Estimation of Influence of ESP on LCV Active Safety in Condition of Curvilinear Movement

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Keywords: Light Commercial Vehicle, Electronic Stability Control, Electronic Stability Program, Road Test, Curvilinear Motion, Line Changing.

Abstract: The article describes the results of road tests of light commercial vehicle equipped by ESP where the effectiveness of the electronic program estimated in conditions curvilinear manoeuvres: start of the corner and line changing (in accordance with Russian Standard GOST 31507-2012). The main objective of the study is the analysis of behaviour of a vehicle equipped with ESP, determination of the moment of ESP activating as well as the effect of ESP influence on LCV dynamics. The object of study is a metal cargo LCV with total mass 4500 kg. During the road tests on dry asphalt the vehicle speed and yaw of the longitudinal and transverse accelerations as well as the steering angle were synchronized registered. The analysis of experimental data shows that during manoeuvre "start of the corner" the threshold of dynamic stabilization was found at 58...59 km/h, when in the "line changing" it was about 60...65 km/h, that close to speeds regulated by GOST binding for all types of LCV (regardless of ESP).

1 INTRODUCTION

One of the main priority directions of Russian government services and vehicle manufacturers is the increasing of traffic safety and particularly vehicles active safety. Light commercial vehicles (LCV) in Russia constitute a sizeable part of all vehicles, produced in The Russian Federation (RF). In this connection, the problems of safety LCV design and using of intelligent systems are pressing nowadays.

It is known that every year about 8000000 road accidents registered in RF. About 30% of them happened with the commercial vehicles participation (including LCV). In the case of heavy road accidents the high percentage of injured and deceased people could be seen. Using of effective active safety systems could change this situation for the better. Intelligent systems, such as electronic stability control (ESC), could help a driver to keep the vehicle on the trajectory in various road conditions, speed of motion and steering manoeuvring.

ESC is well known as various kinds of trade names (such as ESP), but the main operating principles of such systems particularly the same. ESC helps the driver to keep a control over the vehicle during the extreme manoeuvres. The main function of ESC is stabilization of the vehicle by means of trajectory controlling and rollover prevention. Despite that fact that ESC couldn't increase the coefficient of adhesion between the tire and the road surface, it ensures the driver the maximum ability of vehicle's control. ESC systems are widely used in Europe, USA and others countries, but in Russia these systems don't have such wide application (only foreign vehicles – some modifications – has ESC, but none of Russian domestic vehicle has).

In 2008-2009 specialists of Nizhny Novgorod State Technical University n.a. R.E. Alekseev (NNSTU) the analysis of road accident with the participation of commercial vehicles (including LCV) was made (Groshev and Palkovics, 2010).

The analysis of statistics shows that about 14% of commercial vehicles drivers before the the crash made some kind of counter emergency manoeuvres (Figure 1). The technical state and availability of vehicle's equipment play an essential role in such cases. Particularly, a vehicle, equipped with ESC, has the best road holding ability at the highest speeds, in contrast to a similar vehicle without ESC.

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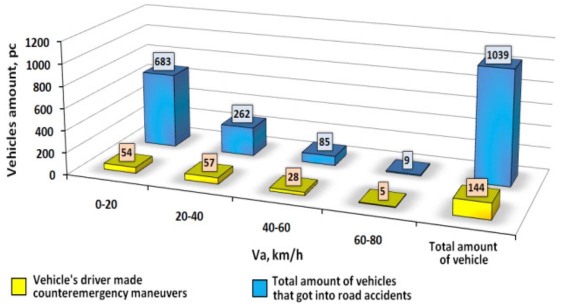

Figure 1: The distribution of amount and velocities of commercial vehicles that took part in mechanical road accidents.

Analysis results show that ESC can be useful in more than 30% cases of vehicle manoeuvring at a speed of 40…60 km/h and in more than 50% cases of vehicle manoeuvring at a speed of 60…80 km/h. It was established that installation of ESC (specifically ESP) system on commercial vehicles can reduce the number of crash situations, associated with counter emergency manoeuvres, at least by 8%.

The detailed analysis of severe and extra heavy road accidents (with injured and deceased people) shows that commercial transport (including LCV) takes part in more than 30% of these accidents. It was found about 20% of severe and extra heavy road accidents could be avoided or mitigated with the help of ESC operating (Figure 2). The detailed analysis of this group of accidents (driveway to the ditch, rollover, losing control over the vehicle) shows that in these cases ESC could be really useful and could be able to come into operation and affect a road accident outcome.

