EXPERIMENTAL ASSESSMENT OF AN ABS SYSTEM

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Autorii au realizat evaluarea in condiții reale de exploatare a performanțelor unui sistem electrohidraulic de frânare antiderapanta (ABS) modern care echipează autoturisme din clasa "premium". Sunt analizate înregistrări complete ale acțiunilor directe exercitate de sistemul de frânare pentru a preveni blocarea roților şi pentru a asigura controlul direcției autoturismului prin corelarea vitezelor unghiulare ale roților în regim de frânare intensivă. Cercetările întreprinse au permis identificarea şi cuantificarea parametrilor esențiali ai sistemului de frânare analizat, precum şi evaluarea influenței acestora față de autoturismul respectiv şi de exigențele siguranței traficului rutier.

The authors have achieved an assessment of the ABS braking system performance of a vehicle which equips the latest generation of Class "premium" in real operating conditions. Complete records of direct actions exerted by the braking system to prevent wheel lock, and to ensure the car stability in different conditions of displacement or under intensive braking. The research led to the identification of the main parameters of the complex electro hydraulic braking system of the car and then to the evaluation of their significance on the requirements of traffic safety.

Keywords: dynamic behavior, anti locking brake, parameters identifications.

1. Introduction

To achieve the maximum friction force, the wheels of a vehicle must be braket until the lowest permanent rotating limit, i.e. rotating without locking. On modern vehicles, this function is performed by the Anti-lock Braking System (ABS). The first generation of modern braking system was launched in 1969 at the International Motor Show (IAA) in Frankfurt and was followed by a spectacular development of specific systems aiming to control the automotive motion in all situations that occur on public roads (Fig. 1). In 1984 the Integrated Electronic System Brake System (EBS) was launched between 1989 and 1992 new modular extensions for Electronic Traction Control (ETC) were developed while in 1995 a new complex control systems for Electronic Brake-Force Distribution (EBD), and finally the Electronic Stability Program (ESP) appeared. These achievements were followed by other sophisticated developments marking

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the interest to reduce the braking time, to increases the systems security or to assure self-diagnosis. The common trend is to include these systems as standard parts in the whole range of automotive systems [1], [2], [3], [4].

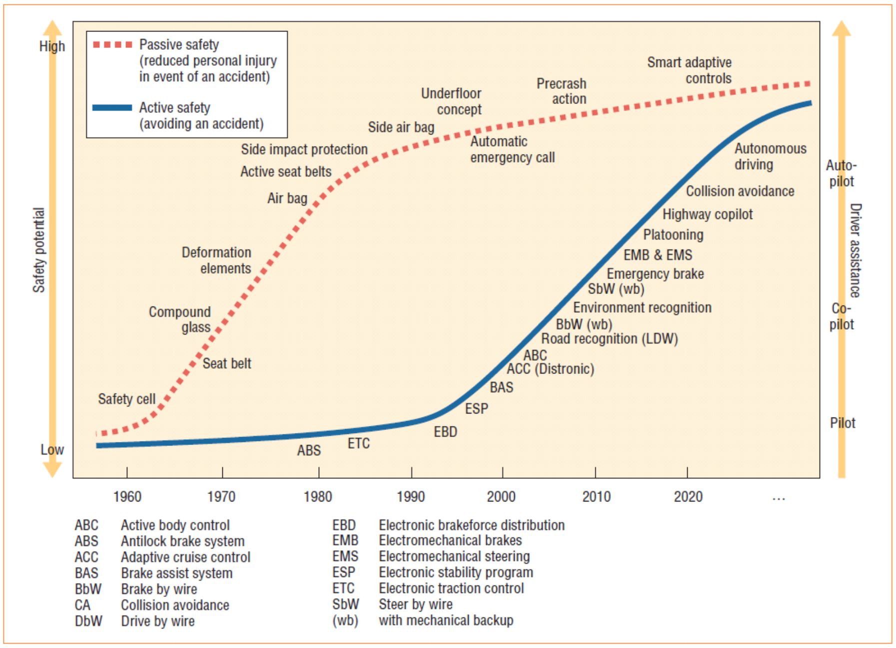


Fig. 1: Evolution of the driver assistance and safety solutions

The main problems raised by ABS systems is the proper fit on the cars, because they need the implementation of all available diagnostics and self-test features, behind the brake function [5], [6]. For example, the implementation test of the system requires some external measurements, rather than reading out an electronic "trouble code." When the engine is started, a self-test sequence occurs. If the ANTILOCK warning light turns "on", some ABS component go out of specifications, but the car still has power-assisted brakes. If both the ANTILOCK and BRAKE lights come "on", the car is losing the power-assisted brakes, which is very dangerous. This study presents the main results of a long series of braking experiments performed in order to point out the dynamic performance and the practical security utility of a modern braking system set up on a commercial M1 car.

