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Crash avoidance systems and collision safety devices for vehicle occupants

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Abstract. Numerous efforts have been made to improve safety on our roads, including the vehicle safety, from passive elements to advanced active systems that are affecting vehicle stability and influencing vehicle dynamics. This paper presents a basic classification of vehicle safety systems, devices and futures. Presented information was compiled from different sources, and is based on the function of these systems over time and their cooperation characteristics. The purpose of this text is to establish a general structure for classification of these systems that make possible the providing of their overview in a comprehensive way.

1 Introduction

Road crashes are uncompromising affairs that can have very negative impact on vehicles and vehicle occupants involved in them. Strong forces that are actuating on human body during a car accident can cause serious injuries and the damage could be very significant, even fatal.

There are many different factors that affect severity of the injury, e.g. kind of crash (rollover, side-on crash head-on crash, etc.), vehicle speed, use/not use of seat belts, vehicle airbags, seat position, kind of collided object (another vehicle, solid object, etc.), and so on. In each case injuries are broadly related to the amount of kinetic energy applied to the human frame. Majority of kinetic forces released in road traffic crashes cannot be tolerated by the human body. For above mentioned reasons it is necessary to take a variety of measures to prevent the crash occurrence and to increase passenger safety.

In vehicles´ development and design it is given increasing emphasis to comply with the requirements of vehicle safety. These requirements are set by the applicable regulatory provisions and also by the requirements of the customers. Precisely because of the customer requirements, vehicle safety becomes one of the cornerstones of a competitiveness in contemporary market. Vehicle manufacturers dedicate to these issues more and more attention in the development of new vehicles and they are working also on the development of a variety of security features that could be installed in vehicles additionally. Modern car is usually designed with a particular emphasis on ensuring a high level of safety of the crew and other road users (pedestrians, cyclists, other vehicles, etc.). To ensure the highest levels of safety the modern vehicles are equipped with systems for driver support that are in

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certain cases even capable replace the driver (e.g. automatic maneuvering system that moves a vehicle from a traffic lane into a parking spot, automatic car accident detection and notification system that identifies the vehicle's position and calls for help, and so on.). All these elements comprise integrated vehicle safety. Integrated vehicle safety systems can be into two basic categories: active safety and passive safety.

2 Active safety

The *active safety* features, devices and systems help maintain vehicle under control and prevent an accident occurrence. Active safety is a result of harmonic structure of the vehicle chassis, which takes into account the wheel guidance, suspension, steering feedback and stability of the brakes. It guaranties the optimum vehicle dynamic behaviour also during the process of evading obstacles.

As a part of the active safety we can recognize:

1. Autonomous active safety systems

- permanently supporting driver,
- actuating in a moment of expected impact;

2. Active safety systems cooperating

- with other vehicles,
- with infrastructure.

2.1 Autonomous active safety systems

The best way to reduce road accidents is prevent them. For this purpose were designed active safety systems. These systems can be classified in terms of their function over time to continuously operating systems and systems that affect vehicle activity at the moment of potential danger (in risky situations that could conclude in traffic accident).

2.1.1 Autonomous active safety systems permanently supporting the driver

Active safety systems that provide permanent support for the driver are also called driver assistance systems and are known as ADAS (from Eng. Advanced Driver Assistance Systems) and DSS systems (from Eng. Driver Support Systems). Autonomous permanently active safety systems support the driver adaptation to the current situation on the road, anticipate the needs and, if necessary, take the initiative [1].

The most known representatives of these systems are Power steering, Electronic Stability Program – ESP, Anti-lock Braking System – ABS, Electronic Brake-force Distribution – EBD, Anti-slip Regulation – ASR, Electronic differential lock – EDS, Break Assist System – BAS, Advanced Emergency Braking System – AEBS, Multi-collision brake – MKB, Regulator of engine torque – MSR, Downhill Assist Control – DAC, Active Body Control – ABC, Speed Alert, Adaptive Cruise Control – ACC, Intelligent Speed Adaptation – ISA, Seat Belts Reminder – SBR, Signalization of an improperly closed doors, Lane Departure Warning System – LW, Blind Spot Monitoring – BLIS, City Safety, Collision Avoidance System – CAS, Pre-crash Sensing, Parking Assistance System – PDC, Driver Monitoring System – DMS, Lighting Xenonheadlight, Adaptive Headlights – AHL, Vision Enhancement System, *Alcohol* Interlocs, Route Guidance and Navigation Systems, Tire-pressure Monitoring Systems (Intelligent Tyre System – ITS, Tyre Pressure Monitoring System – TPMS, Deflation Detection System - DDS), Run Flat tyre – RFT, Heads-Up Display – HUD and Automatic Dimming Mirror – ADM [2-4].

The systems for permanent support of driver actions include the core vehicle technologies that are affecting vehicle stability and dynamics, systems that maintain distance, warning systems and systems for road accident prevention, driver drowsiness detection systems, vision improving systems, pedestrian detection systems, alcohol control systems, navigation systems and other. Systems of vehicle dynamics can be marked as a basic active safety systems.

