Technical Sciences
Academy of Romania
www.jesi.astr.ro

Journal of Engineering Sciences and Innovation
Volume 8, Issue 4 / 2023, pp. 405-414

E. Civil Engineering and Transport Engineering

Received **19 August 2023** Accepted **4 December 2023**
Received in revised form **30 October 2023**

Active and passive safety systems of the automobile

CLAUDIU NEDELESCU*, **ANGHEL CHIRU**

Transilvania University of Brasov, Department of Automotive and Transport Engineering,
29 Eroilor Blvd, 500036 Brasov, Romania

Abstract. This paper focuses on creating an overview of the current state of research (state of the art) on systems and equipment for active and passive safety of the vehicles. After classifying them, the limits are identified, as well as the technical solutions that are based on design technologies intended to increase the safety of vehicle occupants, pedestrians or other traffic participants in the event of an impact or in case of its prevention. Future approaches are presented at the end of the paper in terms of technical solutions of vehicles with Highly Automated Driving (HAD) technology, as well as how autonomous vehicles work.

Keywords: systems, impact, safety, active, passive.

Introduction

Automobile safety is an aspect of the competitiveness of manufacturers and therefore specific importance is given to the development of the safety systems that equip the vehicle. How they lead to traffic safety depends on a number of factors, such as: the transport infrastructure through the construction of roads and their quality, the technical specifications of the vehicle, equipping with intelligent control devices or ITS (Intelligent Transport Systems), the experience and adequate training of the driver, compliance with the rules and road markings, as well as the correct usage of restraint systems intended for the occupant of the vehicle [1]. The safety of a motor vehicle can be assessed by the possibility of an accident occurring or the way in which other traffic participants may be affected, as well as the probability of injury of the occupants or pedestrians [2].

The main objective of this work is to provide an overview of the current state of research (state of the art) on systems and equipment for active and passive vehicle safety. Considering that the improvement of these systems, however, will occur together with the development and modernization of the conventional vehicle, a

---

*Correspondence address: claudiu.nedelescu@unitbv.ro second direction as well as a secondary objective of this paper is the identification of future technical solutions of vehicles with Highly Automated Driving (HAD) technologies, as well as of autonomous vehicle.

Systems classification

Vehicle safety is based on two main categories, namely passive and active safety, through systems and equipment that are integrated inside and outside of a vehicle.

Passive safety includes all the constructive features aimed at reducing the consequences of an accident to a minimum and mitigating injuries to vehicle occupants. These systems play a particularly important role when the driver of the vehicle can no longer actively intervene in avoiding the collision. Passive safety can be divided into external and internal passive safety. External passive safety refers to reducing the risks of road accidents outside the vehicle, in the case of collisions with pedestrians or cyclists by mitigating their injuries and an optimal deformation behavior of the vehicle structure, as shown in Figure 1.

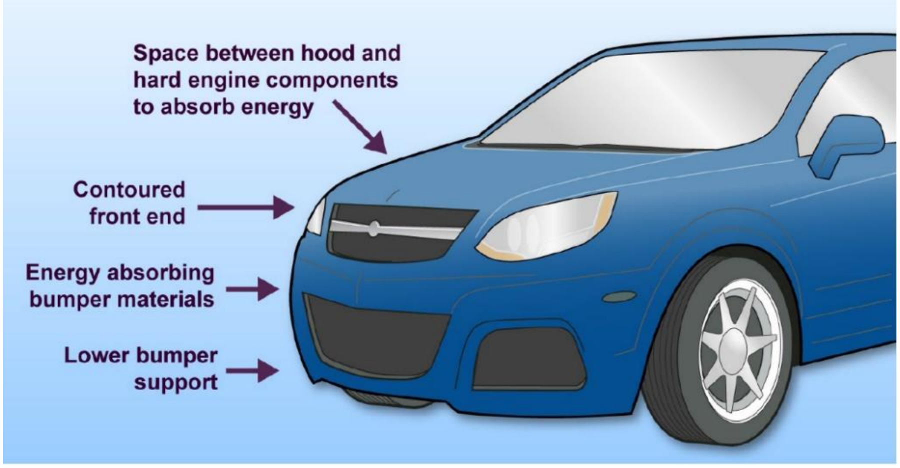

Fig. 1. External passive safety [3].

