INFLUENCE OF A ROAD SURFACE ON A MOTORCYCLE BRAKING PROCESS

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Abstract

The most important aspect of constructions of vehicles is safety. In motorcycles, in contrast to cars is not common to use elements of passive safety which minimalize consequences of collision. Therefore the most important is to ensure the proper possibility to avoid crash that is the adequate level of active safety which is mostly the brake system. It is often assisted by the construction which prevents the wheels to block, however the majority of motorcycles are still not equipped in this kind of system. In order to determine the effectiveness of working of the brake system and its impact on motorcycle's movement safety, it is necessary to focus on case of emergency braking, that is delaying, to full stop where important is to reach the maximal possible delay in the shortest period of time. Because of the changes in road surface, important is to be aware of releasing or stopping the motorcycle in different conditions. It permits us to react properly and avoid dangerous situations in case of noticing a surface with different adherence.

The purpose of the research is to analyze changeability braking process depending on different surfaces on which the motorcycle is moving. The research was carried out on one motorcycle and four different surfaces, reflecting the conditions of every day use of vehicle. It was dry, wet and destroyed asphalt, and gravel surface. Comparing the value of delay, its process and stability in time, velocity of accumulation and way of braking obtained on different surfaces.

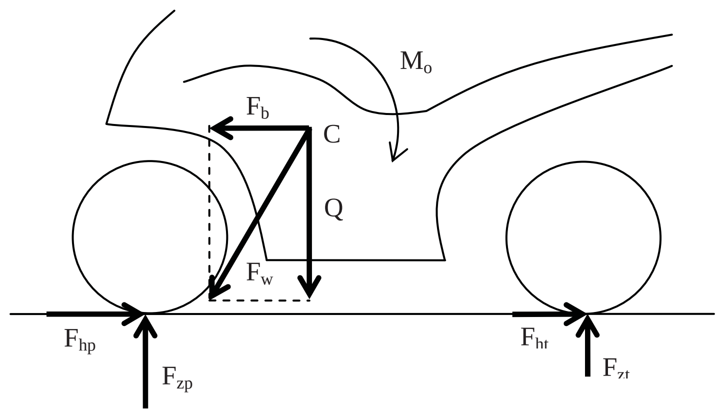
Keywords: *safety, motorcycles, braking process, deceleration*

1. Introduction

Braking is a process of lowering speed of a vehicle. In a particular case leads to stop. Is also one of the most important factors affecting safety while driving. During this process many significant changes occurs concerning parameters of tires and arrangement of pressure. In the simplest form course of braking may be shown in a few stages [1, 2]. The stage of driver's reaction starts when the driver notices an obstacle and finishes when the driver starts pushing break pedal. Duration of this stage depends on the driver, his psychophysical efficiency, concentration, faster of making decision about the necessity of braking and faster of action. The second stage of course of braking starts with pushing the break pedal. Since this moment till the appearance of deceleration, brake master cylinder must create proper pressure of liquid in brake pipe, which has to move pistons in clamp and in the effect to press brake blocks to shield. Big impact on the course of this stage has construction and state of the braking system. The third stage delay of reaction of brake, like in the last one, not much depends on driver, mainly on technical condition of braking system, especially on type and properties of frictional components. The fourth stage called proper braking is the most important stage from the whole process, because braking has the highest value of delay and lasts till the vehicle stops. In case of ideal course of braking, the deceleration should be stable during whole stage, and time of lasting depends mainly on the speed of vehicle and the value of obtained deceleration [3]. However the value of deceleration depends mainly on the type and condition of the road surface, construction and state of the braking system, mass and geometry of vehicle, condition of tires, air pressure in tires and technical condition of suspension system [3-5]. The last stage is the reverse braking during which the value of the lag is rapidly decreasing and vehicle is stopped. This stage is often being skipped because of little impact on the whole process of braking.

Location of the centre of gravity of the motorcycle has the cardinal impact on the course of safe braking. Motorcycle is a vehicle in which the location of centre of gravity changes very often. With regard to relatively small mass of this vehicle, the big significance has the weight of the motorcyclist, his position on the motorcycle, the weight of baggage and its location. Also important is the possibility of free movement of the motorcyclist in regard to motorcycle. During the braking, when on the vehicle and the driver works big inertial force, motorcyclist moves forward, and front suspension weighs down, pressure layout on wheels changes essentially. The pressure layout on axles depends on obtained deceleration of braking and construction of motorcycle, precisely on location of the centre of gravity. The larger the value of deceleration with which the motorcycle brakes, the more the weight of the motorcyclist moves to the front, and the higher pressure on the first wheel and lower on the back wheel. In the Fig. 1 and 2 are presented schemes of action of inertial force and the weight of motorcycle with driver.

