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Investigation of Brake Deceleration of Electric Scooter

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GOAL OF THE STUDY

Over the past few years, the use of electric scooters has increased significantly. According to the latest data, there are about 100,000 electric scooters in Bulgaria. Accidents with this type of vehicle are constantly increasing, with serious accidents for the first half of 2025. are about 470, of which 8 are fatal [7]. This article presents a study showing the possibilities for effective braking of the described vehicles. The maximum braking deceleration, average braking deceleration, braking distance and other specific .

METHODOLOGY OF THE INVESTIGATION

Experimental Apparatus

Braking deceleration can be experimentally determined using several approaches

- Accelerometer method (g-test): The negative acceleration is measured using an inertial transducer. This method requires specialized and expensive equipment, which makes it difficult to apply in individual traffic accident cases.
- Fifth wheel method: A specially designed device – a fifth wheel – is attached to the vehicle to measure the distance traveled. By differentiating the distance–time relationship, the speed and acceleration of the bicycle can be obtained. The method is difficult to apply in practice due to the inconvenience of mounting the mechanism on the bicycles under investigation.
- Braking time measurement: The braking time is measured from the moment the braking system is activated until the bicycle comes to a stop, while speed is recorded using a radar device. This method is inaccurate and may lead to significant measurement errors.

For the braking parameter investigations, a device equipped with an accelerometer and suitable for mounting on the tested electric bicycles was used.

Fig. 1. Apparatus

MAIN RESULTS FROM THE STUDY

The studies were carried out on a dry, horizontal road section, new asphalt, without bumps and undergrowth.

Options for braking with front brake, rear brake and both at the same time have been explored.

Tables 2 and 3 present the experimental results obtained at a speed of 30 km/h and the arithmetic mean values of the investigated parameters during the braking process.

TABLE II. EXPERIMENTAL DATA AT 30KM/H

30km/h		Harley Maxi			Xiaomi Mi M365			Kukirin G2 Max		
		test 1	test 2	ave-rage	test 1	test 2	ave-rage	test 1	test 2	ave-rage
Front brake activa-tion	a_{max} [m/s²]	4,92	3,60	**4,26**	4,53	4,15	**4,34**	4,35	4,20	**4,28**
	$a_{average}$ [m/s²]	3,93	2,33	**3,13**	2,15	1,78	**1,97**	3,20	3,05	**3,13**
	V_{stop} [km/h]	31,50	30,10	**30,80**	29,60	31,20	**30,40**	31,20	30,15	**30,68**
	V_{stop} [m/s]	8,75	8,36	**8,56**	8,22	8,67	**8,44**	8,67	8,38	**8,52**
	L_{stop} [m]	7,78	9,71	**8,75**	7,46	9,05	**8,26**	8,63	8,35	**8,49**
	F_{push} [N]	21,50	22,10	**21,80**	22,35	24,10	**23,23**	19,30	25,12	**22,21**
Rear brake activa-tion	a_{max} [m/s²]	6,21	6,12	**6,17**	5,83	5,45	**5,64**	4,65	5,13	**4,89**
	$a_{average}$ [m/s²]	4,92	4,80	**4,86**	3,02	2,58	**2,80**	3,10	3,85	**3,48**
	V_{stop} [km/h]	29,20	30,60	**29,90**	28,88	29,52	**29,20**	29,65	31,60	**30,63**
	V_{stop} [m/s]	8,11	8,50	**8,31**	8,02	8,20	**8,11**	8,24	8,78	**8,51**
	L_{stop} [m]	5,30	5,90	**5,60**	5,51	5,35	**5,43**	7,29	7,51	**7,40**
	F_{push} [N]	15,60	23,40	**19,50**	18,18	26,94	**22,56**	35,21	31,69	**33,45**
Activa-tion all brakes	a_{max} [m/s²]	7,10	7,25	**7,18**	6,73	7,45	**7,09**	6,90	6,15	**6,53**
	$a_{average}$ [m/s²]	5,05	5,20	**5,13**	5,20	6,00	**5,60**	5,60	4,80	**5,20**
	V_{stop} [km/h]	31,50	32,30	**31,90**	32,00	30,22	**31,11**	32,25	29,60	**30,93**
	V_{stop} [m/s]	8,75	8,97	**8,86**	8,89	8,39	**8,64**	8,96	8,22	**8,59**
	L_{stop} [m]	5,39	5,55	**5,47**	5,87	4,73	**5,30**	5,82	5,50	**5,66**
	F_{push} [N]	20,90	25,10	**23,00**	22,00	26,30	**24,15**	22,10	25,38	**23,74**

TABLE III. AGGREGATED DATA

Electric scooter		Average value at 20km/h	Average value at 30km/h	Average value
Front brake activation	a_{max} [m/s²]	4,38	4,29	**4,34**
	$a_{average}$ [m/s²]	2,32	2,74	**2,53**
	V_{stop} [km/h]	20,81	30,63	**25,72**
	V_{stop} [m/s]	5,78	8,51	**7,14**
	L_{stop} [m]	3,87	8,50	**6,19**
	F_{push} [N]	16,83	22,41	**19,62**
Rear brake activation	a_{max} [m/s²]	4,86	5,57	**5,21**
	$a_{average}$ [m/s²]	2,67	3,71	**3,19**
	V_{stop} [km/h]	20,44	29,91	**25,17**
	V_{stop} [m/s]	5,68	8,31	**6,99**
	L_{stop} [m]	3,38	6,14	**4,76**
	F_{push} [N]	19,02	25,17	**22,09**
Activation all brakes	a_{max} [m/s²]	6,25	6,93	**6,59**
	$a_{average}$ [m/s²]	4,84	5,31	**5,08**
	V_{stop} [km/h]	20,52	31,31	**25,92**
	V_{stop} [m/s]	5,70	8,70	**7,20**
	L_{stop} [m]	2,91	5,48	**4,19**
	F_{push} [N]	22,69	23,63	**23,16**

CONCLUSIONS

For an electric scooter when braking from a speed of 20km/h with front brake, the maximum braking deceleration is 4.38m/s2, when braking with rear brake, the maximum braking deceleration is 4.86m/s2, when braking with both brakes applied, the maximum braking deceleration is 6.25m/s2.

When braking from a speed of 30 km/h with the front brake, the maximum braking deceleration is 4,29m/s2, when braking with rear brake, the maximum braking deceleration is 5,57 m/s2, when braking with both brakes applied, the maximum braking deceleration is 6,93m/s2.

The average maximum braking deceleration for an electric scooter when braking with front brake is 4,34m/s2, when braking with rear braking, the maximum average braking deceleration is 5,21m/s2, when braking with both brakes applied, the average maximum braking deceleration is 6,59m/s2.

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