Internal passive safety is the protection of the vehicle through structural elements that minimize the acceleration and internal forces applied to the occupants in the event of an impact, and also provide sufficient space for survival and ensure operability of critical vehicle components to extricate occupants from the vehicle [1]. The layout of passive safety systems inside a car is shown in Figure 2.

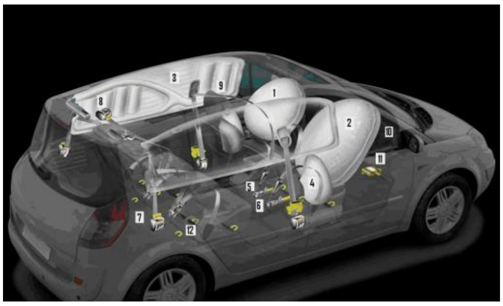

Fig. 2. Internal passive safety [4].

The passive safety systems inside a vehicle are:
1 - Frontal airbag for the driver of the vehicle
2 - Front passenger airbag
3 - Curtain airbag for the side windows
4 - Front side airbag
5 - Driver pretensioner (the seat belt assembly also consists of a buckle and a retractor)
6 - Passenger pretensioner (the seat belt assembly also consists of a buckle and a retractor)
7 - Rear-right retractor (the seat belt assembly also consists of a pretensioner and a buckle)
8 - Rear-left retractor (the seat belt assembly also consists of a pretensioner and a buckle)
9 - Headrest
10 - The internal structure of the board with damping elements
11 - Calculator opening shock sensing airbag
12 - "Isofix" child seat attachment systems [4].

The role of active safety is to prevent accidents and Figure 3 presents a simplified classification that reflects the diversity of active safety systems in the context of different areas of vehicle dynamics [5].

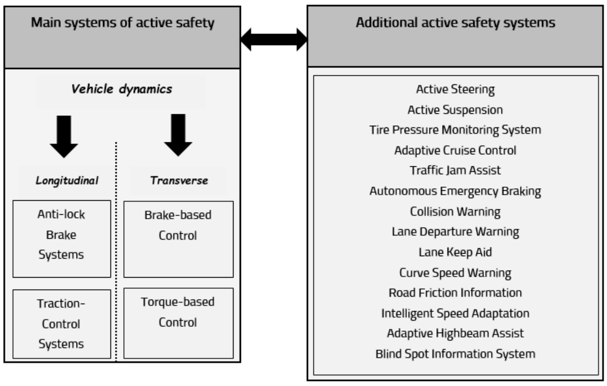

Fig. 3. Overview of active safety systems [5].

Systems limits

The limitations of active or passive safety systems can be classified into two categories: the limits imposed by international regulations, respectively the limits related to comfort, efficiency and functionality.

An aspect that must be mentioned is that the limits of international standards are applied when the provided safety systems are used in a correct way by the occupants of the vehicle. Constructive limits are set by the manufacturer to meet legal criteria and usually these limits are higher than the minimum requirements of international standards. For example, in the case of passive safety systems, various tests are carried out to verify that the constructive dimensions are in accordance with ECE 14 (distance between anchorage points), the tensile breaking limit is in accordance with ECE 16, climatic tests etc. Others factors must be taken into consideration so that the approach is completed, these factors refer to establishing the safety of the vehicle by means of biomechanical criteria, for testing passive safety systems also using dummies that imitate the human response during an accident [6]. An example would be when EURONCAP stars are awarded, an assessment is made of the probability of injury correlated with the kinematics of the occupant, the severity of the injuries being assessed with indices such as HIC (Head Injury Criterion) [7]. The international regulations through which passive and active safety systems are homologated are presented in Table 1 and Table 2.

Table 1. Overview of international standards for passive safety systems.

Equipment	Regulations
Seatbelt	ECE 16, ECE 14, FMVSS 208, FMVSS 209
Airbag	ECE 114, FMVSS 208

Table 2. Overview of international standards for active safety systems.