2. Brake control system of the investigated car

Basically, ABS system uses a combination of electronic and hydraulic components to modulate the brakes individually in order to prevent them to lock.

Anti-lock systems consist of wheelspeed sensors, a hydraulic control unit (HCU), and an electronic control unit (ECU). In the case of the investigated vehicle, Brake Control Module is mounted on hydraulic modulator, both located inside the engine compartment (Figure 2). During breaking the wheel speed sensors measure the angular speed of the wheels and transfer this information to the ECU. If the ECU determines that one wheel is decelerating at a much greater rate than the another (indicating that the brake is about to lock), the ECU cut the connection between the master cylinder and activates a solenoid valve in the HCU in order to release hydraulic pressure in the caliper until the rotational speed of the errant wheel matches the others.

Fig. 2: HCU and ECU location in the engine compartment

A modern brake system includes sensors, electro-hydraulic valves, hydraulic accumulators and pumps which provide supplementary security functions: EBD (Electronic Brake Force Distribution), DSTC (Dynamic Stability and Traction Control) and EBA (Emergency Brake Assistance). Brake Control Module processes all input and output signals by checking them through their self-diagnosis algorithm. If the system detects an anomaly, according to the severity of the problem, some functions are disabled and the driver is warned by turning on a light or displaying a message on board. By manually disabling of the Dynamic Stability and Traction (DSTC), all system functions are disabled except ABS, EBD, EBA and speed measurement system of the car [7].

When starting the car, the control module checks the receipt of all signals from all of the wheel speed sensors. At the first touch of the speed of about 20 km/h the engine control unit verifies the functioning of the hydraulic pump and hydraulic valves through a short activation. ABS function is activated at speeds above 7 km/h. Traction control systems are fully operational right from the start of the car. EBA function detects the state of the braking system by the "stiffness" of the brake pedal. If an emergency state occurs, the main valve of the pneumatic booster is activated in order to obtain a minimum braking distance. Braking force is maintained in the circuit as long as the driver continues to press the brake pedal. When the brake pedal is released, the system goes idle.

3. The measurement program

3.1. Brake system requirements

Automotive braking systems are subject to the same regulations worldwide. European Community Council Directive nr.71/320/CE identifies functions and requirements for these systems. In traffic, the essential role belongs to the service brake system which shall assist the driver to control the movement of the vehicle and stop it safely, quickly and efficiently, regardless of speed, load or position of the road with slopes; the driver must be able to graduate this action and to exercise the brake from his driving seat without removing his hands from the steering wheel. The service braking system shall act on all wheels of the vehicle, and his action has to be properly distributed between vehicle axes, respectively, on the same axis, to be distributed symmetrically about the median longitudinal plane of the vehicle.

3.2. Measurement objectives

According to information from [8]...[12] the objectives of the program of experiments and test management strategy are presented in Table 1.

Table 1

Configuration of the experimental program

	Objectives	Testing conditions	Recorded parameters
1	Identification the operating system assisting ABS with EBA	Car movement with: -constant acceleration -positive or negative acceleration	Wheel: speed and acceleration Car: speed and longitudinal acceleration
		Car movement in a straight line during slow braking action	Wheel: speed and acceleration Car: speed and longitudinal acc. Brake circuit pressure
2	Identification the operating system assisting ABS with DSTC	Car movement in a curve: -without over-steering -with over-steering	Wheel speed, Yaw rate Car lateral acceleration Steering direction Pedal travel
3	Identification the operating system assisting ABS with EBD	Car movement in a straight line during emergency brake	Wheel: speed/acceleration Car: speed/ long. acceleration Brake circuit pressure Pedal travel

3.3. Data acquisition technique

Communication connections of the ABS with the Brake Control Module (BCM) are shown in Fig. 3.

