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BYCICLE ABS PROTOTYPE DEVELOPMENT

R. JAKAB[1], K. ENISZ[1], V. HAUPTMANN[2], F. SPEISER[1]✉, D. FODOR[1]

[1]University of Pannonia, Faculty of Engineering, Institute of Mechanical Engineering
H-8200 Veszprém, Egyetem str. 10., HUNGARY
✉E-mail: ferenc.speiser@gmail.com
[2]Continental TEVES Kft., H-8200 Veszprém, HUNGARY

The passive and also the active safety systems of the vehicles were developed in the last decades. Beside the safety system of cars and trucks the smaller vehicles (like the motorbikes, scooters, e-bikes and bicycles) were developed as well. By emergency or persistent braking the wheel can lock making it impossible to steer the vehicle. [1, 2]. The aim of the project was to create and develop a prototype bicycle that uses a hydraulic type anti-lock braking system called ABS.

Keywords: ABS, hydraulic brake system, bicycle

Introduction

Nowadays more and more efforts are taken to make the road traffic safer. On the traffic side not even for the cars and trucks, but also for the motorbikes and bicycles there are extra safety products as well to avoid or at least to reduce the harms and injuries. Car manufacturers have already developed several built-in safety functions such as pedestrian and bicyclist recognizer camera system or distance estimation with radar system. For motorbikes there are also active protective systems such as airbag, ABS (anti-lock braking system), rear wheel lift off protection, hill start assist and so on. If the wheel of bicycle is locked, then the motor bicycle became uncontrollable and it can slip off the road. This can be handled by ABS, since the system does not let the wheel lock. There is no need to have a driving license for a bicycle therefore it is reachable for everyone as means of traffic. In the last years more and more people choose to use bicycle and thus the number of accidents caused by bicyclist and suffered by bicyclist raised in Hungary. A lot of people use it without the minimum protection, for example helmet, knee- and elbow-protector. By a simple fall serious injuries can happen. The only solution to protect the rider is to have the safety function on the bicycle itself. This is the reason why Continental TEVES started the project together with the University of Pannonia as a pilot project for developing hydraulic ABS for a bicycle.

The primary aims were to:

– develop a new control algorithm for low weight vehicles with two wheels, and optimize this algorithm for use only the data from the wheel speed sensors as input parameters
– create a prototype from existing components and a test environment which is suitable for testing new algorithms.

Existing methods

Results of the market and research survey in the bicycle ABS field shows that there is no widespread active safety product for bicycles nowadays. For electric motor aided or hybrid bicycles are already present, but regular bicycles are still not supported. There are some simple solutions by modifying the brake-pad shape, using springs in the brake wires and also exist more complex methods such as brake force distribution or balancing. Although could not be found any ready to buy product that uses some kind of intelligence, there are a few proof of concepts. The idea to apply some intelligent decision aiding mechanism is relatively new. The following methods are used:

– mechanical brake force distribution,
– pneumatic aided ABS,
– ABS realization with electronic stepper motor,
– hydraulic ABS, only one controlled wheel.

Structure of the system

The difference between the previously mentioned methods and this pilot project is the concept. The ABS control algorithm is able to run on a separate SBC (single board computer) and not only on the ECU (electronic control unit), the bicycle has hydraulic brake system and the algorithm is able to actuate both of the wheels independently but in synchronized manner.

The system consists of three main parts *(Fig. 1)*:

– a PC to observe and modify the parameters of the bicycle and the control algorithm
– a SBC to run the control algorithm and make log from the internal parameters of the algorithm and the data from the sensors
– the control units and the sensors

