Computer Applications in Electrical Engineering
Vol. 14 *2016*
DOI 10.21008/j.1508-4248.2016.0041

Tests of the ACC radar system in traffic conditions

Michał Filipiak, Jarosław Jajczyk
Poznań University of Technology
60–965 Poznań, ul. Piotrowo 3a,
e–mail: {Michal.Filipiak; Jaroslaw.Jajczyk}@put.poznan.pl

The article discusses the construction and principle of operation of the adaptive cruise control system (ACC). The elements constituting an integral part of the ACC system were described, starting with the sensors and ending with the active safety systems such as ABS and ESP. The location of the elements was presented and their cooperation ensuring the proper operation of the ACC system was characterised. Road tests, which were conducted for the purposes of this paper, were used to verify the behaviour of a vehicle equipped with the ACC system during a test drive, braking, stopping and accelerating the vehicle. The system's behaviour while driving the vehicle around a curve behind another vehicle and the response of the system to cutting in by an overtaking vehicle was tested.

KEYWORDS: active safety, ABS, ESP, cruise control, ACC

1. Introduction

Development of the automotive technology is driven to a great extent by the progress in the field of electronics and IT. Comprehensive passive and active safety systems as well as comfort systems can be implemented owing to the progress in the field of microprocessor technology. Systems, which have been developed and implemented in vehicles include: anti–lock braking system (ABS) (ABS) [10], acceleration slip regulation (ASR) system, electronic stability programme (ESP) [2, 11], cruise control, pyrotechnic airbag systems and safety belt pre–tensioner systems, vision systems etc. These systems could be invented and fulfil all expectations owing to rapid microprocessor systems performing complex calculations in real time. The analysis of signals from sensors carried out in a sufficiently short time allows the control of appropriate executive elements. Owing to this, it is possible to prevent hazardous road incidents, minimise negative effects of incidents, which have already taken place, and raise the travelling comfort of the driver and the passengers.

One of the systems which gains more and more popularity is the radar speed control system called ACC (*Adaptive Cruise Control*). This system is responsible for maintaining the speed set by the driver, including the maintenance of the required distance from vehicles ahead.

The test of vehicle systems related to traffic is difficult to carry out in laboratory conditions. In such situations, it is necessary to carry out appropriate tests in traffic conditions. Then, it is possible to test (while maintaining due care) the effectiveness of the given system [3, 5].

The paper presents tests aimed at demonstrating the usefulness of the active speed control system and indicating dangers related to its operation [8, 9].

2. Principle of operation of the ACC system

A driver, while activating the adaptive cruise control (ACC) can set the maximum driving speed and the distances from the vehicle ahead. Other functions such as switching of the system from the traditional cruise control to the automatic speed adjustment, acceleration, deceleration and braking are activated automatically.

The most important element of the ACC system is the radar measuring unit (Fig. 1). It is responsible for the determination of distances from objects in the direct vicinity of the vehicle and their speeds. The ACC system is not an autonomous system. It also uses the signals that are necessary for the correct and safe maintenance of speed and distance from other systems, constituting part of the vehicle's equipment. The information, which the ACC system uses, includes: [1, 7] (Fig. 1):

- the vehicle speed (wheel rotation speed sensors),
- the acceleration or the delay (acceleration sensor),
- the steering angle (steering angle sensor),
- the vehicle's rotary movement (lateral acceleration sensor).

On top of this, the controller which controls the operation of the cruise control takes into consideration the settings made by the driver, introduced by means of a set of indicators and operating elements. These include:

- the maximum vehicle speed,
- the distance from the vehicle ahead.

Based on the read values, the system calculates the operating parameters of the system and sets the vehicle's speed by applying the appropriate engine torque. Such a possibility is created by control systems of engines with positive ignition (PI) and compression ignition (CI). In the former ones, we can distinguish the EGAS (Electronic Glow Adjustable Switch) system and MOTRONIC ME7 while in the diesel engines – EDC controller (Electronic Diesel–Control) [4, 6]. If a significant reduction in speed is necessary, the braking system is activated without the driver's intervention (via the ESP system). This is a particularly useful solution in vehicles provided with the automatic gear box. The control system of the automatic gear box provides important information about the present power/torque ratio.