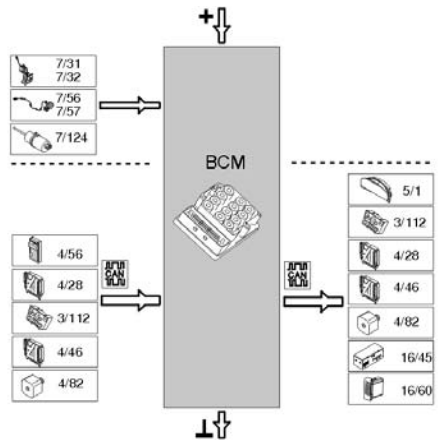


Fig. 3: Input and output signals for BCM with ABS: a) Inputs: Wheel sensors - 4 buc. (7/31, 7/32, 7/56, 7/57); Brake pedal position sensor (7/124); Central Electronic Module (4/56); Transmission Control Module (4/28); Engine Control Module (ECM) (4/46); Differential Electronic Module (4/82); b) Outputs: Driver information module (5/1); Climate control module (3/112); Transmission Control Module (4/28); Engine Control Module (ECM) (4/46); Differential Electronic Module (4/82); Road Traffic Information Module (16/45)

Diagnostic Information System (ADIS) of the car was used for data acquisition (Fig. 4). This was connected with the Controller Area Network (CAN) interface of the car and allowed the storage of the vehicle operating parameters on three channels with a rate of 125 kbps.

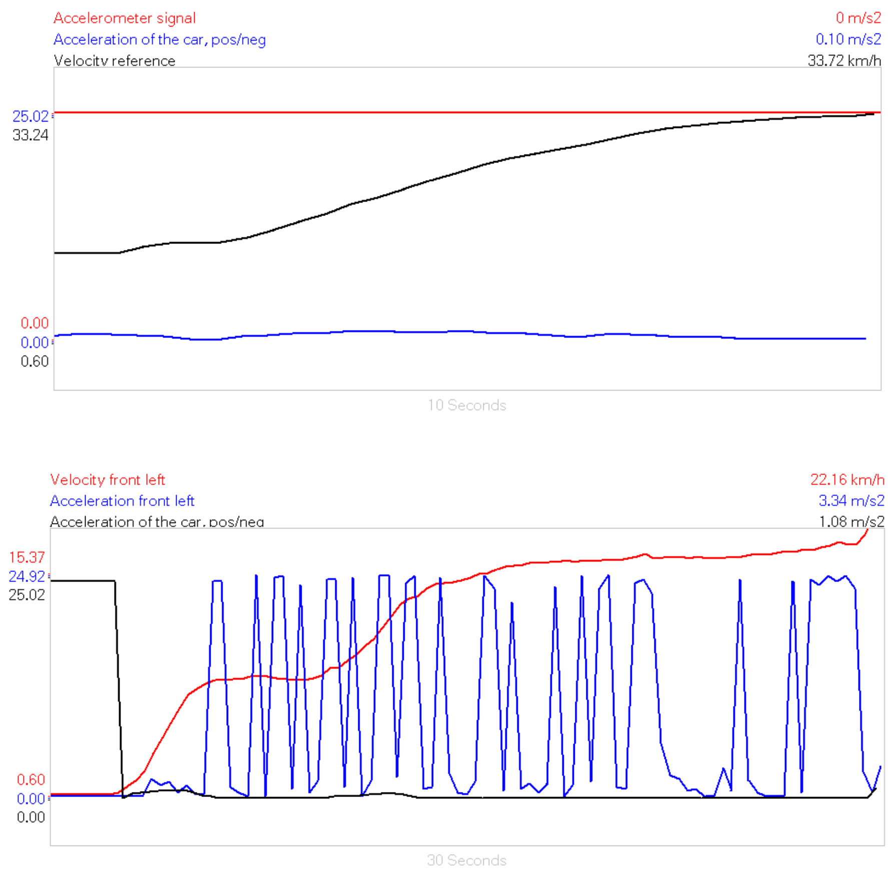
Fig. 4: ADIS system in laptop configuration

5. Results summary

5.1. ABS with EBA for car running in straight direction

a) Constant acceleration or acceleration with sign changing during 10 s. Fig. 5 shows the velocity and acceleration of the car and velocity of the wheel, respectively, during startup of the car with slight, quasi-constant acceleration.

Note the continued increasing car speed during movement with constant acceleration (Fig. 5a) and the wheel motion process which shows a significant variation in speed, respectively, a high frequency variation of the angular acceleration (Fig. 5b).



a)

b)

Fig. 5 : Car velocity and acceleration (a), and wheel velocity (b) during startup of the car with slight, quasi-constant acceleration

Fig. 6 shows the car acceleration variation during a movement with slight acceleration and deceleration tendency.

