RESEARCHING MOTORCYCLE'S STABILITY AT MOTION

Branislav Aleksandrović [1]MSc, Teaching Assistant, Rajko Radonjić [2], PhD, Professor, Dragoljub Radonjić[3], PhD, Professor, Aleksandra Janković[4], PhD, Professor

UDC:629.016

INTRODUCTION

Dynamic characteristics of motorcycles, the conditions and the way of its usage, significantly effect on the behaviour of the driver - a motorcycle and traffic safety. Statistical analyses show that motorcycles are common cause of traffic accidents with severe consequences. The paper [1] presents the data analysed from statistical sample, showing that motorcyclists have 37 times greater probability to cause a traffic accident and 8 times greater probability that doing so he could be more injured compared to the injuries of the driver of passenger car. In paper [2] illustrative data are also presented, about percentage participation of victims in road traffic for two categories of participants, 52% cars, 24% single-track vehicles, of which, mopeds 5%, 6% bicycles, motorcycles 13%. Results of statistical analysis obtained for certain regions of the Republic of Serbia show an increasing number of traffic accidents in which motorcycles participated. [1].

In addition to statistics data regarding on road accidents involving motorcycles, in numerous paper works and studies in this field, the factors that have led to accidents were analysed, as well as the preventive measures for consequence reduction or their exclusion [3], [4], [5]. The specification of these factors is in relation to the goal of this research and in certain way it points out interactive conjunction system; the driver - a motorcycle - the road - the environment, therefore, the distribution of their functions and responsibilities on provoked traffic accidents in all three phases of the relevant events.

In our previous works we have analyzed some of impacting factors as the consequence of motorcycle's potential adverse properties compared to two trace vehicles, [3]. Following impacts are highlighted as dominant: 1 / motorcycle's open support structure that does not provide an integrated protective space for the driver and passenger, with unfavourable conditions of contact seats, supporting structure, brackets, controls, 2 / significant impact of driver's and passenger's body mass on dynamic characteristics of the motorcycle, 3 / the absence of its own stability in vertical position and at movement, which significantly complicates the steering function and increase the level of mental and physical stress. In this sense, numerous conducted expertises also show that the integrity and stability of the motion system, motorcycle - the driver - (co-driver), has a crucial influence on the number of traffic accidents and their consequences [5].

Bearing in mind the above presented approaches on current issues regarding motorcycle's safety, in subsequent chapters of this work are presented an approach of

---

1 Branislav Aleksandrović, Technical College of Appiied Studies Kragujevac, Kosovska 8, Kragujevac, Serbia, banealeksandrovic@gmail.com
2 Rajko Radonjić, Ph.D.,full prof., University of Kragujevac, Faculty of Engineering, Sestre Janjić 6, Kragujevac, Serbia, rradonjic@kg.ac.rs
[3] Dragoljub Radonjić, Ph.D.,full prof., University of Kragujevac, Faculty of Engineering, Sestre Janjić 6, Kragujevac, Serbia, drago@kg.ac.rs
[4] Aleksandra Janković, Ph.D.,full prof., University of Kragujevac, Faculty of Engineering, Sestre Janjić 6, Kragujevac, Serbia, alex@kg.ac.rs

theoretical - experimental research of motorcycle's stability at characteristic modes of motion.

The body of the paper is written using the Text body style. The first line of the paragraph is not indented. Live a blank line between the paragraphs. Do not leave a line of space above and below the headings.

OBJECTIVE

During planning of the research within this paper work, the following goals were settled:

1. certain results about system behaviour during traffic accidents will be analysed in terms of the ability to identify the influencing factors and their further evaluation through theoretical - experimental studies,

2. to form appropriate models and experimental system for such research. The first segment of the research is presented concisely, in this chapter, and the second in the following subsections.

The fact is that the motorcycles do not have seat belts or closed space for driver and passenger protection, thus they cannot prevent them from freely and unexpected moving in space at different stages of traffic accidents. In many cases, it was confirmed that the driver fell off the motorcycle before an accident occur; this is the reason why his injuries were more severe. It is found significant correlation between the number of falling of the driver from the motorcycle and incorrect braking. The term incorrectly braking, in traditional braking system, means untimely response, inadequate selection of braking strategy, or using prospective properties of braking only by the front, only by the rear wheel, with both wheels at the same time, or by the specified "algorithm", and then, panic braking over the limit of tire-road adhesion.

