ELECTRONIC STABILITY CONTROL – STATUS OF THE INTERNATIONAL LEGISLATION WITH COMMERCIAL VEHICLE FOCUS

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ABSTRACT

Electronic stability control systems (ESC) have been installed in vehicles for more than 10 years, and their impact on traffic safety is obviously proved. Several studies from all around the world report around 30% decrease in different accident classes, in some cases, especially within the single vehicle accidents for SUVs and mini vans the reduction reached the level of over 60%. The ESC deployment rate has been increasing continuously; in Europe it exceeds 40%, in some countries (such as Germany) even higher. There are some countries, where ESC has been made mandatory for some vehicle classes (in Denmark for buses, US is close to mandate it for SUVs), and as can be anticipated this rate will futher increase. In Germany the coach manufacturers made a voluntary commitment and equip all newly produced vehicles with ESC. All these activities clearly show the demand of society for improved road safety, that cannot be neglected by law makers either. These activities forced the UN-ECE WP29 to establish a special working group within the frame of the GRRF, whose mandate is to investigate the legislative issues of the ESC systems, and to make recommendations for legislative actions. The committee has been established at the end of 2004 with expected results for the end of 2006.

This paper reports on the actual status of regulatory work, explaining all relevant and still open issues. Although the work has been started as a general regulation, the scope of the ad-hoc group has been changed, and primarily concentrates on commercial vehicles in a first approach, but limits neither the definitions nor the requirements only for those.

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1 INTRODUCTION

The brake systems based Electronic Stability Control systems – although they have been invented much earlier, as seen in the papers of Kimbrough et. al. (1991, 1992) and Palkovics et. al. (1995, 1996) – have became typical in commercial vehicles only few years ago, and also their deployment rate is not too high (in Europe below 5%, on the other market segments does not really exists yet). Passenger cars have a lead position, since in some markets the rate of installed ESC systems goes as high as 60% of the total registered car population (see details later in this paper). The positive impact of the ESC systems on traffic safety has been proven; many accident statistics show very impressive improvement figures in certain accident categories.

These mentioned facts (extremely different values for markets and vehicle categories, the improvement in accident statistics) together with the increasing demand of society for improved road safety raised the question towards legislative bodies: if these facts are correct, why this very important field is not referred in the regulations? This is the reason why the WP29 of the UN-ECE asked GRRF to investigate this issue, and to make a proposal for the future regulation framework.

- Although the ESC systems – at least technically – are easy to understand, their regulation is far from trivial, and many questions have to be answered:
- Why these systems should be regulated at all? Obviously the market recognizes their benefits without any regulation.
- Where should it be regulated? Since all state-of-the-art systems use the brake as actuator, it seems somehow logical to amend the UN-ECE Regulation 13, but what about the other future solutions?
- What should be regulated? The system itself cannot be really defined, so the stability function should be described.
- How shall it be regulated? A minimum specific design should be required or are we in a position to prescribe a test which will produce clear, measurable and assessable performance measures?

Although it is not a technical, but rather political decision, the question of mandating the ESC for certain vehicle types, cannot be avoided.

This paper tries to answer those questions by summarizing the present status of the working group activities.

2 OVERVIEW OF THE WORLD WIDE STATUS OF THE ESC SYSTEMS

2.1 Deployment rate

As mentioned before, the deployment rate of ESC systems is increasing world-wide. The most significant increase can be observed in Europe, as shown in Figure 1. From 2003 to 2004 the average rate in the countries of the European Union has grown from 29% to 36%. The highest rate has been achieved in Germany, where 64% of the total newly registered car population is equipped with ESC system (all major German car manufacturers, such as DaimlerChrysler, BMW, Audi, Volkswagen have the ESC as standard).

	2003	2004
United Kingdom	**20%**	**30%**
Germany	**55%**	**64%**
France	**35%**	**39%**
Spain	**25%**	**30%**
Italy	**14%**	**20%**
European Union	**29%**	**36%**

Figure 1. ESC equipment rate in Europe, 2003-2004

Looking at other countries, USA is catching up; the deployment rate in 2004 exceeded 11%. This dynamics however is mostly driven by passenger cars, the trucks do not participate in this growth yet, although ESC systems have been available from more manufacturers since 2003, at least in Europe for vehicles with electro-pneumatic brake systems. It is interesting to observe that demand for truck ESC systems in the USA seems to be much higher than in Europe, and when the system is available, the deployment rate can rapidly exceed the European values. The difference in the two markets can be found in the dissimilar fleet insurance policies.