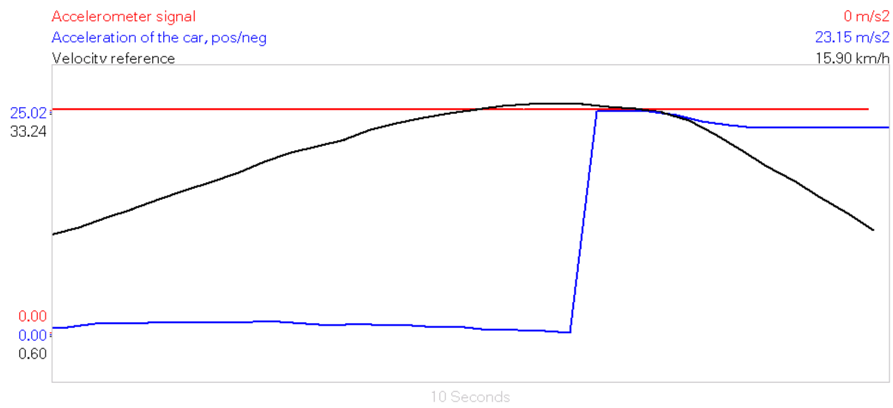


Fig. 6: Car acceleration variation during a movement with slight acceleration and deceleration tendency

b) Slow or energetic brake

The process of braking in a straight line movement of the car causes a continuous decrease of speed, by increasing pressure from the hydraulic brake circuit. Fig. 7 shows the left front wheel speed and acceleration at a slight touch of the brake pedal. It is noted that, while the wheel speed variation indicates a constant deceleration, during the same time, the acceleration presents an amplitude variation of up to 25%.

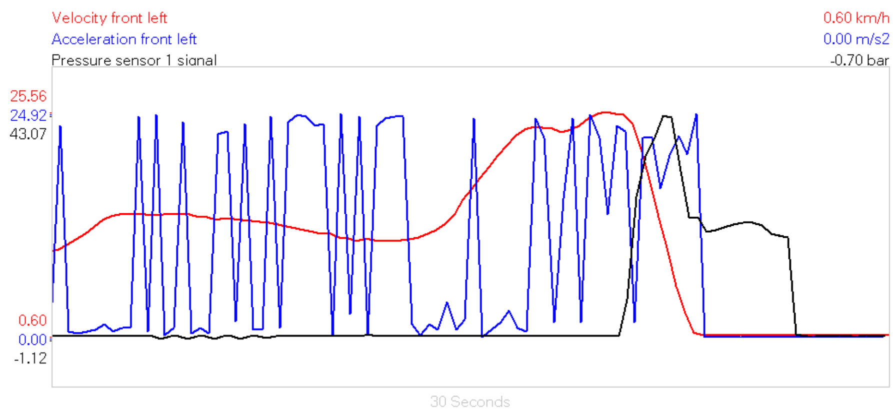


Fig. 7: Wheel speed and acceleration at a slight touch of the brake pedal

The result of a strong braking process is shown in Fig. 8. Brake pressure is proportional to pedal travel, while a small hesitation in the pedal pushing action reveals significant variations in the pedal travel speed.

Fig. 9 shows a complete brake process (till the car stop), achieved by two actions on the pedal. There is a strong correlation between brake pedal travel and brake pressure; we notice a normal evolution of the car speed till the stop.

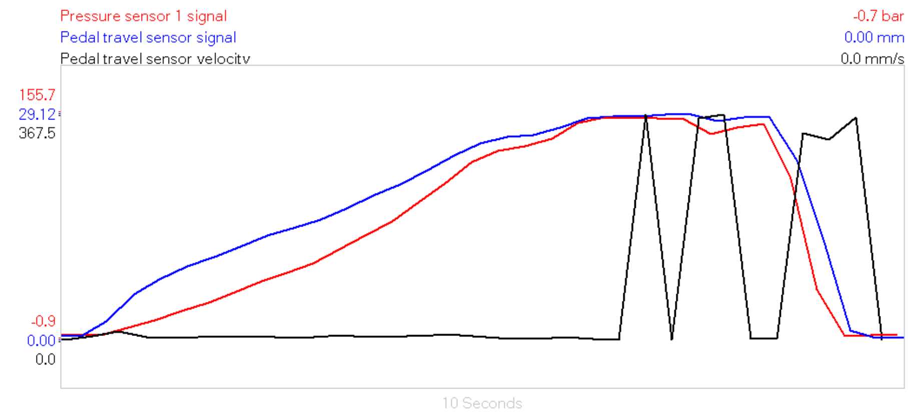


Fig. 8: Brake pressure, pedal travel and pedal travel velocity during a braking action