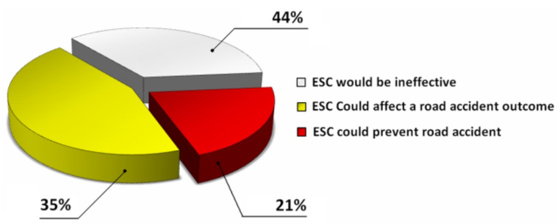

Figure 2: Supposed efficiency of ESC.

It is interesting to know (Figure 3) that domestic (produced in Russia) vehicles are more often fall into road accidents (Nikolskiy, 2010). Meanwhile more accidents happened on a dry road (more often than on a wet or snowy road surface – Figure 4).

Presented data allows making a conclusion that a lot of of severe and extra heavy road accidents with the participation of commercial vehicles (including LCV) could be avoided or mitigated with the help of ESC operating.

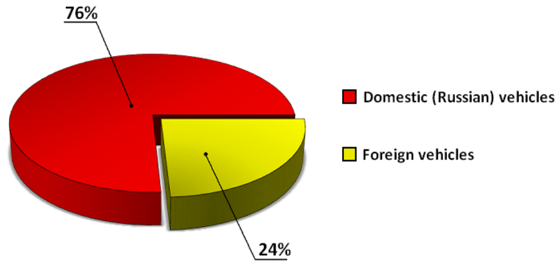

Figure 3: The correlation of domestic (Russian) and foreign commercial vehicles that got into severe and extra heavy road accidents.

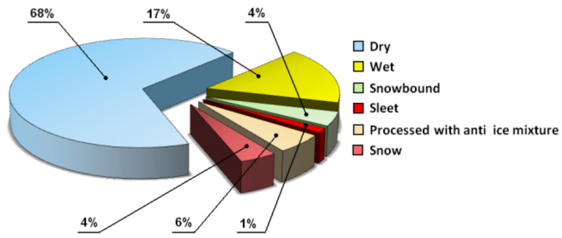

Figure 4: The distribution of severe and extra heavy road accidents with the participation of commercial vehicles that happened on roads with different surface condition.

It is worth to underline that since November 1, 2014 all new passenger vehicles weighing up to 3.5 tons and light commercial vehicles sold in the EU are required to have ESC as standard equipment. In 2015, this requirement extended to other categories of vehicles. In Russian Federation such kind of regulation is under the progress and is going to be obligatory from January 1, 2018. It is also known that in Russia there is lack of specialists and R&D laboratories that would be able to produce and set up ESC systems on vehicles, that is why the domestic vehicles producers use the services of big-name corporations (Bosch, Continental, Wabco, Knorr-Bremse, etc.).

In this case it is interesting to analyze the behavior of existing vehicle with certified ESC in condition of different manoeuvres, regulated by existing Russian Standards, and estimate the moment of ESC activating as well as the effect of its influence on vehicle's dynamics.

2 THE OBJECT OF RESEARCH

The object of the study is a metal cargo LCV Renault Master 2.3 dci 125 (with total mass 4500 kg) equipped by ESP Bosch 9.0. In this modification, angular rate sensors, longitudinal and lateral acceleration sensors are integrated into the electronic control unit and able to withstand the high temperature in the engine compartment.

3 DEMANDS OF SAFETY REGULATION

It was noted above that in Russia there are special Regulations concerning vehicles steerability and stability which are mostly similar to requirements, regulated by Rules of UNECE. At the same time, Russian Regulations include the requirements, which do not have analogy among the international normative documents. The technique of GOST 31507-2012 was taken as a basis for the experimental studies described below.

The most significant tests from the point of view of an assessment of active safety properties are: "start of the corner" and "line changing".

It is possible to allocate the following technical requirements concerning the over-the-road tests:

– The maximum speed of a vehicle when performing manoeuvre (further – speed of manoeuvre V_M) is determined as an arithmetic average value of speeds of three test runs with the highest speed without getting out of road marking limits or any cornering breakaway.
– The V_M values received at tests should not be below standard (regulated) V_M values. For LCV: “start of the corner” V = 60 km/h; “line changing” V = 70 km/h.

"Start of the corner" test is carried out with the purpose to define the indicators characterizing stability of a vehicle in critical modes of movement on a curvilinear trajectory. On Figure 5 the scheme of a curvilinear corridor for "start of the corner" test is shown.