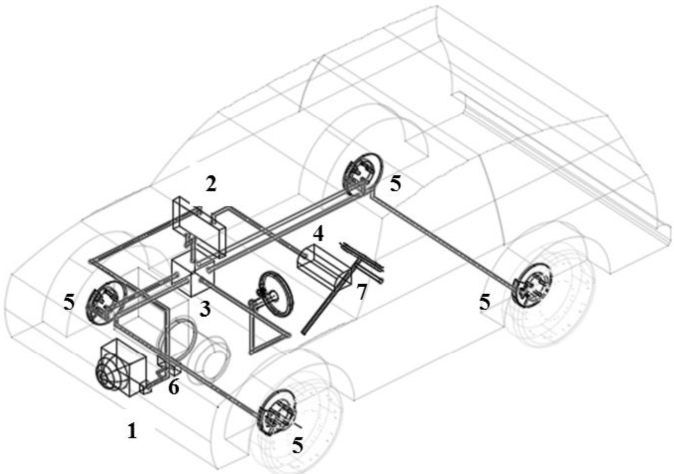

Fig. 1. Construction of the adaptive cruise control system (ACC) [1]: 1 – radar ACC system unit, 2 – engine controller, 3 – braking system including the ESP, 4 – combined indicator and ACC system operating element board, 5 – wheel rotation speed sensors, 6 – automatic gear box controller (optional), 7 – steering angle sensor

The cooperation of both systems mentioned above is presented in Figure 2.

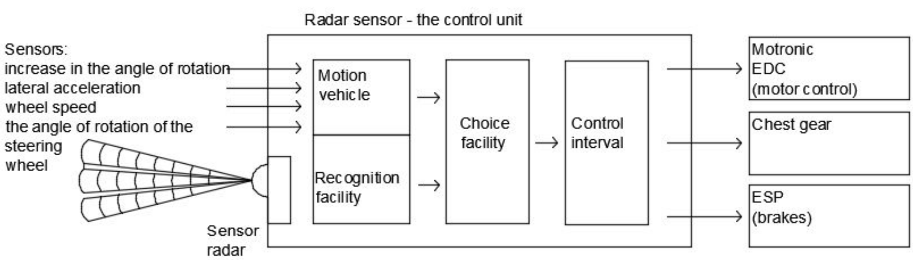

Fig. 2. Structure of the ACC system

The vehicle braking process can be completed in two modes, by means of:

- the active braking force amplifier – electronic control of the brake pedal,
- the hydraulic brake adjuster – control of pressure in the braking system by adjustment of electronic braking pump and hydraulic solenoid valve of the ABS/ESP system.

Connection of the ACC system with the automatic gear box allows bringing the vehicle to a complete stop, and in certain solutions, when the halt does not last longer than several seconds, a repeated drive is possible. In the case of a longer stop, it is necessary to activate the system again, using an appropriate push button.

3. Tests in traffic conditions

3.1. Description and purpose of the tests

Tests aimed at determination of the actual behaviour and response time of the ACC system were conducted in traffic conditions [5, 6]. The tested system was the system manufactured by TRW (3C0 907 567 M) installed in the passenger car – Volkswagen Passat 2.0 TDI with the body type: estate – equipped with the automatic gear box. The system was tested in several typical situations (i.e. the slowing down of the vehicle behind another vehicle in various speed ranges). Tests involving the halting of the vehicle were carried out, including an attempt at detection of a standing obstacle. While following another vehicle, tests regarding the response of the system at sudden cutting in by an overtaking vehicle were carried out. The tests were presented in the form of time runs of such signals as:

- the vehicle's speed,
- the distance from the vehicle ahead,
- the acceleration or the delay of the vehicle,
- the difference in speed between the vehicles.

3.2. Driving with the activated ACC system

The first test was aimed at presentation of the operation of the ACC system while moving on a road with the speed of about 50 km/h. Figure 3 presents the runs of the selected parameters recorded by the ACC controller. One of the most important parameters was the distance from the vehicle ahead.