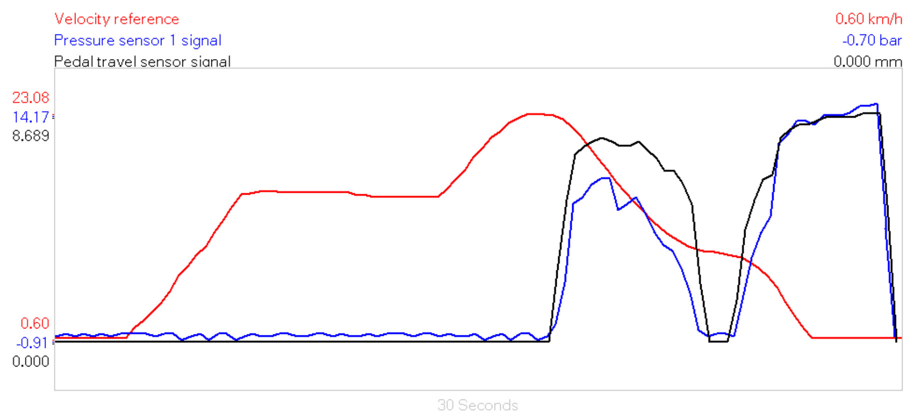


Fig. 9: Brake pressure, pedal travel during an accelerate car movement with speed variation from 0 to 23 km/h followed by brake action till car stop

5.2. ABS with DSTC at car movement in a curved path

a) Driving without over-steering

Figure 10 illustrates successive recordings made during a car turning to the left with a turning radius of 6 m. Note that while the car is moving at relatively constant speed, lateral acceleration (Fig. 10a) and the speed of twisting around the vertical axis (Fig. 10b) have significant variations. Wheel speeds from front left, front right and rear left (Fig. 10c) are different and, for turning requirements, depend on the structural characteristics of the vehicle. Steering wheel rotating during car movement with constant speed rises the lateral acceleration and rate of twist sensors (Fig. 11). Fig. 11a corresponds to the rotation of the steering wheel to the left, and in the case of Fig. 11b the wheel is turned "right-left".