Before entering the corner, a vehicle starts in a straight motion mode. The highest transmission gear speed is chosen for ensuring steady functioning of the engine. At the moment of traversing by the front wheels of vehicle the border between zone 1 and 2 of the marked corridor the driver quickly removes a foot from an accelerator pedal and starts turning a steering wheel to the right for manoeuvre performance. Position of all other control elements has to remain constant.

The outside observer (test engineer) notes cornering breakaway, either getting out of limits of a marking corridor and informs the driver about it. All runs are divided into preliminary and control.

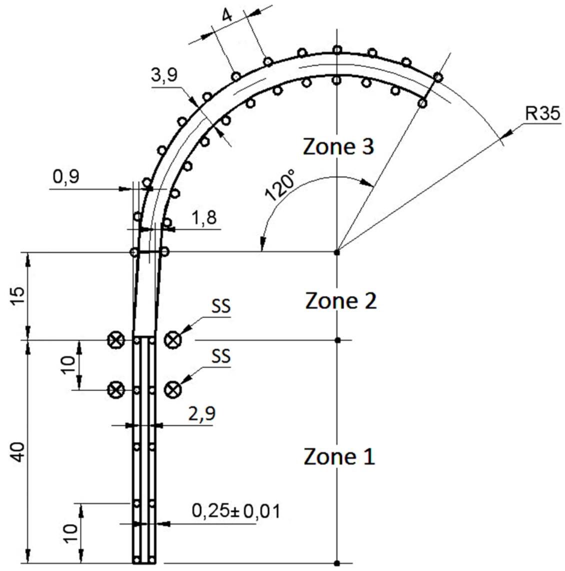

Figure 5: Scheme of the road for “start of the corner” test. All dimensions presented in meters. SS – speed sensors.

Preliminary runs are carried out without registration of measured parameters for determination of range of initial speeds for control runs. Initial speeds of preliminary runs are quite low – there is no dropping of stability characteristics. Preliminary runs are finished at a speed when a vehicle loses its stability.

If cornering breakaway or crossing of the marked corridor is observing during consecutive three runs at one speed, all tests are finished.

During tests both: the speed of V_M of a vehicle at the zone 1 and runs in which there is a cornering breakaway or a crossing of the marked corridor are registered. In addition, the angle of rotation of the steering wheel is registered, allowing define the maximum angle of rotation of a steering wheel, the moment of the beginning of manoeuvre, existence of skid or driver’s mistake. The form of registering record and value of steering wheel rotation angles let to judge about the existence of skid in the run. An average speed of manoeuvres of V_M is the result of "start of the corner" tests.

On Figure 6 the scheme of a curvilinear corridor with characteristic sizes for the “line changing” test is shown. In accordance with Russian regulation, the "line changing" test is intended to determine the maximum speed of manoeuvre at changing the line on a limited track section. Conditions of this test (the technique) are similar to conditions of the "start of the corner" test.

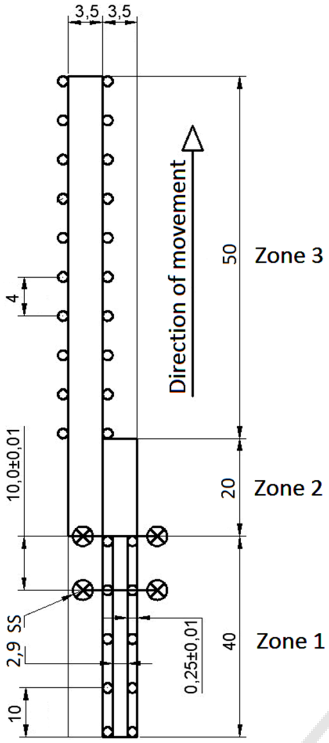

Figure 6: Scheme of the road for “line changing” test. All dimensions presented in meters. SS – speed sensors.

4 TEST EQUIPMENT

The scheme of test equipment and it’s connection is shown on Figure 7. The steering angle data was writing on Kistler Automotive GmbH (steering angle ± 1250°, error ± 0.1%). The speed of vehicle recorded by RacelogicVBOX3i 100Hz Data Logger (absolute error ± 0,1km/ h, the absolute error of distance measurement ±0,2%). The measurement of yaw rate as well as longitudinal and lateral acceleration made by inertial sensor IMU04 Racelogic Ltd. (measuring range: angular velocity of ±450 °/s acceleration ±5g; measurement error: the angular velocity ±0.014 °/s, acceleration 0,00015g). The beginning and ending of vehicle movement fixed by manual trigger timestamp.

