Modeling the braking process for motorcycle with ABS

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Abstract. The project introduces the braking system for motorcycle with ABS and simulation the braking process using the Tire Hardware-In-The-Loop Simulator (Tire HILS). The ABS system includes electronic and hydraulic control units and wheel velocity sensors. The original pre-extreme algorithm is used to ABS control. The mathematical description of the pre-extreme control method is presented. Mathematical model has been developed for this method of anti-lock braking system operation during curvilinear motorcycle driving. This model was developed considering the possibility of obtaining the necessary data for the operation of the ABS without developing a new sensors base.

1 Introduction

Recently exists significant increase a production and selling the two-wheeled vehicle. This is connected with increasing popularity to usages of such technology in large city. (consumption fuel less, absence of the problems with parking, smaller tax and insurance dues). In this connection, to two-wheeled vehicle are presented new requirements to level their active safety.

In the first stage most reasonable develop the anti-locking brake systems for two-wheeled vehicle. However, use of anti-locking brake systems for motorcycles is connected to the following problems. [9, 10, 11, 12, 13, 14, 15, 16,17, 18, 19, 20].

1) Small corners of an inclination front axle pivot in a longitudinal and lateral plane at the car allow to consider the process of braking, without consideration displacement of wheel's contact patch. But, there are lateral withdrawal and big inclination of the TWV's wheel at the motorcycle movement.

2) Blocking of rear wheels is not supposed at automobile braking, but there is an instant blocking of front wheels. But instant blocking of a front wheel at a two-wheeled vehicle results in loss of stability, and in the most cases it leads to overturning [21, 22, 23, 24].

In this regard, for the effective and safe operation of ABS systems on two-wheeled vehicles, it is proposed to use a gradient (pre-extreme) control method in anti-lock braking systems. This will allow you to operate this type of transport as efficiently and safely as possible, considering the above-described features [1, 2, 3, 4, 5, 6, 7, 8].
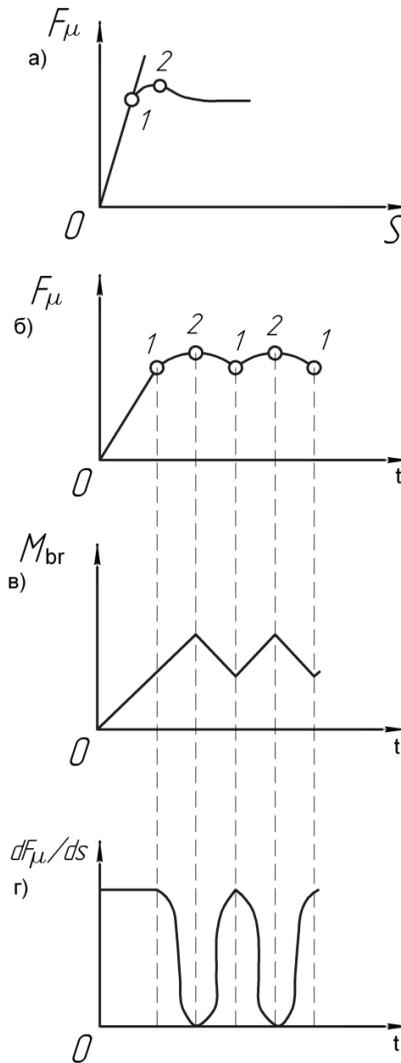
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2 Methods

2.1. Algorithm abs for a motorcycle

The pre-extreme control algorithm can be applied for the given system. Derivative dµ/ds is the parameter of regulation in this case. The main advantage of pre-extreme control will be, that it allows to guarantee the work of a wheel in pre-extreme area of µ-s-dependence. The choice of boundary conditions in this area for definition of thresholds of operation ABS can provide peak efficiency of braking, handling and stability of drive and the minimal power losses in a wheel.

The diagram shows the operation of this algorithm

Fig. 1. ABS operation using pre-extreme algorithm.
a) graph change force F_μ on slip S; b) graph change force F_μ on time t; v) graph change braking moment on time t; g) graph change dF_μ/ds on time t.

Point "1" is the start point of regulation, the lower limit of the pre-extreme region; point "2" is the point of completion of regulation, the extreme value of the adhesion force between
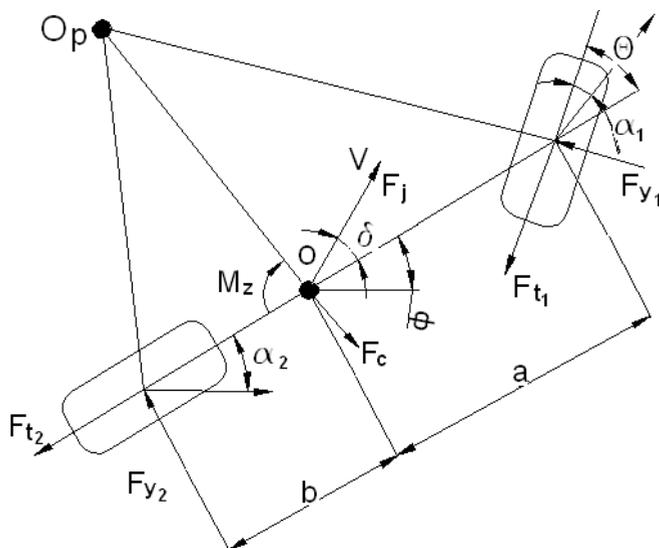
the wheel and the road. Information about changes in the dF_μ/ds parameter can be obtained from the circumferential force or braking torque sensor, or controlled by hardware, pressure sensors in the brake drive and wheel angular speed [38, 39].