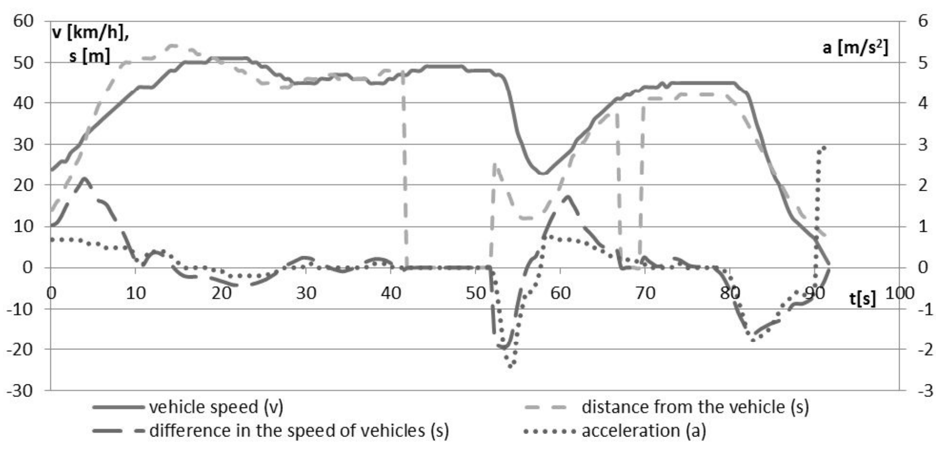

Fig. 3. Runs of vehicle speed, distances from the vehicle ahead, difference in speed and acceleration during a test drive

At the initial stage (up to the time of 40 seconds), the vehicle gained speed until the said speed was finally set. Then, (for 10 seconds) the radar did not detect any vehicle and the system set the permanent acceleration up to the speed of 50 km/h. After a while, a vehicle was detected and the speed decreased rapidly (braking process), after which acceleration and following behind the vehicle which moved away by 40 m took place. Upon reaching the time of 90 seconds, the driver engaged the brake and deactivated the ACC system.

3.3. Speed reduction and vehicle halting

Results of the tests (in the form of time runs) of the vehicle's behaviour during the reduction of speed from 50 km/h to 30 km/h are presented in Figure 4. The ACC system was activated at the ninth second of the measurement. The acceleration characteristics demonstrated that the default value of acceleration at that moment (amounting to 2.919 m/s^2 by default, when the adaptive cruise control system is not active) decreased rapidly almost to zero. By the time of reaching the 15^{th} second, the vehicle gained speed up to the previously set 50 km/h (the speed indicated by the speed meter is always higher by several percent than the speed read by a diagnostic device). After 20 seconds, the vehicle which was at a distance of 80 m was detected. At that point, the system also determined the difference in speed between the vehicles (about 20 km/h). The controller of the ACC system initiated the process of slowing down by engine braking. After about 35 seconds, the speed was compensated. The 47^{th} second marked the halting of the vehicle ahead. This caused the setting of a big delay (3.6 m/s^2) in the "tracking" vehicle, resulting from the engagement of the braking system. The vehicle was brought to a halt after 52 seconds, maintaining a spacing of about 4 m.

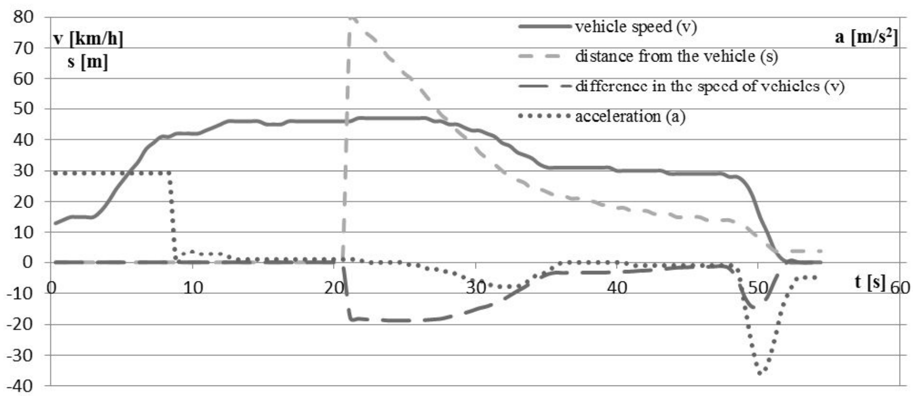

Fig. 4. Runs of vehicle speed, distances from the vehicle ahead, difference in speed and acceleration during the deceleration process

3.4. Driving around a curve

Another tests consisted in the observation of the ACC system behaviour while following another vehicle on a winding road. The recorded time runs are presented in Figure 5.