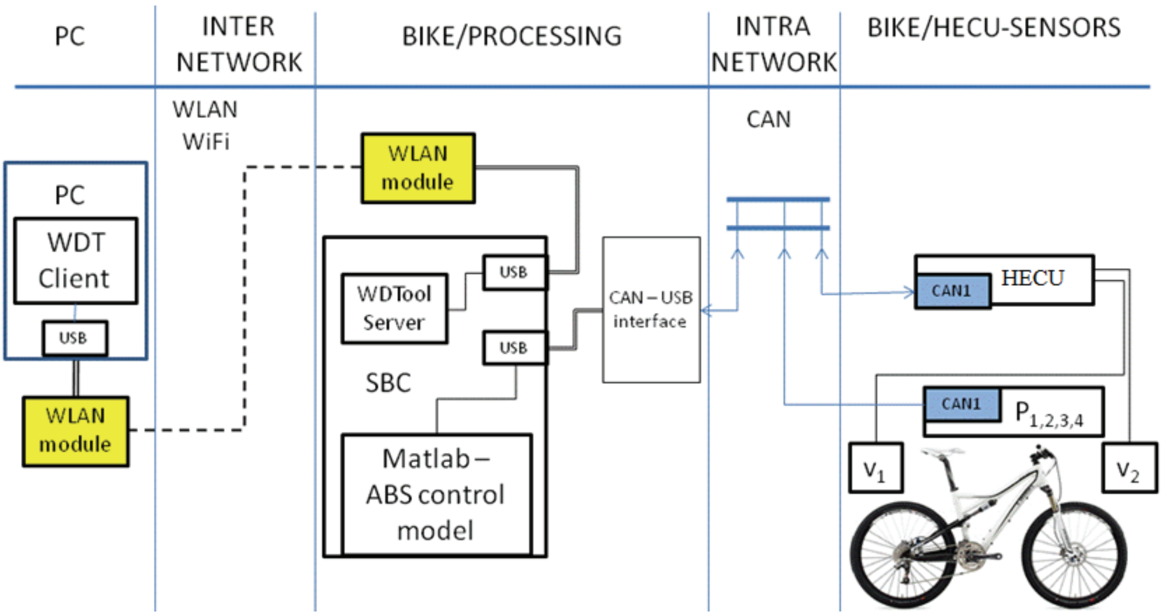

Figure 1: Structure of the system
(where V_1 and V_2 are the wheel speed sensors, the $P_{1,2,3,4}$ are the pressure sensors)

The PC and the monitoring software

An External laptop was utilized to continuously monitor the ABS, download measurement data, monitoring the operation *(Fig. 2)* and upload Matlab/Simulink control model. The external PC connects to the SBC with standard wireless communication.

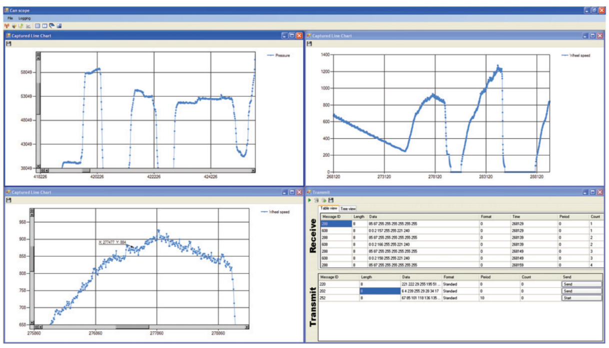

Figure 2: Bicycle monitoring client software

The SBC and the control algorithm

The SBC is a small PC with an Intel Atom processor (Z530P) and with the standard interfaces. On this small computer runs the control algorithm and collects the data from the ECU.

The single board computer

On the SBC an embedded Windows XP is running as an operating system with limited functions, optimized for running the MATLAB/Simulink program and enabled network connections. As there is no direct connection to the SBC an application is used, that is able to function as a diagnostic, control and file transfer tool. On the SBC the module shall run as a server application independently. This module shall observe the status of the control model, such as running, activating the valves, in failure. This should be able to communicate with the external computer (client side), to send new control commands to the SBC, and to receive the log files and monitoring information back to the client side to display them during tests.

The SBC does not have any peripheral device such as display, keyboard, pointer device when it is on the bicycle. There is only a feedback led that is indicating the SBC is powered up and the OS is running. The connection and control to the SBC is made over a wireless connection.

Analogue to Digital converter

Beside the SBC there is an A/D converter for the logging of the pressure values. The converter reads the data from the pressure sensors and forwards it to the single board computer.

Communication

For onboard communication system the Controller Area Network system was chosen. The main reason for using this system was that the ECU and the sensors support this kind of communication system, and other components of the system can be adapted to be able to communicate on CAN. Defined CAN nodes in the onboard network (Fig. 1):

– Hydraulic and Electronic Control Unit (HECU)
– Single Board Computer (SBC) via converter
– Pressure signal adapter ($P_{1,2,3,4}$)

The control algorithm

The control algorithm was implemented in Matlab/ Simulink. The algorithm is based on the comparison of the wheel speed and a calculated ideal speed.