The pre-extremet control method in the sub-extreme region of **μ-s** is dependence requires that the ABS have a high-tech design. At the same time, this ABS allows the vehicle to maintain stability and controllability, since it allows you to control the influence of lateral forces [35, 36, 37].

3 Results and Discussions

3.1. Mathematical Model of The Pre-Extreme Control for Regulating the Operation ABS of TWV During Curvilinear Movement

For this braking mode, the diagram of a two-wheeled vehicle is presented in Fig. 2.

Fig. 2. Two-wheeled vehicle model for curvilinear drive (braking process). O_p is pivot centre; O is mass centre; F_j is force of inertia; F_c is centrifugal force; F_t is braking force; F_y is lateral force; M_z is moment of inertia; θ is steering angle; ϕ is angle of inertia; δ is slip angle; α is wheel slip angle; V is velocity of motorcycle; a,b is weight parameter.

The adjustment parameters dF_μ/ds for each motorcycle wheel are described by the following mathematical equations:

For front wheel

$$\frac{dF_{\mu 1}}{ds} = \frac{d\left(\sqrt{\left(\frac{J_z \cdot \ddot{\phi} + k_{\alpha 2} \cdot \alpha_2 \cdot b - k_{\alpha 1} \cdot \alpha_1 \cdot \cos\theta \cdot a}{a \cdot \sin\theta} \right)^2 + k_{\alpha 1}^2 \cdot \alpha_1^2} \right)}{d\left(\sqrt{\left(\frac{c}{V_a} \right)^2 + 2 \cdot (1 - \cos\alpha_1) \cdot \left(1 - \cos\left(\frac{c}{V_a} \right) \right)} \right)}$$

For rear wheel

$$\frac{dF_{\mu 2}}{ds} = \frac{d\left(\sqrt{A^2 + k_{\alpha 2}^2 \alpha_2^2}\right)}{d\left(\sqrt{\left(\frac{c}{V_a}\right)^2 + 2 \cdot (1 - \cos\alpha_1) \cdot \left(1 - \cos\left(\frac{c}{V_a}\right)\right)}\right)}$$

All parameters presented in these equations are determined in hardware using sensors used in modern anti-lock braking systems, or are specified as constant values in the ABS control unit.
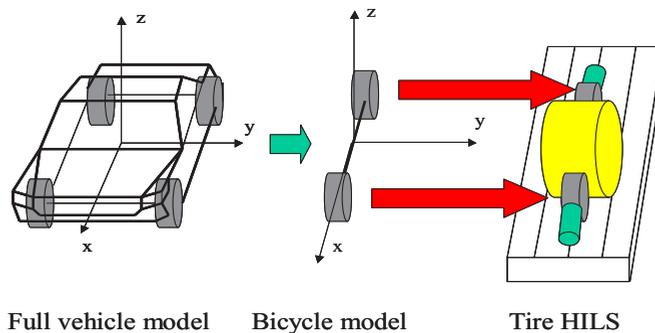
3.2. Modelling for Braking Process

The simulations of braking process carry out on the "Hardware –in-the-loop simulator" (HILS).

HILS consist next basic blocks:

1. Software module;

2. Interface module, which allow to connect software and hardware modules;

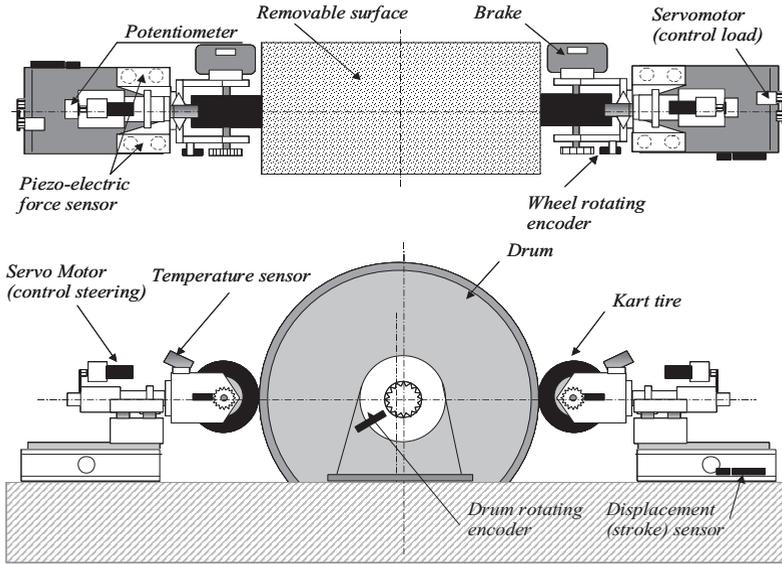3. Hardware module (two tires, rotating drum, servo system, sensors, brake mechanisms).