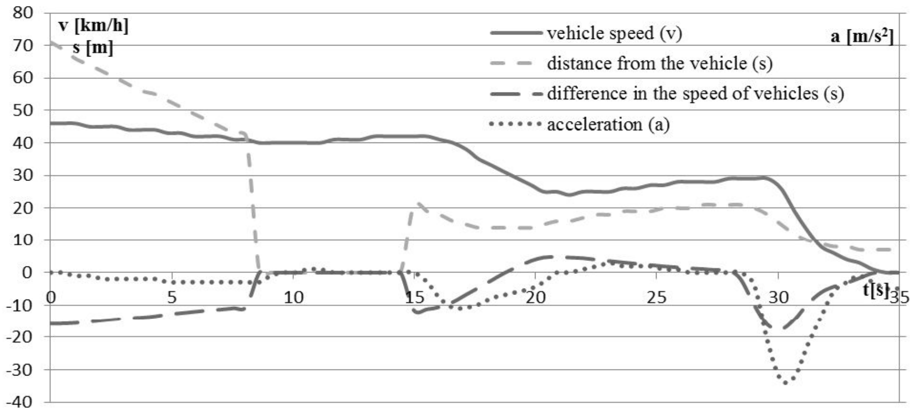

Fig. 5. Runs of vehicle speed, distances from the vehicle ahead, difference in speed and acceleration while driving behind another vehicle around a curve

The vehicle speed set during the test was 50 km/h. In the first section of the chart (up to the time of reaching the eighth) we can observe as the vehicle ahead was reached and the speed was reduced to about 40 km/h. After 8 s, the distance from another vehicle decreased rapidly to zero. This is the point where the road curve began. Because of the fact that the road curve angle was too big, the radar did not detect any object. Despite this, the speed did not change. It is only after the curve ended (information from the steering angle sensor) that after about 15 seconds, the vehicle sped up slightly (by about 2 km/h) and detected an object moving with a lower speed in front of itself. As a consequence of this, the vehicle slowed down (when 22 s pass by) and then followed the vehicle ahead. Upon the time of 29 s the vehicle ahead stopped, which caused the stoppage of the vehicle equipped with the active ACC system.

3.5. Slowing down and following of a vehicle

In the next part of the tests, the behaviour of the vehicle with the active ACC system after detecting a vehicle ahead moving with the lower, fixed speed was analysed. The test was conducted twice for various final speeds: 20 km/h (Fig. 6) and 15 km/h (Fig. 7). The initial speed was about 50 km/h. In both cases, after 3 seconds, the ACC system was activated. After 8 seconds, a vehicle which moved with a lower speed, was detected.