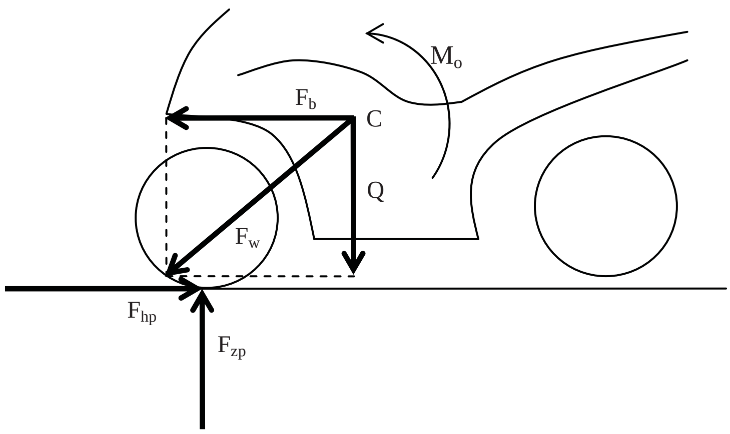
Case 1



During average braking, resultant force F_w crosses the road surface behind the front wheel. This force causes prevention of rotation of the motorcycle around the point of junction of the tire with the surface that is turning back [1, 6].

Fig. 1. Diagram of the action of force on motorcycle during safe braking

Case 2



During sudden braking, inertial force gets bigger and in consequence resultant force F_w crosses the road in front of the wheel, trying to rotate the motorcycle around the point of junction the tire with the surface leading to a dangerous situation of lifting the back wheel of the motorcycle [1, 6].

Fig. 2. Diagram of emergence of moment rotating motorcycle over front wheel

2. Measuring device and research object

Measurement of the lag of braking were carried out by means of decelometer, destine to measure the value of deceleration, braking distance, the time of braking, and the initial speed of braking of different types of vehicles. The device is shown in Fig. 3.

The device makes the measurement automatically, after obtaining the required speed of 30 [km/h] by the vehicle. After executing the measure, the device shows the results, and records the whole

Fig. 3. Decelometer - Brake Test LWS-2MC with acceleration sensor

course of braking in the memory. In research was used the motorcycle Yamaha FZ6 Fazer made in 2004. Technical data of the motorcycle are shown in Tab. 1.

Tab. 1. Technical data of motorcycle Yamaha FZ6 Fazer

Size (length/height/width)	2095 mm/1215 mm/750 mm
Height of seat	795 mm
Span of axles	1440 mm
Mass (tare/admissible)	207 kg / 397 kg
Tires	tubeless, Bridgestone BT 020F GG, year of production 2004
Size of tires (front/back)	120/70 R17 / 180/55 R17
Front brake	dual, disc, dual piston floating clamp, hydraulic, hand-operated, diameter of disc 298 mm
Back brake	single, disc, single piston floating clamp, hydraulic, foot-operated, diameter of disc 245 mm
Front suspension	telescopic crutch, cushion spring, oil repression, stroke 130mm

2.1. Way of making the research

In motorcycle very difficult is precise dosage of braking force of the back brake. That is why for enlarging the comparability of the research results, braking was happening only with the usage of the front brake. The measurement sensor was mounted to the front wing, while the measuring device was in a special bag mounted on the tank of motorcycle. Every time before making the measurement, the sensor was levelled. After starting up the device, measurement was started automatically in the time of reaching the proper speed, and finished after the vehicle stopped. During making the measurement, air temperature was 16°C, tire pressure in the front wheel before heating came to 2.25 bar, tires and brakes were heated by several prior braking. During the measurement the mass of motorcycle with driver was 280 kg. In the first turn was made the measurement of new asphalt surface (Fig. 4a), than destroyed asphalt surface (Fig. 4b), and gravel surface (Fig. 4c). After all the measurements were made after little rain falls.

