Tool assessment of AEBS efficiency during test procedure performed using RuNCAP method

A M Ivanov, S R Kristalniy, N V Popov, M A Toporkov and D V Sidorov
Moscow Automobile and Road Construction State Technical University (MADI), Moscow, Russia
E-mail: ivanov-am@madi.ru

Abstract. The paper describes a necessary set of test equipment that helps to carry out research work on AEBS effectiveness using the RuNCAP method. The measuring complex allows evaluating the ability of the AEBS system to recognize the various “targets”, the incoming moment of the collision warning signal and the effectiveness of automatic braking actions. There is a parametric record appearing while processing the AEBS test results of a Subaru Outback automobile. The TTC parameter (Time to collision parameter) is used to estimate timeliness of incoming moment of collision warning signal and automatic braking phase.

1. Introduction
Automatic emergency braking systems (AEBS - AUTOMATIC EMERGENCY BRAKING SYSTEMS) in accordance with modern trends in automation of control processes are increasingly used in modern automobiles [1, 2]. The introduction of AEBS, despite its obvious positive aspects, raises the question how far a driver may rely on this system to prevent an accident. Taking into the consideration a significant AEBS impact on automobile safety, it is necessary to evaluate the functioning algorithms and an effectiveness of such systems. To perform this, there are already AEBS test methods (UNECE Regulation No. 131, ISO 15623, 22839, EuroNCAP methodology), and new, more advanced ways of testing the functionality of such systems are being developed [2]. AEBS tests require using a large set of modern test equipment.

2. AEBS test method using RuNCAP program
The Automotive MADI Chair, together with NAMI Testing Center experts and “Autorevu” magazine, also suggested an evaluating method for AEBS effectiveness, taking into the consideration peculiarities of using a vehicle in Russian conditions [3, 4, 7]. This methodology was developed during the implementation of the Russian independent evaluation program of new RuNCAP automobiles. AEBS functioning check is carried out when the vehicle is moving towards a fixed “target” standardized according to ISO 19206-1 (Figure 1).
Tests are carried out with "Day" type and "Night" type light conditions. The final assessment of AEBS effectiveness is expressed in credit points.

To perform an instrumental AEBS evaluation using RuNCAP methodology, it is important to solve following tasks:
1. to fix the receipt (or absence) of collision warning signal;
2. to perform a parametric recording of moving object during the test run (speed, deceleration, steering angle, brake pedal depress effort value);
3. to provide a synchronization of incoming collision warning signal with a parametric record;
4. to determine the distance between an automobile and a target during the race;
5. to evaluate the effectiveness of AEBS automatic braking actions.

3. Measuring and recording equipment
To solve the above-mentioned problems, a set of test equipment is developed. It includes:
- dynamometric measuring steering wheel MEASUREMENT STEERING WHEEL (MSW) produced by KISTLER Company, Germany;
- force pressure brake pedal sensor CPFTA produced by KISTLER Company, Germany;
- remote wheel speed sensor WPT produced by KISTLER Company, Germany - to determine peripheral speed of left front wheel;
- acceleration and angular velocity sensor Tri-Axial Navigational Sensor (TANS) produced by KISTLER Company, Germany;
- GPS antenna produced by IMC Company (Germany) and JAVAD Company (USA);
- universal measuring system for data collecting and processing CS 1016 FAMOS Online produced by IMC Company (Germany).

Power supply of test equipment is provided by the Small 12V Power Distributor Box from the onboard electrical system of the vehicle.

The measuring and recording equipment location on the vehicle is shown in Figure 2. The remote wheel speed sensor is used to evaluate the ability of grip limit values of the wheel with the supporting surface at the automatic braking stage.

The compact mobile data acquisition and processing system named as IMC CS 1016 FAMOS ONLINE (Figure 3) is used to record parameters and to perform preliminary data processing work [5]. The main module is located in a backseat and secured against its movement with the help of automobile seat belts.
Figure 2. Location of measuring and recording equipment in the automobile:

1 - automobile battery; 2 - signal lamp for internal light indication; 3 - onboard video recording system; 4 - MSW dynamometric measuring steering wheel; 5 - GPS GARMIN antenna; 6 - onboard video recording system №2; 7 - JAVAD GPS / GLONASS antenna; 8 - compact mobile data acquisition and processing system CS 1016 FAMOS Online; 9 - MSW processor; 10 - Power distribution unit Small 12V Power Distributor Box; 11 - acceleration sensor and angular velocities TANS sensor; 12 - laptop with IMC software; 13 - external video recording system; 14 - external signal lamp; 15 - remote wheel speed sensor WPT; 16 - CDS-GPS-processor.
Figure 3. Measuring system CS 1016 FAMOS Online.