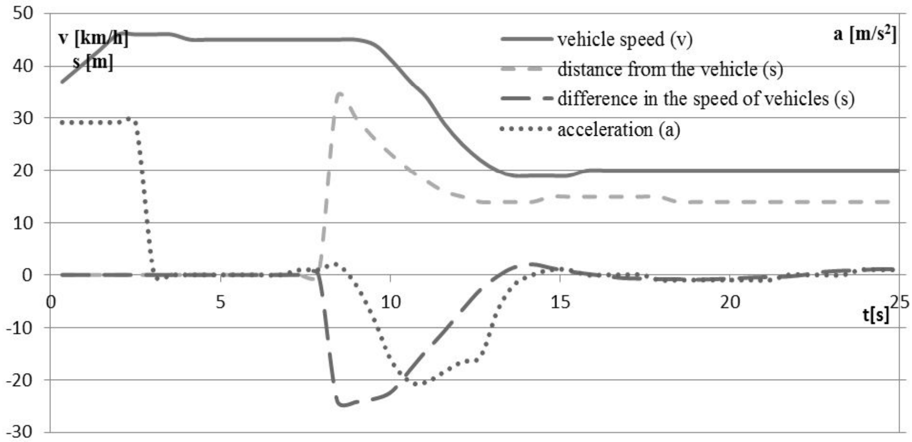

Fig. 6. Vehicle deceleration from 50 km/h to 20km/h including speed compensation

While comparing Figures 6 and 7, it is possible to notice differences in the distance at which the vehicle ahead was detected. This is 35 m and 53 m respectively. This difference results from different traffic and weather conditions during which the tests were carried out.

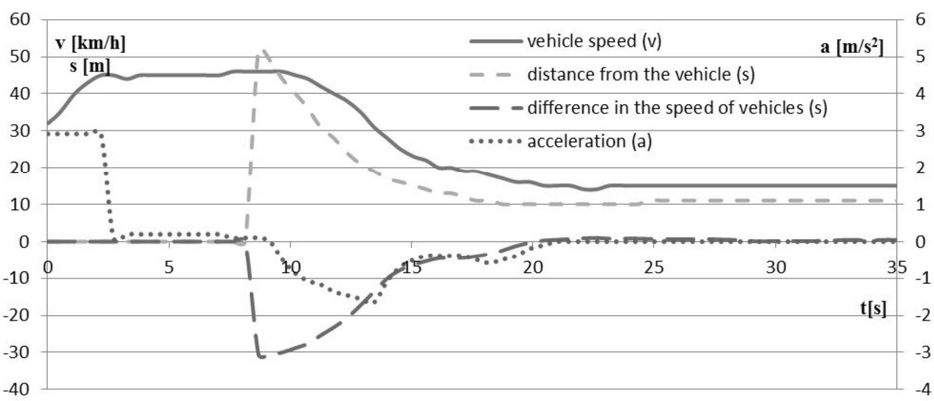

Fig. 7. Vehicle deceleration from 50 km/h to 15km/h including speed compensation

In the first case, due to a smaller distance, the response of the ACC system was more decisive. Rapid braking with a delay of 2 m/s^2 took place. In the second case, the delay amounted to about 1.5 m/s^2. After roughly 15 s of the first test, and 20 seconds of the other, the vehicle speeds were compensated (the speed difference was equal to zero) and the vehicles moved at a constant set distance.

3.6. Bringing of the vehicle to a halt before an obstacle

As well as the possibility of maintaining the speed and adapting it to the speeds of slower vehicles, the adaptive cruise control systems can also bring the vehicle completely to a halt. This refers to cars with the automatic gear box. In accordance with the manual, the manufacturer of the tested system does not provide for the possibility of recognition of objects that do not move, such objects are ignored.

While testing the adaptive cruise control system, an attempt was made to stop the vehicle before a non–moving obstacle (Fig. 8 and Fig. 9). In order to avoid dangerous situations, the first test was carried out at a minimal speed that can be set in the ACC system (30 km/h).

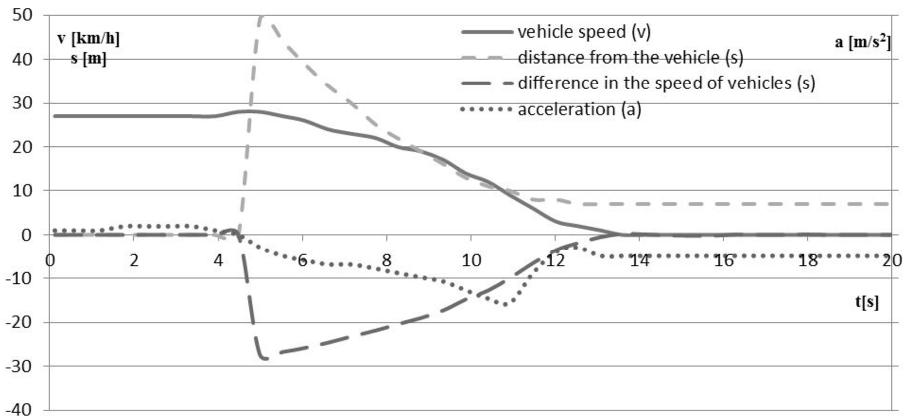

Fig. 8. Bringing of the vehicle moving with the speed of 30 km/h to a halt before a stationary vehicle