3. Results of the research and calculations

Three measures of the deceleration were made on each of analyzed surface. Exemplary obtained courses of deceleration are shown in Fig. 5. On the basis of obtained data, the biggest dimensions needed to characterize the course of braking were calculated:

a) b) c)

Fig. 4. Surfaces on which measurements were made – a) new asphalt, b) destroyed asphalt, c) gravel

- average full lag of braking a_m:

$$a_m = \frac{V_b^2 - V_e^2}{25.92 \cdot (S_e - S_b)} \left[\frac{\mathrm{m}}{\mathrm{s}^2}\right], \tag{1}$$

- distance of braking S:

$$S_h = V_p \cdot \frac{t_n}{2} + \frac{V_p^2}{2 \cdot a_m} \, [\mathrm{m}], \tag{2}$$

- intensity of braking:

$$z_1 = \frac{a_m}{g}, \tag{3}$$

- maximal obtained coefficient of adherence in tire-surface system:

$$u_{p1} = \frac{a_{h\max}}{g}, \tag{4}$$

where:
V_p - initial speed of starting braking [km/h],
V_b - speed of vehicle equivalent to 0.8 V_p, [km/h],
V_e - speed of vehicle equivalent to 0.1 V_p, [km/h],
S_b - distance travelled between V_p and V_b, [m],
S_e - distance travelled V_p and V_e, [m],
$a_{h\max}$ - maxima deceleration of braking obtained during the test [m/s^2],
t_n - time of growth of braking force [s].

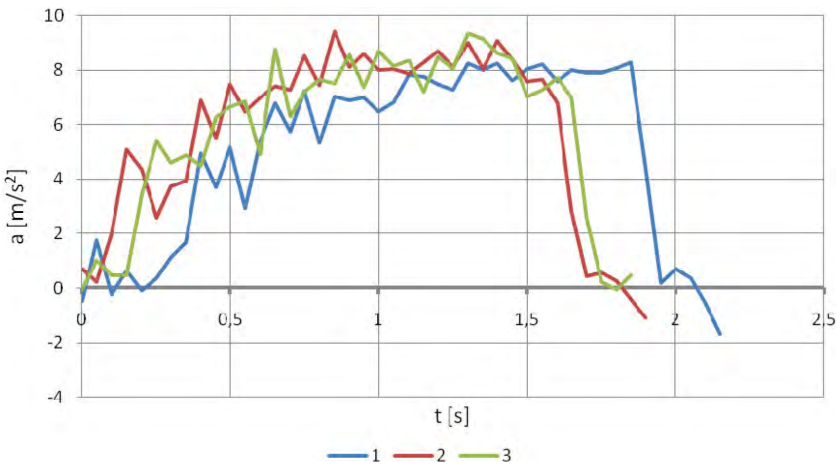


Fig. 5. Combination of the courses of deceleration on dry asphalt surface

Inequalities of the lines are caused by changes in tire adherence to the surface. On gravel, rough, loose and slippery surface, the occurrence is very big. In addition, partial wear of dampers of front suspension of the motorcycle may intensify disturbance of the course of deceleration. From the diagram we may determine stage of growth of the deceleration, stage of stability of the deceleration and the fall of the deceleration.

3.1. Analysis of the research results on various surfaces

Four chosen courses of deceleration compared one from each surface. It is presented in a common diagram in Fig. 6, however the values of several calculated sizes are presented in Tab. 2.

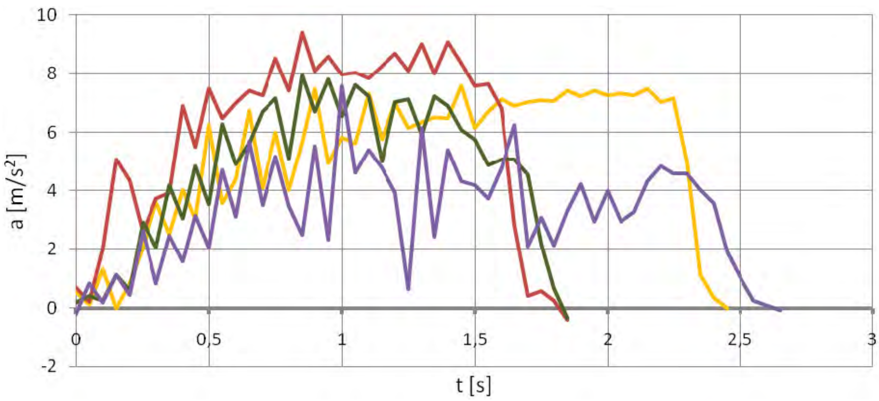


Fig. 6. Combination of the courses of deceleration on various surface, yellow - wet asphalt, red – dry asphalt, green – destroyed asphalt, blue - gravel

Tab. 2. Combination of values of sizes describing the course of braking on various surfaces