2.2 Impact on accident statistics

Because of the increasing deployment rate described in the previous part of this paper, the impact of the ESC systems on the traffic accidents became measurable. Several studies have been made all around the world, and a good summary of these is given by Dang (2004) and Garrot (2005). The numbers reported by the several sources show very similar figures: since ESC has been introduced the single vehicle accidents have been reduced by 30-40%, while in case of the “loss of control” type of accident this reduction reaches up to 60% for fatal accidents. A special attention was paid to the high CG vehicles, such as minivans, SUVs, where these figures are even more impressive.

2.3 Local legislation activities

As the deployment rate is increasing, the impact of the ESC systems seems also to be proved, several countries and technical associations started to generate terms of references for the ESC. A large effort is being currently put forth (by the time of the publication of this paper these activities might even be concluded) to define the requirements for ESC systems in the United States. The target of the US government is to mandate the ESC system for some vehicle classes. Denmark has recently mandated the ESC system for touring coaches, for that reasons they generated their own definition what ESC is. Technical associations, such SAE are defining also the stability control systems; there are on-going activities even in New Zealand.

3 REGULATION OF ESC IN THE UN-ECE LEGISLATION FRAMEWORK

As it was discussed in Part 2 of this paper the electronic stability control systems attract quite significant attention because of their increasing deployment rate and also because of their very positive impact on traffic safety (some people say that since the safety belt was invented the ESC is the second most significant system leading to dramatic improvement in the severity and frequency of vehicle accidents). Nevertheless, the situation is not very typical: the industry provides a system with the described impact, the society demand is given, but there is no regulation, which would describe what to call an ESC system, what are the design or performance requirements, and last, but not least, which are the relevant vehicle categories, where the system should be mandated. The work of the UN-ECE initiated ad-hoc expert group intends to close this gap by means of providing world-wide unified terms of references for the ESC function.

3.1 Technical issues of the ESC function

Although the principal operation of the electronic stability control function is well known, there are some basic issues, that must be mentioned here. Figure 2 shows the control principle of the ESC function based on the so-called reference model following control.

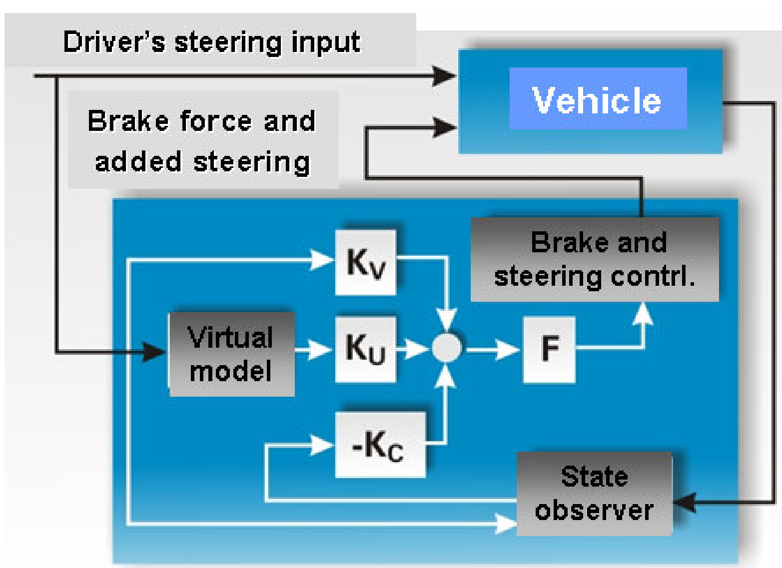

Figure 2. Basic control principle of the ESC function

The basic requirement for the ESC function is that the driver's intention must be followed in every situation; this means:

- The system intervenes if the driver cannot control the situation,
- The optimal vehicle behavior is calculated from a reference model based on the measured driver's intention,
- The intervention should minimize the error between the measured and the calculated (optimal) variables.

This requirement means that although the ESC function intervenes into the vehicle dynamic behavior, it always supports the driver, and does not make any decision against the driver's intention. In addition, similar to ABS the ESC function should have fail-safe characteristics, meaning a safe termination of its operation in case of a system failure.

When talking about ESC function one has to distinguish between the in-plane and out-of-plane functionalities, since in different vehicle types these can be separated from each other, and some vehicle might have only one of them (for example semi-trailer does not require yaw control, but it does require roll-control).

It is important to note here that the regulation consequently talks about stability control function and not a system. The reason is that the ESC functionality – even though they are functionally the same – will be realized on different platforms in passenger cars (hydraulic brake system with electric components, electro-hydraulic or electro-mechanical brake system), and in trucks (where the electro-pneumatic brake provides the platform) or in trailers.