For easy installation, the IMC module is connected to the CLSMA CDS-GPS data acquisition module from the JAVAD antenna and with the MSW steering wheel processor module. The IMC CS 1016 FAMOS ONLINE system has 16 analog, 8 digital, 4 incremental inputs, 4 analog, 8 digital outputs, a slot for a memory card, and an internal memory. To synchronize the measurement results in real time, the system has an integrated GPS receiver. The sensor sampling frequency rate in the IMC system was set at 100 Hz value.

Management of the measuring complex and data display is performed by using a laptop computer with IMC DEVICES 2.7R3 software package.

To fix the moment of filing an audiovisual collision warning signal, a video camera is installed on the cover of the steering column.

4. Synchronization Method of Collision Warning Signal Moment with a Parametric Record

To determine parameters of the vehicle during the period of audiovisual warning of a collision, the authors have developed a method that allows synchronizing time of filing of this signal with the parametric recording of test run. The advantage of proposed method is the ability to record any audiovisual signals regardless their nature: appearance of a sound signal, warning light on instrument panel, appearance of a message on the on-board computer screen, etc. Disadvantages of this method are the inability to fix tactile signals (the increase of accelerator pedal force value, belt tension, rapid gap of brake pedal, etc.), complexity and long data processing time. To synchronize parametric recording and video recording together, LEDs lamps of internal and external light indications were used (Figure 4). The switch on the parametric recording mode is accompanied by lighting up the corresponding alarm lamps. In this case, in parametric recording, the moment of control signal supplying is fixed. The fact of collision control signal and collision warning signal is recorded by a video camera. Using the recording made by a camcorder, you can synchronize time of the collision warning signal with parametric entry. The presence of an external indication lamp also allows (with outdoor video recording) synchronizing with parametric recording all processes occurring with an automobile during a test run, for example, the moment of turning on brake lights.
5. Processing of test results
With the help of developed measuring complex, AEBS tests are performed on Subaru Outback automobile. The IMC FAMOS Enterprise software is used to process data and create graphical dependencies. There were performed time dependencies for each test run (Figure 5):
- the longitudinal velocity of test object (V);
- peripheral speed of front left wheel (Vк);
- longitudinal deceleration (jx);
- steering angle (α);
- the distance between the test object to the “target” (D);
- pressing brake pedal efforts (Ppp).

The starting time point on charts is considered as a moment of the possible collision warning signal. The distance between the test object and the “target” is determined by coordinates of the global positioning system. The method for determining the distance is presented in [6].

The TTC parameter - time to collision (Time to collision parameter) with a fixed target - allows estimating the lead time for a warning signal about a possible collision or the start moment of automatic braking actions. The TTC parameter was calculated using the formula: TTC = D / V, where V is the object speed at the moment of the collision warning signal or automatic braking start; D - the distance between the object and the target at collision warning moment or the start moment of automatic braking.

![Figure 4. Light indication lamps: A - internal; B – external.](image)

![Figure 5. An example of parametric record of test run](image)
V₁ - longitudinal velocity of an object at time of possible collision warning moment; V₂ - object speed at time of collision with the "target"; D₁ - the distance between the object and the "target" at warning time of a possible collision; D₂ - the distance between the object and the "target" at the time of automatic braking start; TTC₁ - time before collision at possible collision warning moment; TTC₂ - time before collision at the moment of automatic braking beginning; - the moment of visual signal switch on during the detection of an obstacle (orange bar); - the moment of switching on brake signals on test object (red vertical line); - the moment of collision of an object with a “target” (blue vertical bar).

6. Conclusion
A complex of measuring and recording equipment has been developed for testing of automatic emergency braking systems by using the RuNCAP method. Specific features of the complex are as follows:
- fixation of visual and acoustic collision warning signal;
- registration of switching on moment of stoplights;
- evaluation of the effectiveness of automatic braking is made by the front left wheel speed sensor;
- the distance between an automobile and the target during the race is determined by signals from global positioning system satellites;
- evaluation of the timeliness of collision warning signal incoming moment when automatic braking starts, it may be used the TTC (Time to collision) parameter.

The efficiency of the measuring complex is confirmed by tests that were performed on Subaru Outback vehicle. Such measuring complex may be used during the AEBS test procedure with the help of other methods listed above.

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