	Type of surface			
	Wet asphalt	Dry asphalt	Destroyed asphalt	Gravel
Initial Speed of braking, V_p [km/h]	46.07	39.84	31.75	31.07
Time of braking, Δt_c [s] (comparison not authoritative because of different initial speeds)	2.45	1.85	1.85	2.65
Maxima deceleration, a_{hmax} [m/s^2]	7.57	9.07	7.94	6.26
Distance of braking received/calculated, S [m] (comparison not authoritative because of different initial speeds)	17.98/17.99	10.82/10.88	9.21/8.78	12.06/12.68
Average full deceleration of braking, a_m [m/s^2]	6.52	7.81	6.57	4.04
Intensity of braking, z [-]	0.66	0.80	0.67	0.41
Adherence coefficient, μ_p	0.77	0.92	0.81	0.64

Absolutely the most effective braking is on dry, smooth asphalt surface. All sizes and parameters obtained on this surface are the most favourable comparing to other tested surfaces. On the diagram we see that the growth of deceleration is the fastest in the proper stage of braking, the deceleration stays in the stable, the biggest level among tested, and at the end of braking suddenly falls. Diversity of values of the diagram is moderate because of smooth and clean surface.

A little bit weaker effective braking is on the same surface but wet. Deceleration grows slower but not lazy. A lot of time passes before the highest value is obtained, which due to presence of water is anyways lower than on dry surface. It causes that the force of braking is not used in the initial stage. In dependence on the amount of water on the surface, stronger or weaker strokes of deceleration appear. Nevertheless whole braking precedes stable.

Destroyed, rough and locally dirty asphalt characterizes with values of sizes describing the process of braking similar to smooth but wet surface. Problems with maintenance proper contact of tire and destroyed surface reveal in bigger strokes of the value of deceleration and lower stability of drive than previously. The tire block more often, thus possibilities of braking are limited. Despite that the speed of growing of the deceleration is similar to the wet surface, the fall of value of the deceleration is milder and causes losses as unused possibilities of braking.

Definitely the worst tested surface in case of effectiveness of braking is gravel surface. Its structure is effectively restricts possibility of braking. The tire once touches loose rocks and than sandy surface, in results value of deceleration changes rapidly depends on not big adherence coefficients of proper surface. The course of deceleration is strongly diversed, but nevertheless all stages characterizing course of braking are well-defined.

4. Final conclusions

On the basis of analysis of conducted research, can be concluded that:

- course and effectiveness of braking of motorcycle changes in dependence of surface on which the motorcycle moves. The worst quality and lower adherence of surface the lowers the effectiveness of braking,
- course and effectiveness of braking of motorcycle changes also in dependence on atmospheric conditions. Measures for the surface after rain fall, display visible worsening of braking.
- maximal obtained value of braking characterizes only temporary adherence of surface, without taking under consideration other factors as roughness, dirt, water, and is not good indicator while considering the braking process as a whole,
- beside obtained values of maximal and average full deceleration, very big impact on general effectiveness of braking has the speed of growing of the deceleration. Slow growth causes that motorcycle moves with high speed longer, and that is why covers a longer distance from the beginning of braking till the vehicle stops,
- significant impact on maintenance proper contact between tire and surface during process of braking has the technical condition of front suspension of motorcycle, thus has essential influence on general effectiveness of braking.

References

[1] Mitschke, M., *Dynamika samochodu - Napęd i hamowanie*, Wydawnictwa Komunikacji i Łączności, Warszawa 1987.
[2] Leiter, R., *Hamulce samochodów osobowych i motocykli*, Wydawnictwa Komunikacji i Łączności, Warszawa 1998.
[3] Broughton, P. S., Fuller, R., Stradling, S., Gormley, M., Kinnear, N., O'Dolan, C., Hannigan, B., *Conditions for speeding behaviour: A comparison of car drivers and powered two wheeled riders*, Transportation Research, Part F 12, 2009.
[4] Langley, J., Mullin, B., Jackson, R., Norton, R., *Motorcycle engine size and risk of moderate to fatal injury from a motorcycle crash*, Accident Analysis and Prevention 32, 2000.
[5] Guo, L, Jin, X. L., Zhang, X. Y., Shen, J., Chen, Y. J., Chen, J. G., *Study of injuries combining computer simulation in motorcycle–car collision accidents*, Forensic Science International, Vol. 177, 2008.
[6] Cossalter, V., *Motorcycle Dynamics*, Lulu, Editor 2006.