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Investigation of Brake Deceleration of Electric Bicycles

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GOAL OF THE STUDY

Over the past few years, the use of electric bikes has increased significantly. Accidents with this type of vehicle are constantly increasing, due to the continuous increase in their number. Electric bikes are generally treated as upgraded bikes for driving up to a certain speed (usually up to 25 km/h) and do not need a license or registration as motorcycles if they meet bicycle standards. This article presents a study showing the possibilities for effective braking of the described vehicles. The maximum braking delay, average braking delay, braking distance and other specific parameters in an emergency braking situation are examined.

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.
- Sled method: A specially designed sled with a rubber pad is towed, and the pulling force – representing the frictional force between the sled and the road surface – is measured using a dynamometer. This method is highly inaccurate, as it does not account for the dynamics of bicycle braking, the influence of tires, or weight redistribution between the wheels.

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

MAIN RESULTS FROM THE STUDY

The experiments were conducted on a dry, horizontal road section with new asphalt, free of irregularities and deformations. All tests were carried out under identical external conditions, with the asphalt surface temperature maintained at 28 °C.

Braking scenarios were examined using the front brake, the rear brake, and both brakes simultaneously.

Tables 2 and 4 present the experimental results obtained at a speed of 20 km/h and the arithmetic mean values of the investigated parameters during the braking process.

TABLE II. EXPERIMENTAL DATA AT 20 KM/H

20km/h		„RK5 Motor RV10"			HYBRID RACE 750 OLV			Average value
		test 1	*test 2*	*average*	*test 1*	*test 2*	*average*	
Front brake activation	a_{max} [m/s²]	6,17	6,84	**6,51**	5,96	5,72	**5,84**	*6,17*
	$a_{average}$ [m/s²]	2,75	2,89	**2,82**	4,76	3,37	**4,07**	*3,44*
	V_{stop} [km/h]	20,51	21,21	**20,86**	21,87	20,47	**21,17**	*21,02*
	V_{stop} [m/s]	5,70	5,89	**5,79**	6,08	5,69	**5,88**	*5,84*
	L_{stop} [m]	2,25	2,53	**2,39**	3,09	2,82	**2,96**	*2,67*
	F_{push} [N]	29,67	31,58	**30,63**	20,92	20,23	**20,58**	*25,60*
Rear brake activation	a_{max} [m/s²]	4,23	5,06	**4,65**	5,17	5,42	**5,30**	*4,97*
	$a_{average}$ [m/s²]	2,81	3,60	**3,21**	3,49	3,26	**3,38**	*3,29*
	V_{stop} [km/h]	22,87	20,95	**21,91**	21,09	21,48	**21,29**	*21,60*
	V_{stop} [m/s]	6,35	5,82	**6,09**	5,86	5,97	**5,91**	*6,00*
	L_{stop} [m]	4,76	3,35	**4,05**	3,32	3,28	**3,30**	*3,68*
	F_{push} [N]	24,34	25,35	**24,85**	24,47	22,15	**23,31**	*24,08*
Activation all brakes	a_{max} [m/s²]	6,77	7,25	**7,01**	7,24	7,12	**7,18**	*7,10*
	$a_{average}$ [m/s²]	4,59	5,12	**4,86**	5,15	5,06	**5,11**	*4,98*
	V_{stop} [km/h]	21,66	20,28	**20,97**	21,89	21,05	**21,47**	*21,22*
	V_{stop} [m/s]	6,02	5,63	**5,83**	6,08	5,85	**5,96**	*5,89*
	L_{stop} [m]	2,67	2,19	**2,43**	2,55	2,40	**2,48**	*2,45*
	F_{push} [N]	29,94	30,26	**30,10**	24,47	20,78	**22,63**	*26,36*

TABLE IV. SUMMARY DATA

Electric bicycles		Average value at 20km/h	Average value at 30km/h	Average value
Front brake activation	a_{max} [m/s²]	6,17	6,56	**6,37**
	$a_{average}$ [m/s²]	3,44	4,52	**3,98**
	V_{stop} [km/h]	21,02	29,93	**25,47**
	V_{stop} [m/s]	5,84	8,31	**7,08**
	L_{stop} [m]	2,67	5,30	**3,98**
	F_{push} [N]	25,60	33,03	**29,32**
Rear brake activation	a_{max} [m/s²]	4,97	5,06	**5,01**
	$a_{average}$ [m/s²]	3,29	3,43	**3,36**
	V_{stop} [km/h]	21,60	30,53	**26,06**
	V_{stop} [m/s]	6,00	8,48	**7,24**
	L_{stop} [m]	3,68	7,16	**5,42**
	F_{push} [N]	24,08	34,62	**29,35**
Activation all brakes	a_{max} [m/s²]	7,10	7,25	**7,17**
	$a_{average}$ [m/s²]	4,98	5,34	**5,16**
	V_{stop} [km/h]	21,22	29,95	**25,58**
	V_{stop} [m/s]	5,89	8,32	**7,11**
	L_{stop} [m]	2,45	4,78	**3,62**
	F_{push} [N]	26,36	27,56	**26,96**

CONCLUSIONS

For the electric bicycle, at a braking speed of 20 km/h with the front brake, the maximum deceleration was 6.17 m/s²; when braking with the rear brake, the maximum deceleration was 4.97 m/s²; and when both brakes were applied simultaneously, the maximum deceleration was 7.10 m/s².

At a braking speed of 30 km/h with the front brake, the maximum deceleration was 6.56 m/s²; when braking with the rear brake, the maximum deceleration was 5.06 m/s²; and when both brakes were applied simultaneously, the maximum deceleration was 7.25 m/s².

The arithmetic mean of the maximum braking deceleration for the electric bicycle was 6.37 m/s² when braking with the front brake, 5.01 m/s² when braking with the rear brake, and 7.17 m/s² when braking with both brakes engaged.

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