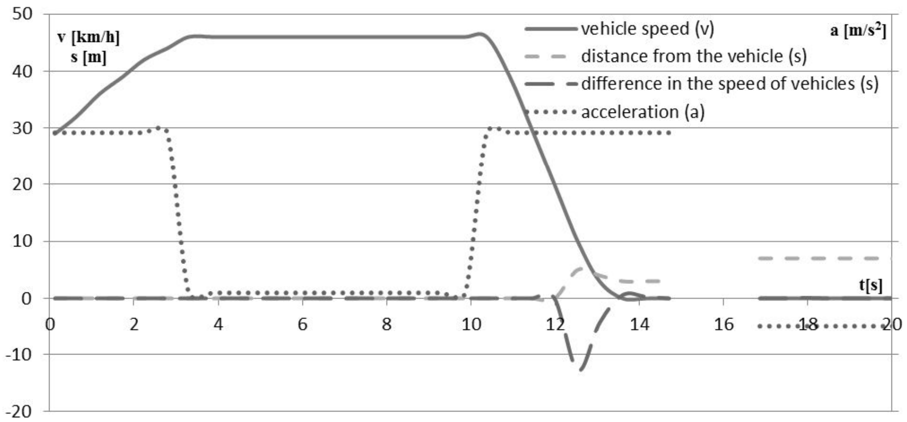

Fig. 9. Bringing of the vehicle moving with the speed of 50 km/h to a halt before a stationary vehicle

While analysing the runs shown in Fig. 8, it is possible to notice that before the time of 5 seconds passed by, the vehicle moved with a constant speed, and then detected an object located at a distance of 50 metres. At that moment, the process of vehicle deceleration and braking took place until the vehicle was brought to a complete halt.

In the next test, the speed of the moving vehicle was increased to 50 km/h. In this case, after the ACC system was activated (at 3 seconds), the vehicle moved with the constant speed and did not detect any objects (Fig. 9). At 10 seconds, the driver initiated the emergency braking process in order to avoid a crash.

The tests were repeated for different set distances between the vehicles. This did not bring any change – the vehicle never stopped.

3.7. Cutting in by an overtaking vehicle

The last test was aimed at checking the behaviour of the system at the moment of sudden appearance of an obstacle. Such a situation could occur, for instance, when an overtaking vehicle cuts in before the vehicle provided with the ACC system, which is overtaken. Figure 10 presents the recorded runs. It is possible to observe that at the time of 12 seconds while moving with the speed of 100 km/h, the distance from the vehicle ahead decreased rapidly from 119 meters to about 10 meters. In order to avoid the collision of the vehicle, the ACC system responded immediately by reducing the engine torque (engine braking – delay of about 1 m/s^2). As the distance between the vehicles started to increase and the difference in speed started to decrease (until the speed compensation), the system reduced the delay to zero.