The Software part of Tire HILS is a computer program to simulate the vehicle model, control the moving part of hardware and also save the data collecting from sensors into the hard disk. The programs are based on the MATLAB and SIMULINK program type linking with the program of DSP board. Example of SIMULINK program, which is bicycle model for operating on Tire HILS.

Hardware is a module consists of two steer-able axle shafts with small tires (for racing kart) rotating on the drum for simulating front and rear tires of a bicycle model. A software module consists of an analytical bicycle and suspension model simulated on the computer. (Fig.3.)
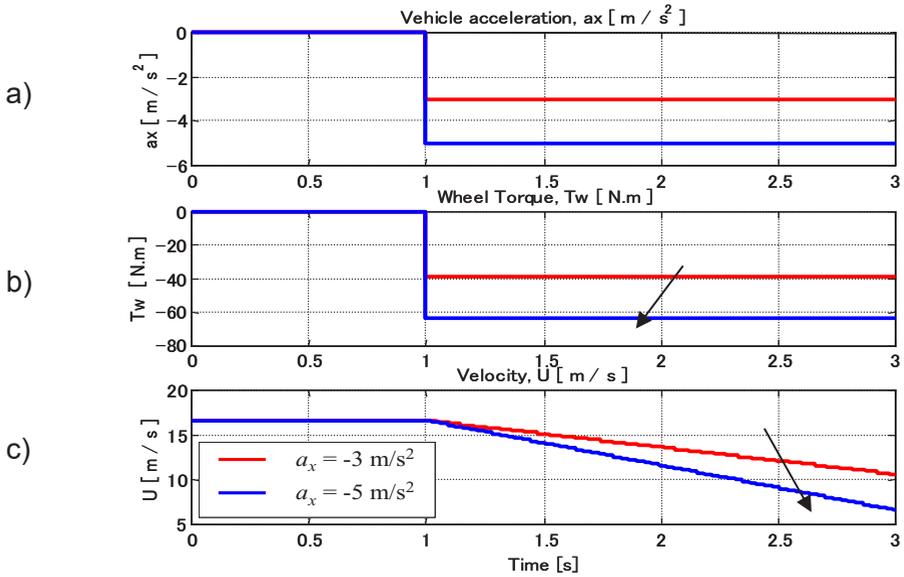

Full vehicle model   **Bicycle model**   **Tire HILS**

Fig. 3. Concept of Tire HILS

Details of hardware module are shown in Figure 4.

Fig. 4. Diagram of Hardware module of Tire HILS.

As a result of simulation were received next data. At the first stage, braking was simulated without ABS system, results present on the next graph.

Fig. 5. Braking process graphs (wthout ABS): change in deceleration; b) change in braking torque; c) change in vehicle speed

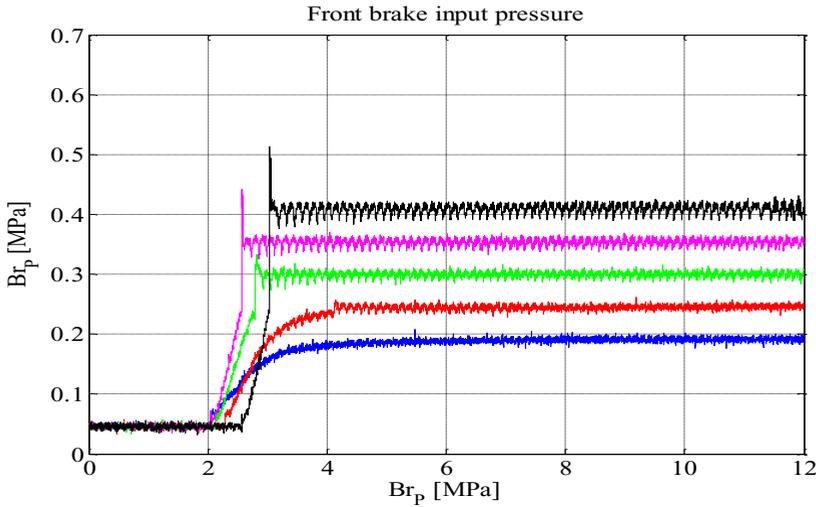Second stage of simulation, modelling braking process with ABS system.

Fig.6. Change the pressure in the front brake mechanism depending on change influencing pressures

Fig.7. Braking process graphs (with ABS): change in deceleration; b) change in braking torque; c) change in vehicle speed.

Analysing all the data received during experiment, and also after processing diagrams, it is possible to draw the following conclusion:

- use of the anti-locking braking system, which used the pre-extreme control algorithm, allows to guarantee stability of a TWV at braking, without decrease the efficiency of braking;
- reduction of brake way (panic braking).

4 Conclusions

1. Using the ABS system allows to increase the active safety level for motorcycle.

2. Investigation driving the motorcycle on intermediate stage of design necessary to simulation on HILS- stand.

3. This modeling method can be used in the creation and testing of experimental braking systems. It allows you to reduce the time for testing and creating natural models for road tests.

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