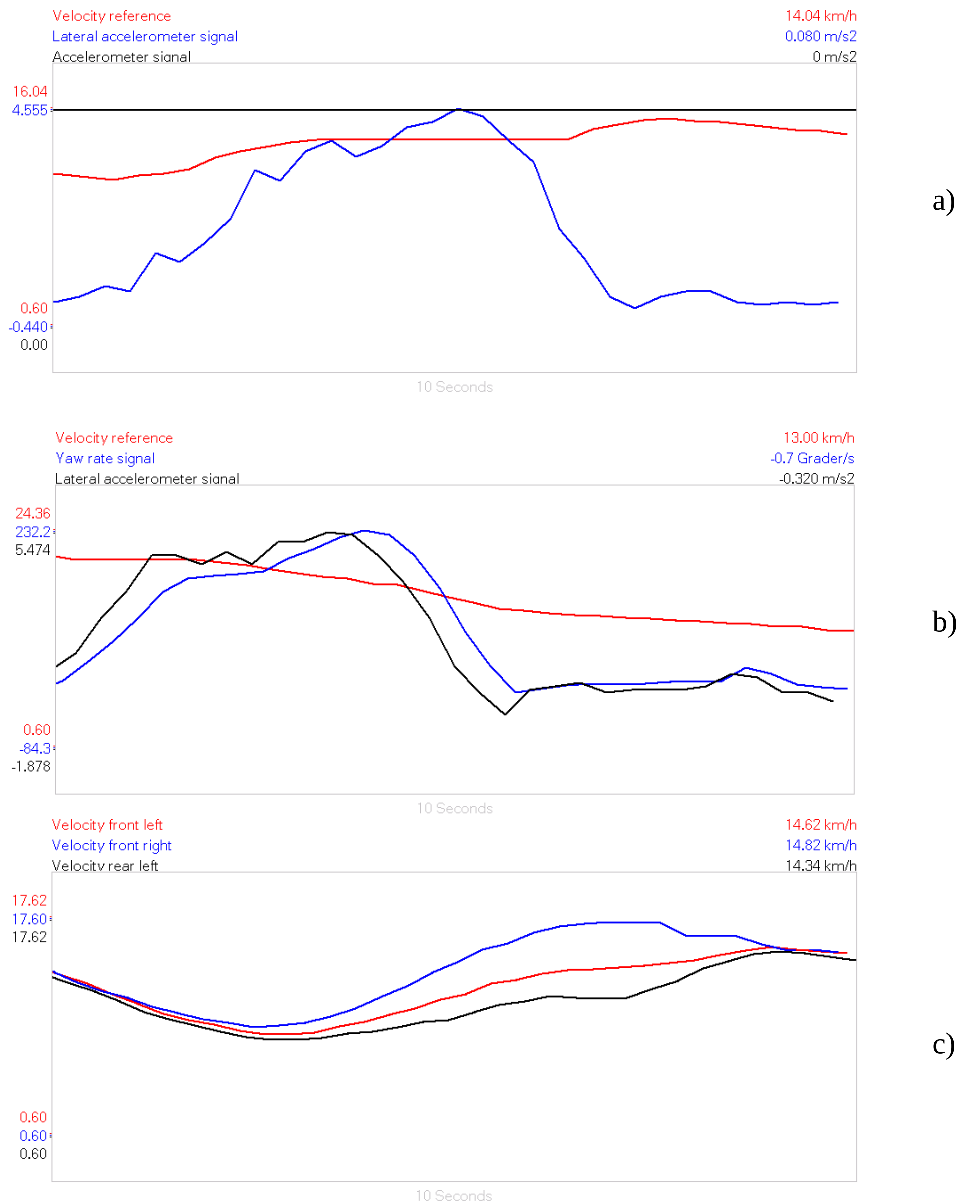
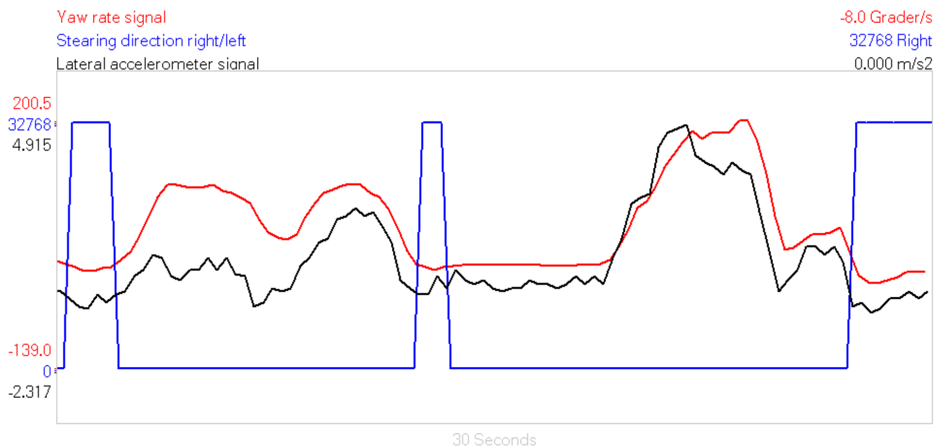
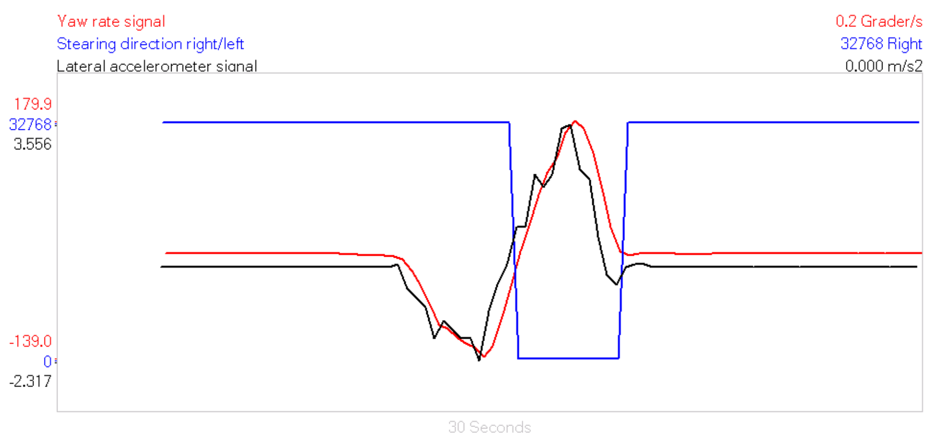


Fig. 10: Sensors signals during the car turn to left under a radius of 6 m



a)



b)

Fig. 11: Lateral acceleration and yaw rate of the car during steering whell rotation to left (a) or right/left (b)

b) Driving with over-steering

Braking pressure variation and the brake pedal stroke during driving with over-steering are shown in Figure 12. In the final part of the record time, the system has a quick action to correct this dangerous symptom. The piston of the active brake [7] is automatically actuated, increasing the braking pressure in one of the circuits compared to the other.