Equipment	Regulations
ABS	ECE 78, ECE 139, ECE 140, FMVSS 105, FMVSS 121, FMVSS 135
ESC	ECE 140, ECE 13-H, FMVSS 126, FMVSS 136

The second approach refers to the limitations of passive safety systems that are related to the low comfort of vehicle occupants, such as wearing a seat belt, but there may also be limitations in terms of the functionality of these systems. Improper usage of seatbelt equipment can lead to injury and even death of passengers and the driver involved in the accident, one of the main factors being human error. Another limitation may be the impact protection of the airbags used, they either deploy too quickly or do not provide full protection for the occupants depending on the type of accident. Another limitation of the airbag exists in the case of multiple collisions, as they are designed to deploy only once, being ineffective after that. Also, when the impact sensors are avoided, the energy produced during the crash is no longer absorbed efficiently and the sensors may trigger with delays, leading to decreased safety during impact [19].

In the case of active safety systems, the ABS equipment has an important limitation, namely that braking with ABS activation does not take into account the distance to the next vehicle. These systems are also less effective on snow or ice. The efficiency of the ESC/ESP systems is significantly reduced for vehicles with a high center of gravity or when driving on the ground and individual settings are required to calibrate the driver monitoring system [8]. The effectiveness of active safety systems can be reduced when human error is also involved, such as the production of unexpected and unnecessary warnings due to a lack of attention or an inadequate driver reaction by braking hard. Another situation can be when the signals emitted by the safety systems are in contradiction with the driver's desire and frustration can occur at the psychological level, which can lead to unwanted behavior or even to a decrease in attention while driving [9].

Technical solutions

The systems identified for passive and active safety are based on design technologies intended to increase the safety of vehicle occupants, but also of pedestrians or other traffic participants in the event of an impact or in case of its prevention.

In the case of three-point seat belts, in order to increase safety, some assemblies have pretensioning devices. During an impact, they have the role to retract off a part of the webbing, thus tightening the seat belt on the occupant and holding him in the seat. These devices are triggered very quickly, thus reducing the forces developed during the collision and the occupant's forward movement is reduced. In general, after the pyrotechnic capsule inside the pretensioning device exploded, the occupant is held in the seat until a certain load is applied. To decrease the load applied to the occupant's chest, the load limiter device gradually releases the webbing from the retractor, allowing the occupant to move forward while absorbing energy, Figure 4, [10], [20].

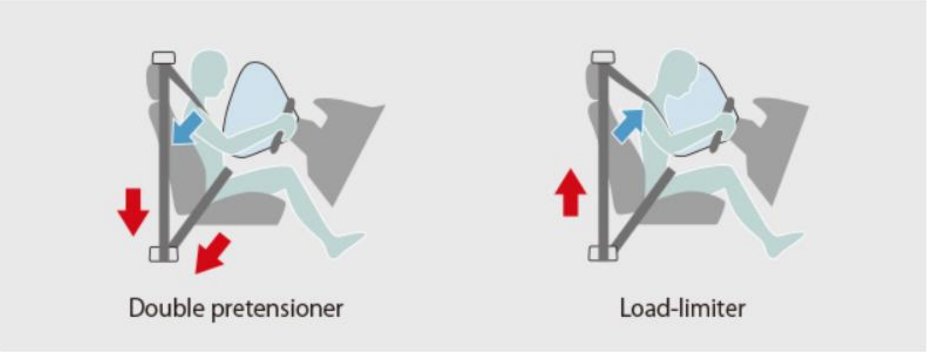

Fig. 4. How three-point seat belt with load-limiter and pretensioner works [20].

The airbag is a passive safety system, which has an air cushion that inflates quickly during a collision to protect the occupant from hitting objects inside the vehicle [11].

The seat belt and airbag can be combined to form the so-called inflatable seatbelt. The concept has existed since 1975, the technical solution being presented in the studies [12] and [13].

However, the use of conventional safety belts can cause certain injuries to the occupants, so to combat this effect the inflatable belt is the most suitable, Figure 5. The area where the webbing comes into contact with the occupant is larger, thus improving protection. Therefore, the load generated after the collision will not be distributed in a single area of the occupant [14].