Another problem with the unified regulation is the variety of the vehicle types: the legislation should cover a wide range starting with a simple 2-axle vehicle, up-to a 8x8 heavy truck or pusher type of articulated bus. In order to cover all these types, the regulation requires a certain level of flexibility, which, however, does not endanger the objective type approval process conducted by 3rd party institutions in the UN-ECE regulatory framework.

3.2 Definition of the function

Regardless of the system platform, sensors and actuators used the stability control functions can be categorized into one of the two major classes: either controlling the vehicle yaw behavior or influencing the roll dynamics. The former covers the directional control, the latter targets the prevention of roll-over. There are solutions available for both, the yaw control is the basic function of all electronic stability control systems, the roll control is used mostly in trailers as a standalone function, but also as a part of the ESC for trucks.

These two functions are defined in the text as follows:

- "Directional control" means a function within a vehicle stability function that assists the driver within the physical limits of the vehicle in maintaining the direction intended by the driver in the case of a power-driven vehicle, and assists in maintaining the direction of the trailer with that of the towing vehicle in the case of a trailer.

- "Roll-over control" means a function within a vehicle stability function that reacts to the potential of roll-over to stabilize the power-driven vehicle or towing vehicle and trailer combination or the trailer during dynamic maneuvers within the physical limits of the vehicle

As seen, the definitions are giving only the basic description of the function, and not specifying anything on how they should be realized, while this will be given in a special Annex to the regulation. The definition of the functions will be a part of the main text of the future regulation.

Since the above given description is only a definition, it might raise a problem: if a simple roll-over control system will be installed in the vehicle, it can also be called as vehicle stability function, meaning competitive disadvantage for those manufacturers who have the yaw control in the vehicle as well. This problem should be overcome even in the cases when the function is not mandatory to use.

3.3 Where to regulate the vehicle stability function?

One of the very first questions, what the group had to answer was: where the regulation of the vehicle stability functions should be embedded? Since currently there is no vehicle level (not subsystem) regulation in the UN-ECE framework, there are four options left: to amend the ECE 13 (brake) or ECE 79 (steering) regulations as those are the ones dealing with the potential actuators for vehicle stability functions, or include this in the Regulation 111, or create a completely new regulation. The last option had to be discarded rather soon, since creating a new regulation might take several years to formulate, and from than until it comes into effect it can be close to 5-10 years. Regulation 111 deals with special topics of dangerous good vehicles, where the stability functions definitely play important role, but that regulation is rather specific. The first two regulations (brake and steering) are definitely good candidates, since they exist, and have all other components necessary for the regulation of such a complicated issue as the stability function. The reason that the ECE 13 has been chosen is that all the state-of-the-art stability control systems use the brake as a primary actuator for influencing the vehicle dynamical behavior in the most efficient way. In addition, the ECE 13 provides the frame for such an amendment. Of coarse, this does not exclude any other potential future actuator (for example the steering system with angle or torque superimposing possibilities will appear in the vehicle stability arena shortly), a reference to those regulations (if any, ECE 79 for the steering) can be made.

3.4 How to regulate?

One of the most critical questions is how to regulate the vehicle stability function? There are two competing concepts that can be followed:

- A design based requirement set, meaning that only those systems can qualify for stability function that fulfills a number of design criteria (number and type of sensors, actuators, intelligence, layout etc.). In this case the assumption is that if all the components in the prescribed hierarchy are installed in the vehicle, the system will provide the legislation required performance (if any).

- A clearly defined performance requirement, where only the expected performance limits and the related test methodology is defined, all the rest is up-to the system and vehicle manufacturers on how they achieve these goals.

3.4.1 Design vs. performance requirements

Both concepts have advantages and disadvantages, but sometimes certain compromise has to be found. At the beginning of the ABS introduction, the ECE 13 specified design requirements, since there was no clearly defined test and performance criteria developed (lack of experience with a new system), which has been modified over the years and what we have today is more of a performance requirement.

The ad-hoc group faces this challenge as well, since on one hand it would be much easier to define clear, easy measurable, objective performance requirements, on the other hand the large variety of vehicles, the lacking experience on how to make such investigations by third parties (technical services) raise several problems.