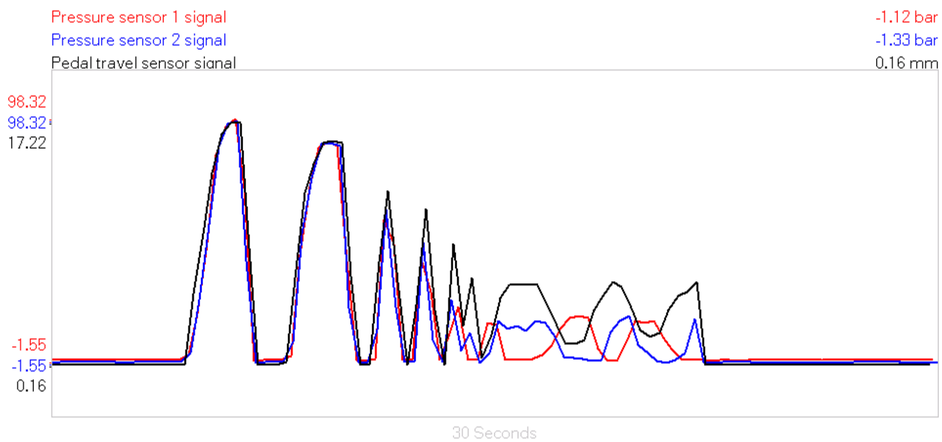


Fig.12: Braking pressure (in red) and the brake pedal stroke during driving with over-steering

5.3. ABS with EBD at car movement in a straight line during emergency brake

ABS system response, regarded as the pressure applied on the calipers is shown in Fig. 13. The hydraulic brake acts by successive pulse.

During an emergency braking of the car from a velocity of 65 km/h with a deceleration of 6.48 m/s^2 the pressure pulses have an average frequency of 82 Hz.

Fig. 14 shows different situations when the brake pedal is pushed. Note the difference between a light touch (Fig. 14a), a medium one (Fig. 14b) and a sudden pedal push.

Fig.14c clearly shows the action of the emergency braking system (EBA).