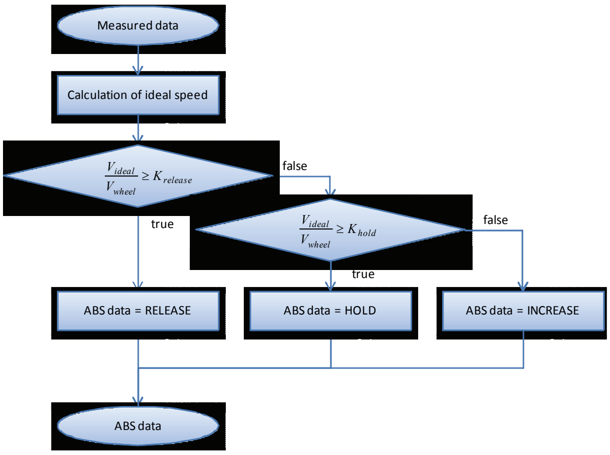

Figure 3: ABS control flowchart

The calculation of the ideal speed value is based on a linear function defined by a speed slope value and the initial speed value.

$$V_{ideal} = N * S + V_{start} \quad (1)$$

where:

V_{ideal} – ideal speed value defined by linear function

N – elapsed time from measurement of initial speed (the number of steps)

S – defined speed slope

V_{start} – initial speed (offset, the last valid speed value, before the actuation)

The comparison of speed and the calculated ideal speed is based on the Eq. 2 and Eq. 3.

$$ABSdata = -1 \text{ if } \frac{V_{ideal}}{V_{wheel}} \geq K_{\max dif} \text{ and } V_{ideal} > V_{\lim it} \quad (2)$$

$$ABSdata = 1 \text{ if } \frac{V_{ideal}}{V_{wheel}} < K_{\max dif} \text{ or } V_{ideal} < V_{\lim it} \quad (3)$$

where:

ABSdata – is the actuation request (normally the -1 is the release, the +1 is the increase state of the ABS)

V_{wheel} – actual speed value of the wheel

$K_{max\ dif}$ – is a defined maximum "difference"

V_{limit} –speed limit for ABS actuation

The algorithm calculates the V_{start} value in every loop (Eq. 4, Eq. 5)

$$V_{start} = V_{wheel} \text{ if } V_{ideal} \leq V_{wheel} \quad (4)$$

$$V_{start} = V_{start} \text{ if } V_{ideal} > V_{wheel} \quad (5)$$

The current algorithm has only two states (the release and the increase state), because it is the simplest and the fastest version of the actuation, but in the control part there is a third state, the hold, which will be used in the future for the more effective braking.

The HECU / ECU and the sensors

The HECU is a modified motorbike HECU, which currently works as a dummy ECU without a control algorithm, thus an external controller has to send the control messages for valves and pump states.

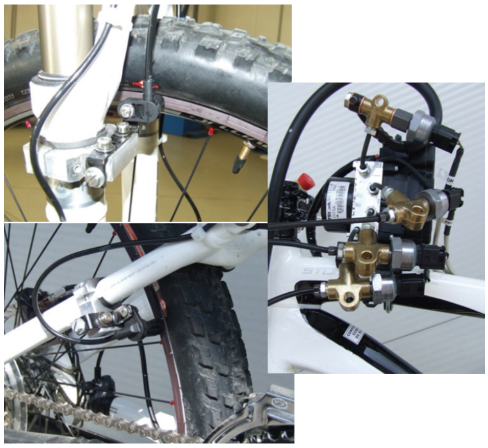

Figure 4: Speed and pressure sensors on the bicycle

To create the connection between the hydraulic system of the motorbike ABS and the brake system of the bicycle was hard, because these parts were designed for different pressure intervals and were designed for different filling methods.

For monitoring the different parameters of the bicycle, some sensors were mounted. The pressure sensors were connected to the inlet and outlet lines of the ABS, and four different wheel speed sensors *(Fig. 4)* were mounted to test which one is the most suitable for this application.

Test and measurements

The first test was made on dry asphalt with the manoeuvre of emergency braking from 15 km/h speed and the results are promising. The diagram on *Fig. 5* shows the data for the rear wheel. When the difference between the ideal and filtered wheel speed were increasing the ABS decreased the brake pressures and the wheel was accelerated near to the ideal speed.