The vehicle and system manufacturers make a wide variety of function tests during the product development however; most of these are not standardized tests due to the specialties of the stability functions. Also these tests require conditions, which are normally not available everywhere (reproducible surface conditions for low adhesion investigations normally available for bigger manufacturers close to the artic circle, large vehicle dynamic surfaces). Also the installation of vehicle safety devices required for such tests (safety cage, anti-jackknifing device, outrigger, etc.) in a wide variety is not easy and cheap to be solved. If the 3rd party investigations must be conducted under these conditions, it will result in additional burden on the vehicle manufacturers that they are most likely will be unwilling to pay, since they have already made it all. In addition, there is no unified test and evaluation procedure for the variety of vehicles and systems today mentioned earlier.

3.4.2 Current proposal – a mixture of performance and design based requirements

The challenging task of the working group was (in fact, still is) to find a solution, which is somewhere in between the design and performance requirements. The short content of the current proposal can be summarized as follows:

- In case of the applied actuators a certain minimum level of design is prescribed: the autonomous (i.e. driver independent) engine control and individual wheel brake application (either automatically commanded or wheel/axle selective) must be possible. The justification for these design requirements is clear: the brake system is able to control the tire in-plane forces in the entire slip range (unlike steering does), and the engine throttle control, which is an effective means of reducing the kinetic energy of the vehicle. Other actuators (i.e. steering, controlled torsion bar, etc.) not excluded either, but only in combination with the brake and engine control systems. These design constraints are not questioned by the technical community, everybody seems to accept that an efficient stability control cannot function without them. In addition, both systems are state-of-the-art both in passenger cars and commercial vehicles as well, unlike the others, which will come in the future and will require longer time to become state-of-the-art.

- Although in the very first version of the proposal similar design constraints have been defined for the sensors, it was replaced by more performance like requirements. In the current version of the text the yaw rate as a variable that must be controlled is defined for the in-plane stabilization, and the vertical tire load for the roll control, no sensor is specified for how to obtain these values. Any sensor could be used to generate these variables, provided that the calculated signal is available under any conditions, generated by an on-board sensor and shows a good alignment with a reference signal proved by the technical service. This was necessary in order to recognize the rapid technological development of vehicle on-board sensors.
- In order to temporarily overcome the difficulties with the third party testing and the lacking performance criteria, the group proposes a solution, which goes towards the unified testing and performance measurement. This means the following:
    - The technical service should make a dynamic demonstrative test on one vehicle configuration, which shall include the critical conditions of directional control and roll-over as appropriate to the vehicle stability function installed on the vehicle with the method of demonstration and results being appended to the type approval report. This test may be carried-out other than at the time of type approval, opening the opportunity for the technical service to use the facilities and installation of the vehicle manufacturer thus reducing the costs. The type of the test should be agreed between the technical service and vehicle manufacturer,
    - For the other vehicle configurations (but equipped with the same stability function) it is enough to submit measurement data made earlier by the manufacturer, or

- Computer simulation data can also be used, provided that the simulator is validated and verified on measured data. This is a new element in the UN-ECE regulation framework; a special appendix to the annex is being created in order to specify the conditions of the simulation.

Following the above logic, the ad-hoc working group believes that this amendment to the Regulation 13 can be introduced in the short term, and can effectively regulate the vehicle stability function related issues. Of course, there is an agreement in the group that this regulation will be re-worked in a certain time. The stability control systems are still in their infancy, the rapid technology development in the actuator and sensor field will bring new and new solutions, which must be considered, but this very important field should not be left unaddressed in the legislation already today.

3.5 Effect of the amendment – why it is important to generate terms of references?

The mandate of the group was limited to technical investigations, but some "political" questions cannot be separated entirely. There are several fields, where the clear definition and requirements of the stability function is needed: when the function is mandated, when incentive is given to the vehicles (road toll and tax reduction), or in general, if a vehicle is fitted with the function, it must comply with the regulations (like in case of ABS).

These are the questions of mandating the stability function that are purely political decisions. The group has been asked where does the mandating bring the highest impact on traffic safety? Based on the attempts that have been made so far, and the availability of the function for the different vehicle categories, the group proposes to start with touring coaches, where the directional stabilization will be required, and in the case of dangerous good vehicles and semi-trailer tractors the former must have at least directional, and the latter at least roll-over control function.

4 SUMMARY

This paper described the current status and the main directions of the electronic stability control function-related UN-ECE regulatory activities. Because of the complexity of the system, it is not obvious how to structure the regulation, and many questions have been asked. The current version of the proposal attempts to find an acceptable compromise among the different expectations in order to submit a consolidated amendment to the Regulation 13 as soon as possible. Due to the infancy of the stability control systems it will be modified based on the experiences on the other legislative solutions (such as the one will be introduced in the US), investigations of public institutions, technical services and also the manufacturers. However, as the saying says: "a bird in the hand is worse two in the bush"

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