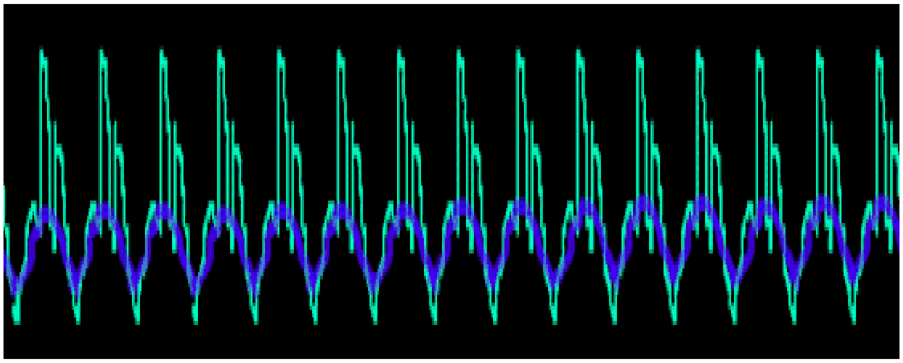
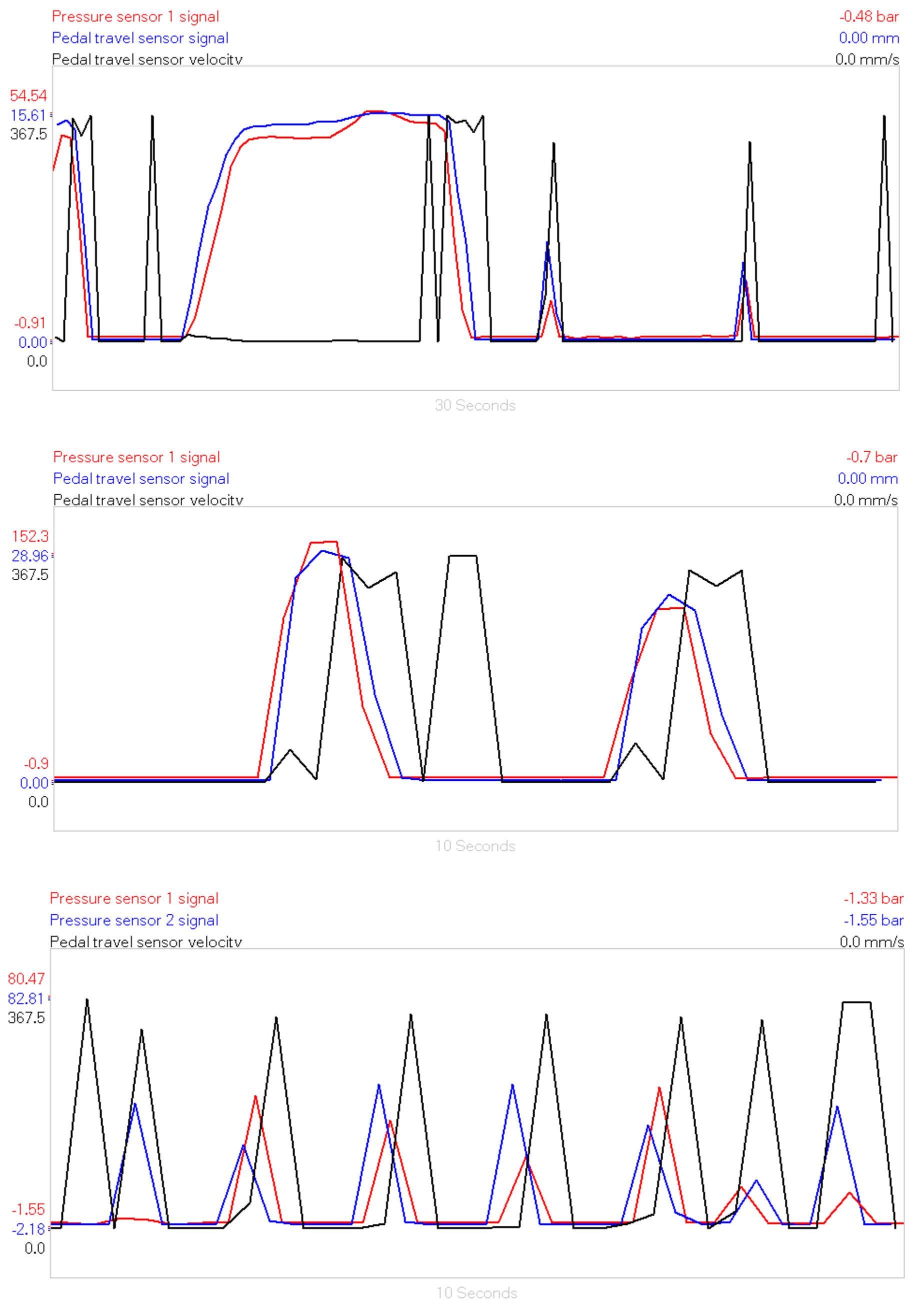


Fig. 13: Variation of brake pressure acting on the wheel during a emergency brake of the ABS with EBA system



a)

b)

c)

Fig. 14: Braking pressure, pedal travel and speed during emergency brake (EBA)

6. Conclusions

The experimental research carried out under real conditions on a modern car braking system new class led to following conclusions.

1. All vehicle manufacturers are concerned about the continuous improvement of the braking system, by reducing the brake time response and the efficiency of the braking action itself.
2. ABS braking system became standard equipment because it prevents the wheels from locking during braking action, keeping the car steering control while allowing rotation of the four wheels.
3. Optimum operating of the ABS braking system requires proper operation of all its components, and adjusting the control circuits. The authors performed a series of experimental measurements on the complex brake system of a new modern car in order to create a concrete image of a complex and basic automotive process.
4. The future of electronic braking systems is the type of EBA, DSTC and EBD systems. Thus, if for a classic ABS equipped with vacuum servo, the time needed to achieve the nominal pressure in the hydraulic circuit is about 300 ms, for an EBA braking system with pressure accumulator this time is reduced to 100 ms. At a first glance, the difference seems insignificant, but it is important because during this delay the car is moving at high speed, covering a significant distance. For example, a car moving at 100 km/h (about 28 meters each second), within 0.2 seconds of braking distance of 100 km/h can be reduced by 6 m. This distance, though small, may be sufficient to prevent or avoid a collision or reduce its effects. Another advantage of the new systems is that during the ABS system operation under no pressure, pulses transmitted from the brake circuit to the brake pedal, bringing the comfort of the driver. The new braking system also has the advantage that, in case of emergency, braking pressure gradient is very high (about 2,000 bar / s), significantly reducing braking distance.

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