With the above quoted facts it should be noted that most modern motorcycles possesses separate braking systems; front wheels breaking by the manual control of the right hand, and the rear wheel breaking via foot controls by right leg. This concept of braking system gives the driver more options to choose the appropriate braking strategy in some regular conditions. However, the unexpected and stressful situations, this concept often leads to mistakes, in the form of reflex and panic braking [6], [7]. For these reasons, the structural integrity of the system, driver - motorcycle, i. e., the stability of its movement during braking is an actual problem, and that's why this subject is chosen to be studied in this paper work.

DYNAMIC MODELS OF MOTORCYCLES

As the base for simulation studies in this work was used the physical model of longitudinal - vertical dynamics of motorcycles, shown in Figure 1.b, which is created on the basis of appearance and technical characteristics of motorcycle, shown in Figure 1.a which was also used for the experimental researches.

In Figure 1.b are presented some basic parameters crucial for mathematic model creation, which are presented by the equations, (1), (2) and (3):

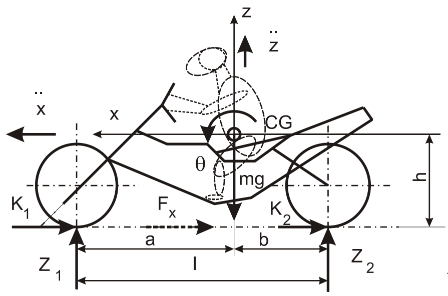
$$m\ddot{x} = F_x + R_f + R_v + R_\alpha \quad , \tag{1}$$

$$m\ddot{z} = f_z\left(Z_f, Z_r C_{zi}, v\right) \quad , \tag{2}$$

$$J_\theta \ddot{\theta} = f_\theta\left(Z_f, Z_r, a, b, l, h, F_x, C_{\theta i}, v\right) \quad , \tag{3}$$

where: F_x – is longitudinal force between contact surface of the road and the wheels, driving or braking force, or their resultant, depending on the observed cases, R_f, R_v, R_α - rolling resistance, air, inclination - respectively; Z_f, Z_r - vertical forces on the front and rear wheel - respectively; C_{zi}, $C_{\theta i}$ – parameters of aerodynamic forces and moments in the vertical - longitudinal plane, v - speed of movement, a, b, h - the coordinates of the center of masses, l – distance between the front and the rear wheel. Model (1) is given in the developed, explicit form, while models (2) and (3) are given in an implicit condition of variables and impacting parameters.


a)



b)

Figure 1 a) apperiance of experimental motorcycle, b) physical motorcycle model.

The structure and parameters of the mathematical models (1), (2) and (3) enable studying of interaction of relevant dynamic values in the longitudinal and vertical plane in the process of motorcycle's acceleration and braking, in order to establish criteria for evaluation of system stability at motion under these regimes. Some practical issues of stability at motion of the motorcycle in the longitudinal - vertical plane, related to the possibility of rolling over, blocking of the wheels, sliding, changing the trajectory, losing manoeuvrability and similar, were discussed in this paper work, using simulation models which were formed on the basis of above presented mathematical models, (1), (2), (3).

Illustrative examples of simulation results of braking process are given in Figure 2. Figure 2.a shows the redistribution of vertical dynamic loads on the wheels depending on longitudinal deceleration at braking. Based on this image it can be seen that increasing the intensity of braking, respectively, longitudinal deceleration on the rear wheel is relieved while the front, for the same grade is additionally burden in relation to the static loads. The graphics are given for two variants of distribution of the static load along the axle: 1/symmetric, $G_1=G_2$, and asymmetric, $G_1<G_2$, in both cases at $x''=0$. Appropriate variation of braking force depending on longitudinal deceleration, for these two cases, is presented in Figure 2.b. From motorcycle's stability at motion viewpoint characteristic is the braking regime when rear wheel loose the contact i.e., when it is being separated from the soil. For a symmetrical load distribution this will happen at longitudinal deceleration of 8.4 m/s^2 and for the asymmetric, at 10.2 m/s2, according to the conditions presented in Figure 2.a, $Z_{2i}=0$. In these conditions, front wheel receives the total weight of the motorcycle, $Z_{1i}=G$ and achieves the total braking force, $K_{1i}=K$.. These relations can lead further to blocking of the front wheel, to its sliding in longitudinal-lateral direction and complex motorcycle movements along the front wheel, up to roll over.