They ensure traction and stabilization control of vehicle in different types of traffic situations and under various driving conditions. Many times there are critical road conditions (e.g. icy road) or critical road incidents (that requires e.g. emergency braking) or cases when correction of driver´s error is needed (for example when cornering or during fast changes of vehicle direction). Some of these systems are often used when braking. Traction control is particularly acute during starting and acceleration of the vehicle when the traction systems´ mission is to improve the transmission of torque from the drive axle to the ground. Other systems, if necessary, are pumping without breaking the wheels. Almost all of these systems utilize a substantial part of the ABS system.

The purpose of the maintaining the distance control systems are assuring a safe distance from the vehicle ahead. A device used for this purpose is a part of the most automatic driving control systems.

Warning systems and systems to prevent collision detect obstacles (vehicles or static objects) with digital CCD cameras, millimetre-wave radars, laser radars, piezo ceramic devices (Polaroid), or are detecting distance on all vehicle sides (Delco). This group includes systems to warn against frontal collisions, systems to warn against a side collision, systems for night vision and systems to warn against lane departure. In some cases, these systems are connected with the automatic braking of the vehicle. The main difference between the standoff and preventive action against the collision occurrence is a lack of ability of ACC systems to adequately respond to solid objects. In recent years there is a strong trend towards the integration of the functions of all the systems of this group [5].

Driver drowsiness detection systems are operating by analysing the driver's steering bavoir or selected driver's physiological parameters. They are based on an analysis of the stability of steering wheel (measured in relation to keep vehicle in the lane) or on the condition of the driver by measured by specified physiological parameters. Whenever the driver's performance, measured by either method, exceeds a certain limit the driver is considered drowsy, respectively sleepy and specific predefined countermeasures are activated.

Another group of active safety futures are vision improving systems. There are two basic groups of these systems.

The first group - *active VES* - use additional sensors, information sources such as digital maps and special facilities that seek headlights of the vehicle on the part of road space ahead of the vehicle, which should be subject of justified interest of the driver. Intelligent vehicle systems from this group can additionally adapt the light distribution according to the vehicle speed.

Systems of the second group - *passive VES* – are using invisible light sources on the road that light over a greater distance or a greater width comparing with the basic vehicle headlights. Reflected radiance is captured by special sensors that transform it into visible light. Then additional image of a road space ahead of the vehicle is reproduced to the driver.

Pedestrian detection systems are designed for the purpose of detecting pedestrians (or single barriers) located in the closeness of the vehicle or in its roadway. Various development workplaces are using different techniques, different sensor technologies and different ranges of space where the system is looking for obstacles or pedestrians. For example the trend of Japanese vehicle producers is the realization of the idea of detecting pedestrians at night and address the problem of the blind spot.

Among the active safety systems continuously supporting the activity of the driver we can also include the usual elements of the vehicle, such as vehicle lights, wipers, heaters, heated rear glasses and mirrors and so on. The reason why these systems are considered as an active safety systems is that they maintain comfort of the driver and thereby facilitate maintaining his vigilance and attention while driving [6].

2.1.2 Autonomous active safety systems actuating in a moment of expected impact

With a purpose of increasing active vehicle safety some car producers are assembled systems that are activated in a moment of the expected impact in the higher classes of their vehicles. These so called Intelligent Vehicles, automatically effectuate series of steps in the case of imminent danger and expectance of the accident, including:
- mechanical or visual driver warning (light vibration of the steering wheel or seat);
- activation of the braking system (adjustment of the brake elements into working position);
- tensioning seat belts, to shorten the time of a stretch in a case of possible impact;
- anchoring electrically operated seats to the optimum position in terms of safety;
- activate the automatic vehicle braking system if the collision could not be stave off.

2.2 Cooperating active safety systems

Safe and intelligent vehicles are characterized not only by the ability to communicate with each other but they also have the ability to interact with intelligent infrastructure. Overview of the active safety systems able to cooperate with other elements of the transport system is provided in Table 1. These systems are currently in development and testing phase.

Table 1. Cooperating active safety systems.

Systems'categorization		**Name of the systems**
Active safety systems	cooperating with other vehicles	Car2Car systems (communication between vehicles themselves)
	cooperating with infrastructure	systems Car2infrastructure (communication between vehicle and any stationary communication equipment, including portable traffic signs and warning devices)

The implementation of intelligent vehicles that are based on cooperating active safety systems into ordinary traffic flow could bring numerous benefits such as e.g. [7]:
- road safety improvement;
- reduced fuel consumption;
- improved traffic flow associated with communication between vehicles;
- reduced congestion in urban areas.

2.2.1 Active safety systems cooperating with other vehicles

In addition to the vehicle active safety systems that communicate with each other, there are exist also cooperating systems that make possible communication between vehicles. They are called Car2Car systems.

Car2Car system consists of vehicles that are in a range of each other and can create an ad hoc network in which the vehicles know their location, speed and direction between them [8]. Car2Car system allows providing and exchange of warnings and information between vehicles.