Figure 8 shows fragments of LCV tests.

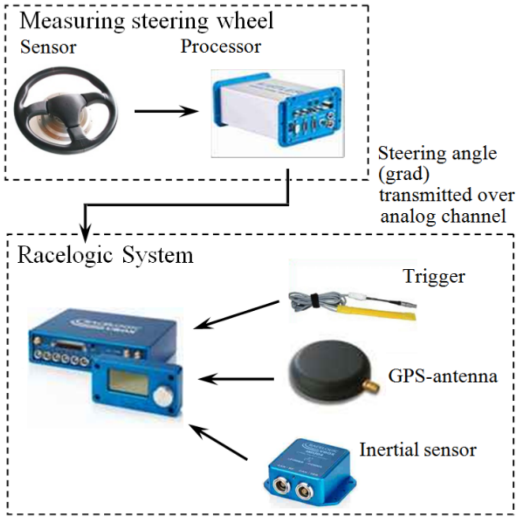

Figure 7: The scheme of test equipment.

a)

b)

Figure 8: LCV road tests: a - “start of the corner” V = 60 km/; b - “line changing” V = 70 km/h.

5 TEST RESULTS

Graphs of Figure 9 show the results of “start of the corner” tests. By the character of steering angle and yaw rate changing it is possible to conclude that a special function ESP-RMF (rollover suppressing) was activated. ESP System ESC automatically broke LCV wheels decreasing the critical lateral acceleration and the speed of rotation around the vertical axis, preventing cornering breakaway.

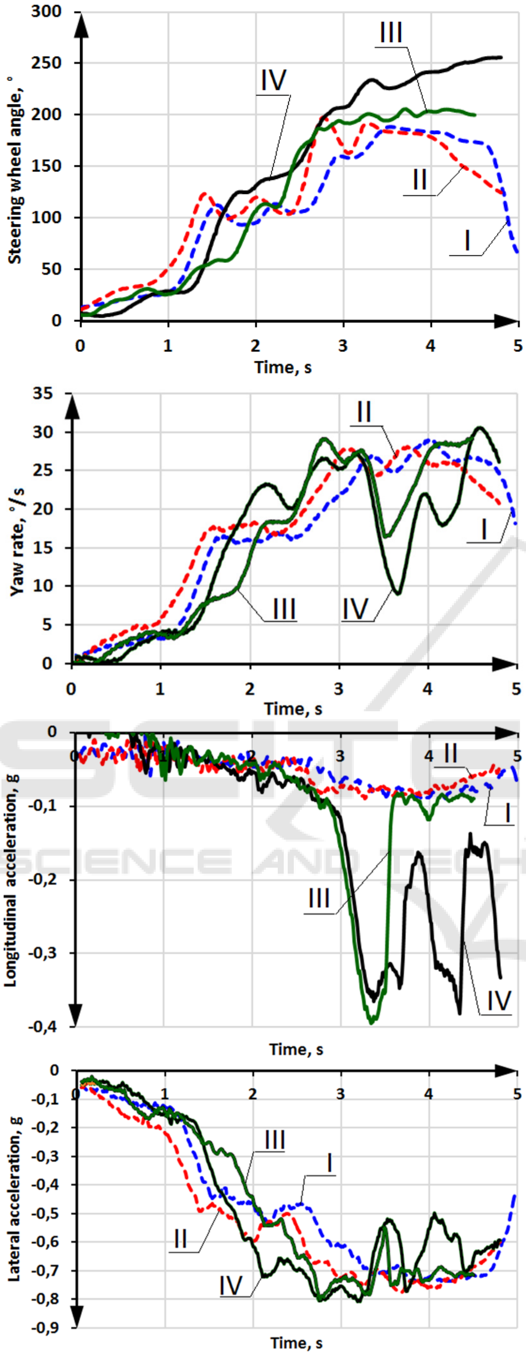

Figure 9: Results of “start of the corner” tests: I – 55 km/h (ESP was not activated); II – 57,7 km/h (ESP was not activated); III – 59,2 km/h (ESP was activated); IV – 63 km/h (ESP was activated).