Loosing stability of motion while motorcycle is braking, because one of the wheels is blocked, at the different strategies of braking, may be considered on the basis of the simulation results given in Figure 2.c, and Figure 2.d. For symmetrical load distribution, according to Figure. 2.c, and when braking is achieved only with the rear wheel, required adhesion coefficient φ_2, reaches a boundary value at decelerating of 2.8 m/s^2, and it leads to a wheel blocking, it means, it leads to further braking inefficiency and unstable movement. Braking only with the front wheel, the limit value of the required coefficient of adhesion, φ_1, is in the domain over 10m/s^2, of longitudinal deceleration values, that means, above the value of the deceleration at which the rear wheel lose the contact with the ground, for this case – above value 8.4 m/s^2. In the case of simultaneous braking with both wheels in the domain of stable movement, the boundary values of slowing reduction in contact between rear wheel and the ground, the values of the required coefficient of adhesion, φ are the lowest. In the case of asymmetric load distribution, as it is shown in Figure 2.d, the boundary values, for deceleration parameters which were analysed in the previous segment, were shifted for φ_2, at 3.8m/s^2, Z_2=0, to 10.2 m/s^2, at efficient and stable braking with both wheels and with front wheel even over 10 m/s^2, respectively.

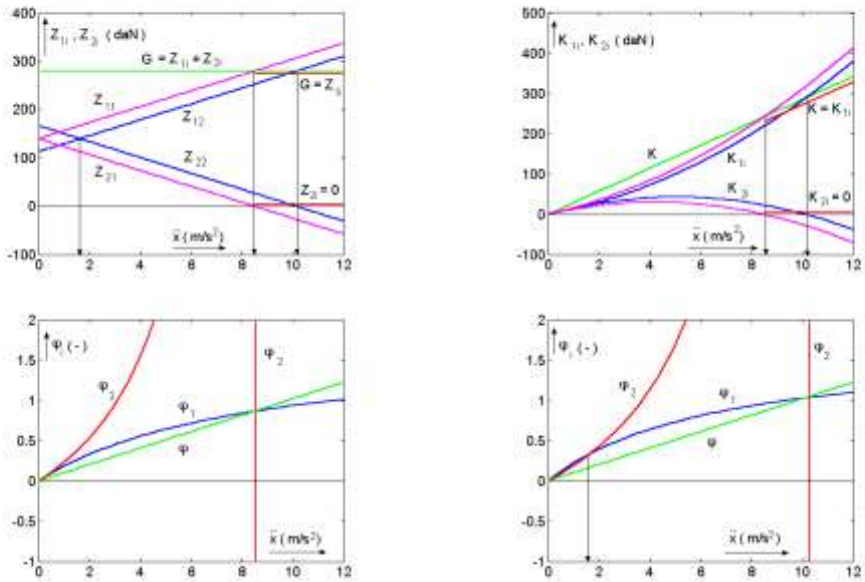
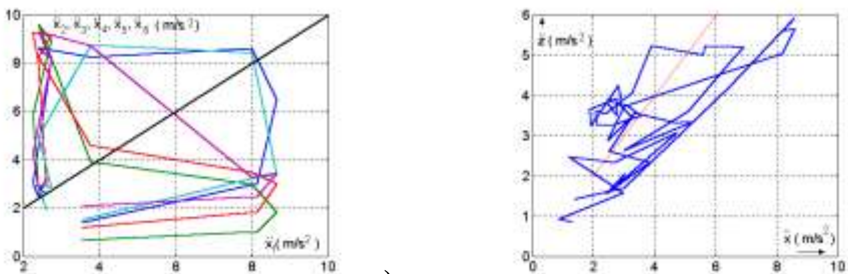


Figure 2 The results of motorcycle braking simulation depending on longitudinal deceleration: a/ vertical force, b/ braking force, c/ d/ required values of adhesion coefficient.