2.2.2 Active safety systems cooperating with infrastructure

Active safety systems cooperating with infrastructure are known as Car2Infrastructure Systems. They incorporate all the communication technology between the vehicles and any stationary communication equipment (stationary in this case refers to static at a given time). This group includes also vehicle communication with portable traffic signs or warning devices.

3 Passive safety

According to statistics the most often cause of traffic accidents is reduced alertness of the driver when driving [9]. This occurs mainly due to driver´s fatigue or because the driver is devoted to activities which conduct its attention away while driving, such e.g. turning on the radio or mobile use and communication with other passengers. In this case, even the use of the widest range of active safety features cannot prevent the accidents. In this situation are applied elements of passive safety.

Passive safety include all the vehicle facilities and measures that minimize the impact and damage during an accident. It is especially important if the driver can not actively intervene in the events in road traffic. Elements of passive safety should minimize the consequences of an accident that is already in progress, protect the vehicle occupants prior to the occurrence of injuries or reduce their extent and minimize resulting damages.

The passive safety systems can be divided into:

1. Safety systems activated at the moment of impact;

2. Safety systems activated after the impact

- autonomous,
- cooperating.

Table 2. Passive safety systems.

Systems'categorization		Name of the system
Passive safety systems	activated at the moment of impact	belt tensioners child seats airbags system for protection of vehicle occupants active headrests active front seat rollover protection vehicles system airbag system for pedestrian protection active front bonnet active spoiler active bumper
	activated after the impact	fuel cut-off unlock the vehicle disconnection of the vehicle battery launch warning light

3.1 Passive safety systems activated at the moment of impact

Passive safety systems active at the moment of impact includes features as:
- belt tensioners,
- child seats,
- airbags systems for protection of vehicle occupants (driver airbag, passenger airbag, side airbags for the front seats, front and side airbags for the rear seats, roof airbags),
- active headrests,
- active front seat,
- rollover protection vehicle system [10].

Other passive safety features, activated at the moment of the impact, that actuate as a protection of vulnerable road users (particularly pedestrians) are [11]:
- airbags system for pedestrian protection,
- active front bonnet,
- active spoiler.

3.2 Passive safety systems activated after the moment of impact

Passive safety systems activated after the impact in road accident can be divided into two groups: autonomous systems and cooperating systems.

Autonomous passive safety systems are designed to protect the vehicle occupants against any possible dangers after the occurrence of the accident.

In this case the most commonly applied autonomous vehicle operations are:
- fuel cut-off,
- unlock the vehicle,
- battery disconnection,
- turning on the warning lights.

Safety cooperating systems activated after the crash includes automatic reporting system for emergency situations known as an E-Call.

E-Call is the name of pan-European system for vehicle, which in case of an accident automatically call the emergency unit of the integrated rescue system. This emergency system is based on use of satellites and classic SIM card (like in mobile phones). In the event of a critical situation or accident, E-Call can significantly reduce the response time of emergency services. This emergency call system can be activated manually or automatically by the vehicle passengers if the sensors register the car collision. E-Call then contact the closest coordination centre 112 and transmits important information such as location of the accident, the time of the accident and the type of vehicle. After that the operator is able to send rescue services to the place of accident without any co-operation with other people or with a crew that may not be conscious. The system does not send only location information of the vehicle at the time of the accident, but also data from 60 seconds before the accident, and 15 seconds after the accident, containing for example, information on overload of the vehicle in the moment of impact. Based on all this information the operator can assess accident severity and deduce if it is not only a false alarm. This system can be also very helpful in determining the driver at fault.

3.3 Passive safety outside the vehicle

Passive safety is not just about vehicles. As elements of passive safety can be considered the highlight border traffic signs by fluorescence method, different traffic lights, their different sizes or colour. Furthermore, it can also be construction of road signs, which allows them to break away from surface in the case of impact and avoid that vehicle get "wrapped" around them. For passive safety guardrails we can also be seen, for example, or even a fence along the highway, which should prevent the entry of unwanted wildlife and pedestrians on the roads. The cities are the different fences that prevent free movement of pedestrians.

4 Conclusion

Currently, vehicles tend to be mostly equipped with smart technologies in the field of safety, which would avoid the risks associated with driving or minimize the consequences in the event of an accident. These systems provide an improved control of the vehicle in different driving situations, increase the safety and comfort of passengers, and facilitate communication and control of the situation on the road. Vehicles are equipped with a large number of sensors, transducers, actuators and control units whose task is to coordinate cooperation of all electronic and mechatronic components of the vehicle and to improve communication between other road users. Deploying these systems into vehicles is partly optional (a competitive advantage in terms of safety) and partly mandatory due to the legislation for vehicle type approval to operate in traffic. Actual developments in vehicle safety focus on linking existing systems to increase their efficiency and lower their prices, allowing these systems can be applied to the lower categories of vehicles [12]. This massive extension of safety systems contributes to an overall increase of all types of vehicle safety (operational, perceptual, etc.). The question is how this share of the development will be reflected in real reduction of the number of road accidents, as drivers supported by a quantity of systems and technologies thanks to their sense of security often apply riskier vehicle driven manner.

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