C-Evolution and a Harley-Davidson Livewire were subjected to test runs of approximately 40 mph. The lower observed drag factors here are not surprising since at low speeds the fully applied brakes often don't reach full force before the test vehicle stops.

The author took advantage of the opportunity add a few data points to the limited research on four-wheel vehicles braking on a gravel road surface. Three tests of the Jeep conducted between 17.3 and 24.9 mph yielded an average deceleration of 0.44 g. This compares to a Canadian study [Ref. 6] in which a Mazda CX5 generated an average

0.57 g. Test speeds were between 12 and 36 mph. Four test runs conducted by Martin [Ref. 7] at speeds of 20 to 26 mph resulted in an average level drag factor of 0.52.

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TABLE 1. Individual Braking Test Results (continued)

Test No.	Vehicle	Veh./Rider Weight (lb)	Braking	Speed (mph)	Avg. g's	Peak g's	Meas. Device	Test Surface
49	ATV	290/170	Front	13	.22	.40	VC3000	Paved
50	Jetson	290/110	Rear @ 100%	6.8	.15	.19	VC3000	Paved
51	Jetson	290/110	Rear @ 100%	10.87	.10	.70	VC3000	Paved
52	Jetson	290/110	Rear @ 100%	12.50	.22	.61	VC3000	Paved
53	Jetson	290/110	Rear @ 100%	8.25	.28	.62	VC3000	Paved
54	Jetson	290/110	Rear @ 100%	9.20	,17	.30	VC3000	Paved
Test No.	**Vehicle**	**Driver**	**Braking**	**Speed (mph)**	**Avg. g's**	**Peak g's**	**Meas. Device**	**Test Surface**
55	Wrangler	RH	All @ 100%	7.3	.37	.52	VC3000	Grass
56	Wrangler	RH	All @ 100%	11.2	.46	.60	VC3000	Grass
57	Wrangler	RH	All @ 100%	17.3	.45	.59	VC3000	Gravel
58	Wrangler	RH	All @ 100%	20.7	.49	.61	VC3000	Paved
59	Wrangler	RH	All @ 100%	22.1	.46	.55	VC3000	Gravel
60	Wrangler	RH	All @ 100%	23.8	.39	.56	VC3000	Grass
61	Wrangler	RH	All @ 100%	24.9	.40	.69	VC3000	Gravel
62	Wrangler	RH	All @ 100%	26.1	.51	.79	VC3000	Paved
63	Wrangler	RH	All @ 100%	28.4	.41	.90	VC3000	Grass
64	Wrangler	RH	All @ 100%	34.7	.41	.73	VC3000	Grass
65	Wrangler	RH	All @ 100%	15.4	.49	.49	VC3000	Paved
66	SIERRA	RH	All @ 100%	21.8	.59	.75	VC3000	Paved
67	SIERRA	RH	All @ 100%	27.8	.69	.82	VC3000	Paved
68	SIERRA	RH	All @ 100%	28.2	.69	.81	VC3000	Paved

TABLE 2. Individual Acceleration Test Results

Test No.	Veh.	Driver Wt. (lb)	Accelera-tion Level	Speed (mph)	Dist. (ft) / Time (sec)	Avg. g's	Meas. Device	Test Surface
69	Fly-7	170	100%	29.3	100 / 4.8	.24	VC3000	Paved
70	Fly-7	350	100%	28.1	100 / 5.3	.22	VC3000	Paved
71	Fly-7	110	100%	30.3	200 / 6.1	.33	VC3000	Paved
72	Fly-7	110	100%	29.4	100 / 4.5	.31	VC3000	Paved
73	Fly-7	170	100%	29.3	100 / 4.7	.28	VC3000	Paved
74	Fly-7	170	100%	29.5	100 / 4.7	.28	VC3000	Paved