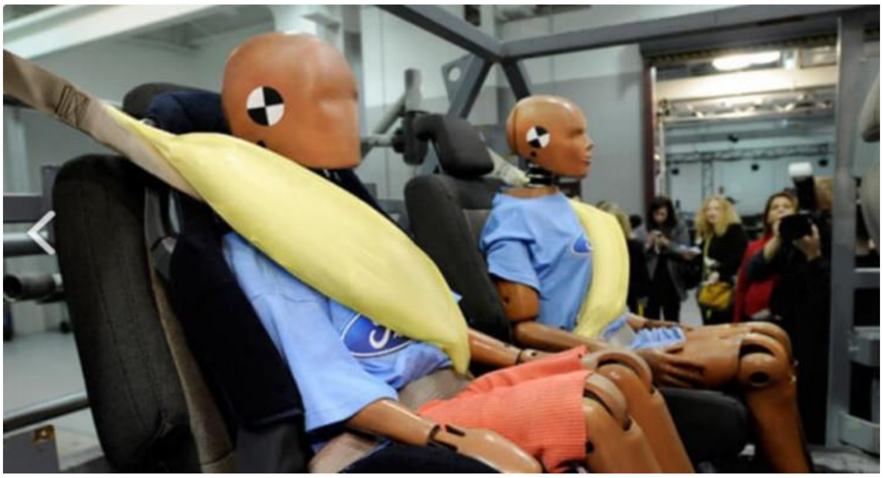

Fig. 5. Inflatable seat belts [21].

Inflatable shoulder belts (Figure 6) can offer a solution to reduce the load applied to the neck and to mitigate the injuries in case of side impact, because after inflation they can protect the chin of the occupant, limiting the movement of the head [15].

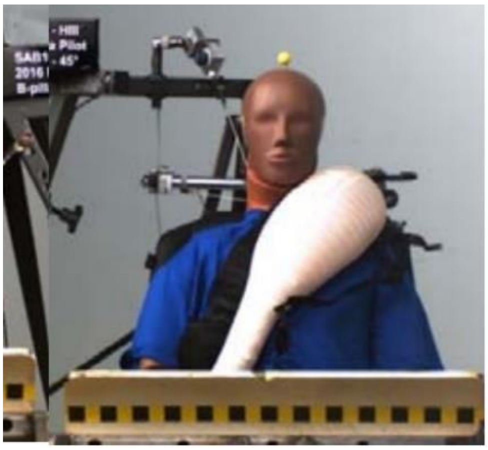

Fig. 6. Inflatable shoulder belt [15].

The technical solutions of the active safety systems must ensure higher safety in order to prevent road accidents, as well as a high level of comfort for the occupants. To fulfill these requirements, along with the modernization of the main active safety systems, the Advanced Driver Assistance Systems (ADAS) were developed. Equipping vehicles with radars and cameras made it possible to communicate with the environment, a schematic illustration of these systems being presented in Figure 7. The information is transmitted to the ECU, which also receives the information from the active safety systems. Consequently, objects such as a vehicle or truck, as well as pedestrians, can be identified and distinguished. It also became possible to establish the position and movement velocity of these objects. Another characteristic is that they can recognize traffic signs.

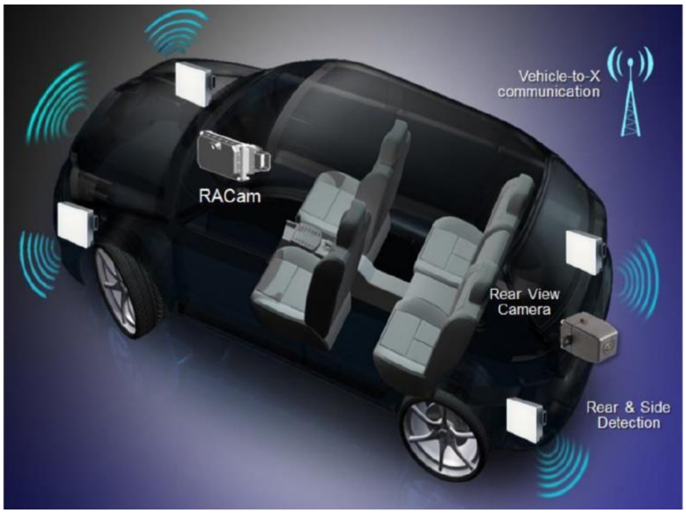

Fig. 7. Communication of active safety systems [16].

Accessing all information about the status of vehicles equipped with such systems while driving is possible through the FlexRay or CAN common vehicle networks [16].