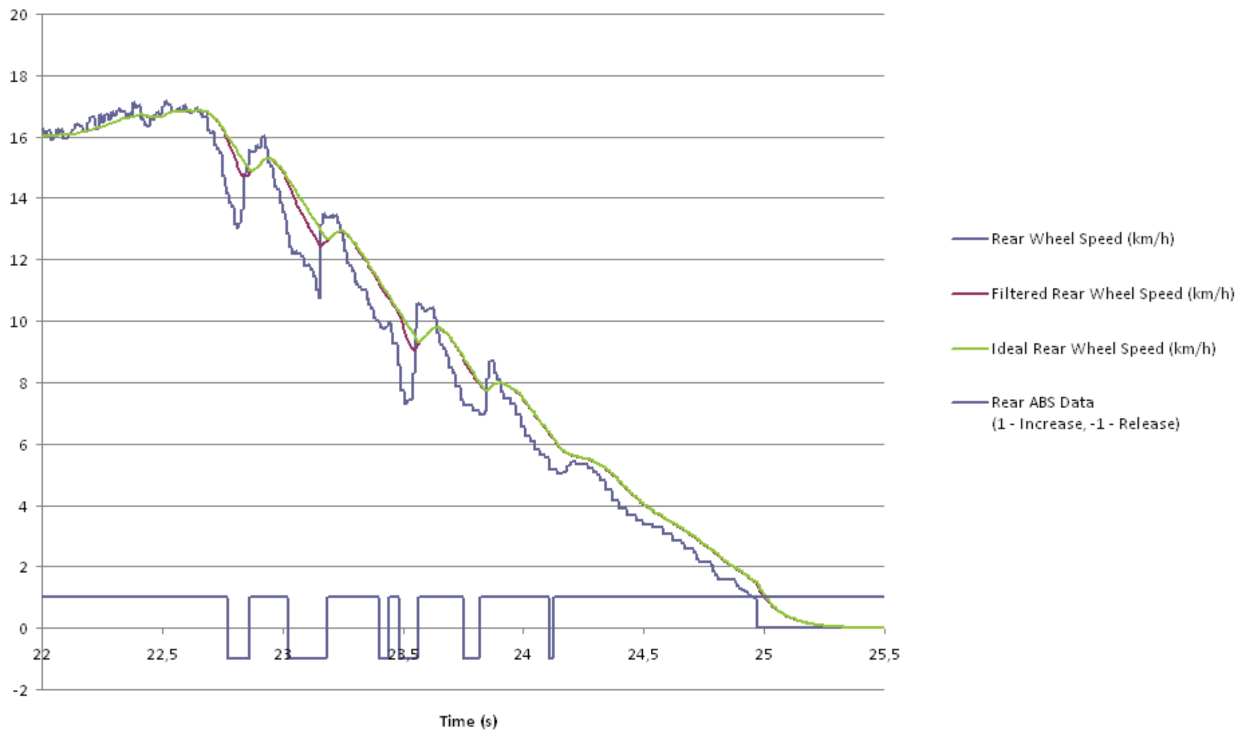

Figure 5: Braking maneuvre (Rear wheel)

Conclusions

In many countries all around the world a lot of people use bicycle not just for spare-time activity but also as part of their everyday life to commute to the workplace. During these times accidents can happen to anybody, so it is important to prevent the bicycle riders from injuries. With this prototype the aim of the project team is to show that the ABS technology is also a solution for bicycles. After testing and further improvements of the software should be realized that can help the riders in dangerous situations to mitigate collision or just to stop in a safe way.

For car industry it started the same way and now it is a compulsory supplement in every produced car in Europe and America also. Though the anti-lock braking system theory is the same for cars and bicycles the circumstances are really different. The point of later development shall be to keep the focus on the helping the rider to run in a safe way. In the future if the development of the bicycle brake assist system evolves as the brake systems for the car, in some-ten years the

ABS for high-end bicycles or mopeds may be compulsory also.

The first concept of electrical and hydraulic components are mounted on the bicycle *(Fig. 6)*, the control model can be tested and tuned now on. In automotive industry the ABS system tuning for a vehicle is a long process based on the experience of the drivers and engineers. For the bicycle it is even more specific because there is no previous test result.

In a later development phase beside ABS other safety and comfort control functions can be added to the system (e.g.: lift-off protection, hold-and-go function, brake-by-wire).

Figure 6: The bicycle

ACKNOWLEDGEMENT

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