A part of the experimental results presented in this paper, should confirm some of the findings about simulation studies regarding boundary deceleration and domain of efficient braking and also about the stable movement of the motorcycle. Experiments were conducted with the motorcycle and the measurement system shown in Figure 1a. The measurement system includes 4 measuring locations, with six measuring values: vertical acceleration at the centers of the wheels, vertical, longitudinal and lateral acceleration of the center of mass of the system motorcycle-driver and turning angle of the steering forks. Measured signals were inserted into the PC electronic measurement system called “Spider 8” produced by “HBM”, that includes the components for preparation, further processing, storage and transmission of data by the computer systems. In this specific case, from eight available channels, that measuring system possess, 6 of them were engaged, and for the purposes of this study, the data obtained from three measuring channels are presented in this paper, same as the components of the acceleration/deceleration of the center of mass of the system. The results are shown in Figure 3.a and Figure 3.b.

The results shown in Figure 3.a, show the mutual relations of the wheels deceleration for 6 repeated braking, at the same conditions and at the same initial speed. The condition of ideal repeatability for this experiment is defined by linear relation of deceleration variation in the first and subsequent experiments, which is presented by the straight line in the Figure 3a. Deviation of hysteresis loops from this direction presents the effects of many factors during experiments performing and also it shows the efforts of drivers to optimize their action, it means, to achieve a boundary deceleration at braking, and yet to maintain stable movement. In doing so, the extreme values of the deceleration up to 8.4 m/s2 at abscissa axis and up to 9.85 m/s2 on ordinate axis, (in some cases) were achieved, and they are compliant with the above analyzed simulation results. The same levels are also visible on the presentation of motorcycles vertical and longitudinal dynamics interaction presented in Figure 3.b.



a) b)

Figure 3 Experimental results about researching of motorcycle braking process a/ test of experiment repeatability , b/ interaction of vertical and longitudinal motorcycle dynamics.

CONCLUSIONS

Motorcycle as single trace vehicle, doesn't possess its own stability position nor the stability of direction. For these reasons it is difficult steering it and there is a high risk of causing traffic accidents and injuries of the driver. A common cause of traffic accidents is wrong braking or falling down of the driver from a motorcycle. The simulation and experimental results show that the critical braking regimes, in terms of the stability of motion of the system are, when the rear wheel loses the contact with the ground, as well as regimes in which the front wheel blocks. Boundary deceleration in these two regimes; defines the domain of stable and unstable braking. Simulation and performed experimental researching, as well as numerous expertise of traffic accidents where motorcycles participated, indicate the need for more extensive application of technology for active braking control in stressful situations.

REFERENCES

[1] Aleksandrović, B., Radonjić,R., Đapan, M., Janković, A. (2011). "The research of correlations between motorcycle oscillatory processes during the non-steady modes of motions". DEMI 2011, 10th Anniversary International Conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology, p. 765-770.

[2] Danner, M., Langwieder, K., Sporner, A. (1985). "Accidents of Motorcyclists – increase of safety by technical measures on the basis of knowledge derived from real-

life accidents”. HUK-Verband, Insitut fur Zweirad Sicherheit, ESV-Conference, Oxford.

[3] Funke, J., Breuer, B. (2000). “Dynamische Vorderrad-Uberbremsung bei Motorraden. Forschungsbericht”, TU Darmstadt.

[4] Hurt, N., et al. (1981). “Motorcycle accident cause factors and identification of countermeasures”. Technical report, Traffic Safety Center, University of Southern California, p. 1-435.

[5] Road accident statistics in Europe.

[6] White, S. (2008). “Motorcycle safety and risk factors”. On line Journal of Population Healt, University New England, p. 1-4.

[7] Willumeit, H-P. (1994). Nick- und Hubbewegung, “Radlasten und Umfangskrafte beim Abbremsen eines Motorrades”. VDI Bericte, Motorrad-6.Fachtagung, Koln.