One of the future technologies for the safety of a vehicle is Highly Automated Driving (HAD), offering the possibility for the driver to partially withdraw from the task of driving. The main objective of Highly Automated Driving is to increase safety, comfort and also efficiency. The development of this technology is not simple, because it must at least ensure the already existing safety of conventional vehicles and has hardware components, but also very complex software applications. Another difficulty is ensuring reliability and avoiding some defects of the parts that can endanger the occupants of the vehicle and other traffic participants. Complexity also increases because the technology must not rely on human supervision. Using wireless connections, the vehicles will connect to map services, the infrastructure also consisting of back-end, cloud-type systems, traffic lights etc. [17]. The scheme of such a vehicle is shown in Figure 8.

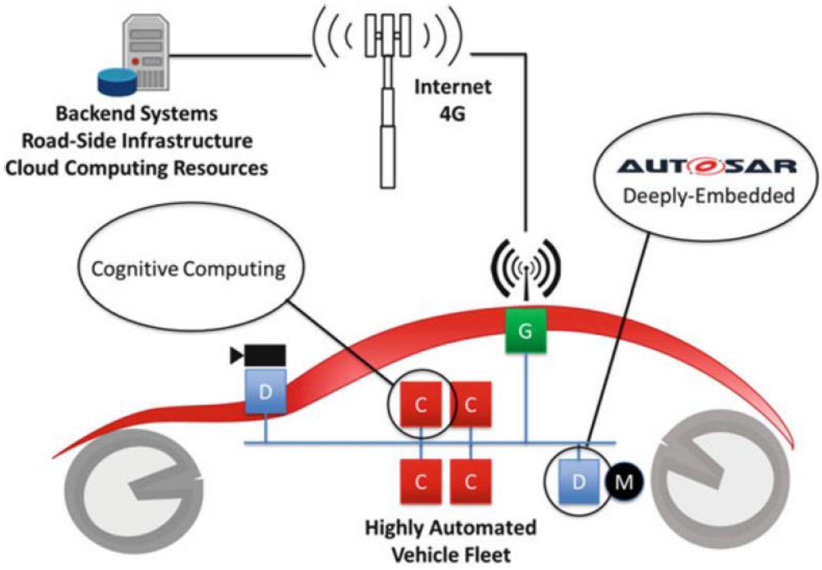

Fig. 8. Schematic illustration of Highly Automated Driving technology [17].

In the future, the modernization of the conventional vehicle will offer the possibility of autonomous driving. How does such an autonomous vehicle work? A schematic illustration of how it works and how to ensure traffic safety is shown in Figure 9.

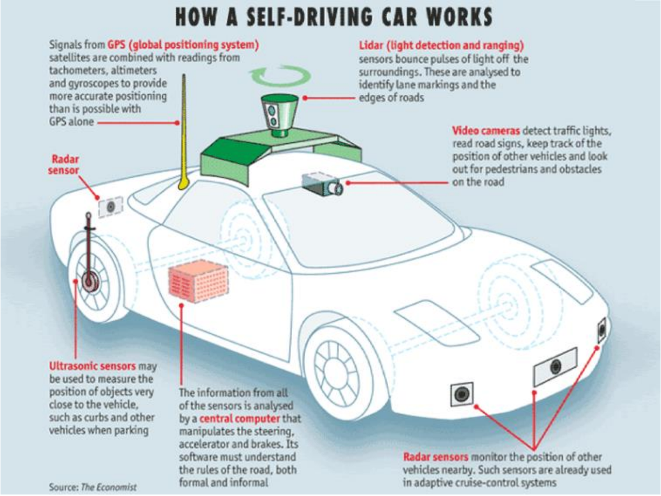

Fig. 9. How a self-driving vehicle works [18].

The autonomous vehicle technology will be improved and it will be highly researched, where the driver's driving task is reduced to a minimum or completely. However, this technology is not without risks for the occupants and other traffic participants, especially due to the complexity of the situations that may arise in traffic [18].

Conclusions

Vehicle safety has a particular importance in the construction of a vehicle, representing an aspect of the competitiveness of vehicle manufacturers, as well as a legal aspect in international regulations regarding homologation.

Active and passive safety systems are used to ensure the safety of vehicle occupants, pedestrians, as well as to reduce or even prevent vehicle accidents.

To increase comfort, safety and efficiency, a new concept of driving the vehicle has been developed, an autonomous vehicle concept, based on multiple researches and expertise, the technology representing the future in terms of driving a vehicle.