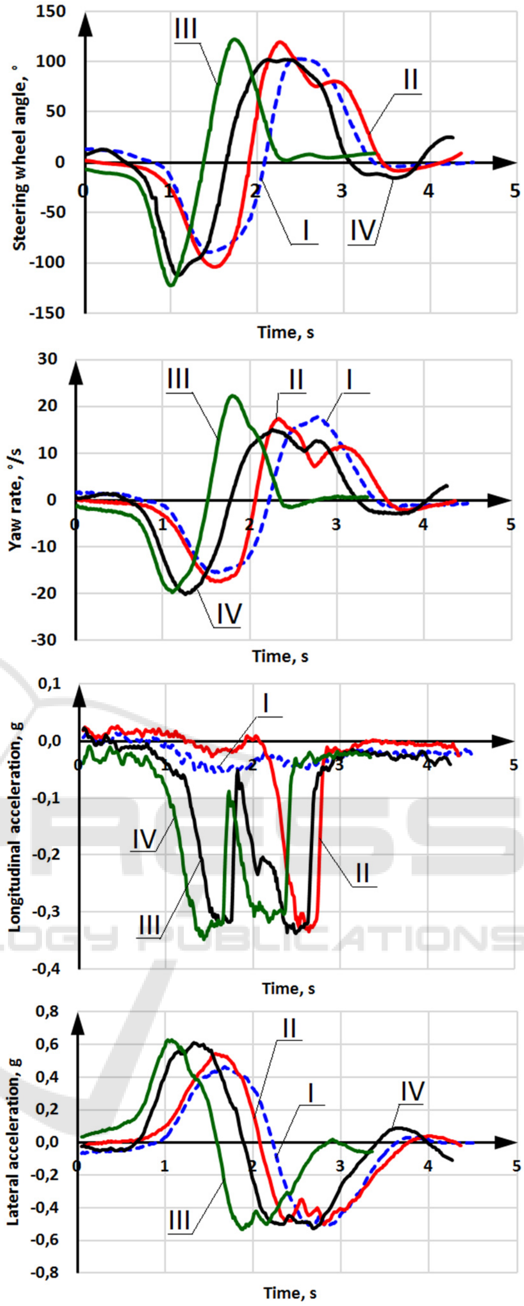

Figure 10: Results of “line changing” tests: I – 60 km/h (ESP was not activated); II – 65 km/h (ESP was activated); III – 77 km/h (ESP was activated); IV – 84 km/h (ESP was activated).

Graphs of Figure 10 show the results of “line changing” tests. In this test (opposed to " start of the corner ") curves of the angular rotation velocity (yaw rate) and curves of the steering wheel angle have similar behavior, thereby driving stability maintained, LCV continues to move along a path predetermined by the driver. Threshold ESP during "line changing" tests was activated at 60…65 km/ h. ESP broke LCV wheels, corrected lateral acceleration thus restoring stability.

This study was conducted in dry weather on dry pavement as provided in GOST 31507-2012. As it is shown on Figure 4, more than 25% of severe and extra heavy road accidents happened on wet and snowy road surfaces (with a low coefficient of adhesion). The analysis of dynamics of LCV equipped by ESP in these conditions could be a further extension of the performed work.

6 CONCLUSIONS

1. The problem of installation of ESC (specifically ESP) on commercial vehicles is topical nowadays in Russia, because commercial transport takes part in more than 30% of severe and extra heavy road accidents. Analysis results show that about 20% of severe and extra heavy road accidents with the participation of commercial vehicles (including LCV) could be avoided or mitigated with the help of ESC operating. ESC system can be useful in more than 30% cases of vehicle's manoeuvring of a speed of 40…60 km/h and in more than 50% cases of vehicle's manoeuvring at a speed of 60…80 km/h.
2. Road tests of light commercial vehicle equipped by ESP where performed for estimation of the effectiveness of the electronic program in conditions curvilinear manoeuvres: start of the corner and line changing (in accordance with Russian Standard GOST 31507-2012).
3. The analysis of experimental data shows that during manoeuvre "start of the corner" the threshold of dynamic stabilization was found at 58...59 km/h, when in the "line changing" it was about 60...65 km/h, that close to speeds regulated by GOST binding for all types of LCV (regardless of ESP).
4. During "start of the corner" tests a special function ESP-RMF (rollover suppressing) was activated by means of braking of LCV wheels, decreasing the critical lateral acceleration and the speed of rotation around the vertical axis. During "line changing" tests ESP broke LCV wheels, corrected lateral acceleration thus restoring stability.
5. Further research should be implemented on wet and snowy road surfaces (with a low coefficient of adhesion) that will help to analyse the effectiveness of ESP in different critical conditions that could happen with a driver.

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