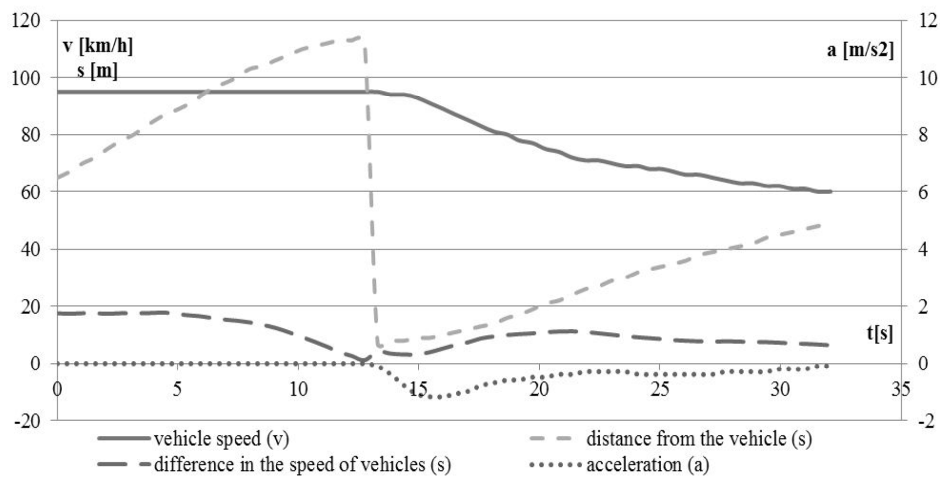

Fig. 10. Driving on the expressway and cutting in by another vehicle (overtaking)

4. Summary

The analysed adaptive cruise control system can be activated with the minimum set speed equal to 30 km/h. As a result of the conducted tests, a conclusion was drawn that the system allowed following another vehicle, which moved with the speed lower than 30 km/h. It was also noticed that the ACC system could bring the vehicle to a halt. This was possible in vehicles provided with the automatic gear box.

While driving around a curve behind a vehicle that moved slower than the set speed, the ACC system tended to „lose" the vehicles ahead because of the limited width of the radar beam. However, such a situation did not result in the acceleration to a pre–set speed. The system maintained the existing speed and accelerated only after the road curve ended.

It was noticed that the distance in which the radar system detected other objects, depended, to a great extent, on the traffic conditions (road topology, weather conditions) as well as the driving speed and the set distance. During the tests, the smallest distance at which the system detected an object was 35 m (Fig. 6), and the longest one was about 110 m (Fig. 10).

In principle, the adaptive cruise control system cannot detect stationary vehicles on the road. However, it was noticed during the tests that, for a minimum set speed (30 km/h), the system detected a stationary object and brought the vehicle to halt before it (Fig. 8). When moving with the speed higher than (50 km/h), the system did not respond (Fig. 9)

During the test for cutting in by the overtaking vehicle, the ACC system response was correct. Initially, it caused a delay to increase the distance to the vehicle ahead and then its aim was to maintain the set distance.

The conducted tests confirmed the usefulness of the adaptive cruise control system, which has a positive effect on the comfort and safety of travelling.

References

[1] Bosch Team, Adaptacyjna regulacja prędkości jazdy ACC, Wydawnictwa Komunikacji i Łączności, Warszawa 2005.

[2] Filipiak M., Jajczyk J., Nawrowski R., Putz Ł.: Systemy bezpieczeństwa czynnego i ich diagnostyka, Poznan University of Technology Electrical Engineering Academic Journals, zeszyt 69, s. 219–226, Poznań, kwiecień 2012, s. 219–226.

[3] Filipiak M., Jajczyk J., Nawrowski R., Putz Ł.: Urządzenia diagnostyczne w pojazdach samochodowych, Poznan University of Technology Electrical Engineering Academic Journals, zeszyt 69, Poznań, kwiecień 2012, s. 227–234.

[4] Herner A., Riehl H.J., Elektrotechnika i elektronika w pojazdach samochodowych, Wydawnictwa Komunikacji i Łączności, Warszawa 2002.

[5] KTS 570 User Manual.

[6] Myszkowski S., Poradnik serwisowy. Diagnostyka pokładowa. Standard OBD II/EOBD, Instalator Polski, Warszawa 5/2003.

[7] Schmidgall R., Zimmermann W., Magistrale wymiany danych w pojazdach. Protokoły i standardy, Wydawnictwa Komunikacji i Łączności, Warszawa 2008.
[8] Sitek K., Syta S., Pojazdy samochodowe. Badania stanowiskowe i diagnostyka, Wydawnictwa Komunikacji i Łączności, Warszawa 2011.
[9] Trzeciak K., Diagnostyka samochodów osobowych, Wydawnictwa Komunikacji i Łączności, Warszawa 2010.
[10] Konwencjonalne i elektroniczne układy hamulcowe, Praca zbiorowa, WKŁ 2006.
[11] Układ stabilizacji toru jazdy, Praca zbiorowa, WKŁ 2000.

(Received: 12. 10. 2016, revised: 14. 11. 2016)