Future studies should not be limited to a few types of accidents with limited variation, but should interpret the traffic situation as a whole. Using this premise, the concept of autonomous driving can raise many dilemmas, the most important being the simulation of a rational decision, through the use of artificial intelligence.

References

[1] Liščák Š., Moravčík Ľ, *Safety requirements for road vehicles*, Perner's Contacts, **8**, 4, 2013, p. 49-59.

[2] Morello L., Rossini L. R., Pia G., Tonoli A., *Passive Safety*, The Automotive Body (p. 463-558), Springer, Dordrecht, 2011.

[3] United States, National Highway Traffic Safety Administration NHTSA Pedestrian safety:

Needs to Decide Whether to Include Pedestrian Safety Tests in Its New Car Assessment Program, 2020.

[4] Iovănescu N., Iovănescu S. A., *Considerations on present solutions for passive safety systems of motor vehicles*, Annals of Faculty Engineering Hunedoara - International Journal of Engineering Tome IX, Fascicule 3.

[5] Ivanov V., *Advanced automotive active safety systems: Focus on integrated chassis control for conventional and electric vehicles with identification of road conditions,* Ilmenau University of Technology (Habilitation Thesis), 2017.

[6] Woźniak D., Kukiełka L., Woźniak J., *Modern active and passive safety systems in cars: chosen aspects*, Autobusy: technika, eksploatacja, systemy transportowe, **14**, 10, 2013, p. 272-277.

[7] Ilie S, *Modelarea fenomenelor de impact ale autovehiculelor*, AGIR, 2012.

[8] Buznikov S. E., *System analysis of vehicle active safety problem*, IOP Conference Series: Materials Science and Engineering, Vol. 315, 2018, p. 012005.

[9] Hojjati-Emami K., Dhillon B., Jenab, K., *Reliability prediction for the vehicles equipped with advanced driver assistance systems (ADAS) and passive safety systems (PSS)*, International Journal of Industrial Engineering Computations, 3, **5**, 2012, p. 731-742.

[10] Hu J., Reed M. P., Rupp J. D., Fischer K., Lange P., Adler A., *Optimizing seat belt and airbag designs for rear seat occupant protection in frontal crashes*, SAE Technical Paper (No. 2017-22-0004), 2017.

[11] Shaikh T. N., Chaudhari S., Rasania H., *Air bag: A safety restraint system of an automobile*, Int J Eng Res Appl, **3**, 5, 2013, p. 615-621.

[12] Burkes J. M., *Impact testing of allied chemical "inflataband" with dummies and human volunteers* (Vol. 2), Department of Transportation, National Highway Traffic Safety Administration, 1975.

[13] Fitzpatrick M., Egbert T., *Inflatable Belt Development for Subcompact Car Passengers* (No. DOT-HS-801719 Final Rpt.), 1975.

[14] Lohar S. R., Vanjara N. D., Dhokad R. A., Sumit S. K., *Comparative analysis of conventional and inflatable seat belt references*, International Journal of Engineering and Advanced Technology (IJEAT), **4**, 4, 2015, p. 139-140.

[15] Edwards M. A., Nash C. E., *Inflatable shoulder belts and inboard upper anchor shoulder-belt geometry in far-side oblique impacts*, Proceedings of IRCOBI conference, Antwerp, Belgium, 2017, p. 373-389.

[16] Skruch P., Dlugosz R., Kogut K., Markiewicz P., Sasin D., Różewicz M., *The simulation strategy and its realization in the development process of active safety and advanced driver assistance systems* (No. 2015-01-1401), SAE Technical Paper, 2015.

[17] Watzenig D., Horn M, *Automated driving: safer and more efficient future driving*, Springer, 2017.

[18] Ondruš J., Kolla E., Vertal P., Šarić Ž., *How do autonomous cars work*?, Transportation Research Procedia - Elsevier, **44**, 2020, p. 226-233.

[19] https://wikicro.icu/wiki/airbag#Limitations (accessed August 2023)

[20] https://www.mazda.com/en/archives/safety2/passive_safety/pre_load_seatbelt (accessed August 2023)

[21] https://ford-focus.st/en/inflatable-seatbelts/ (accessed August 2023).