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Professional paper

EVALUATION OF CRASH TESTS AND THE SYSTEM OF EVALUATION THROUGH ANALYSIS OF COLLISION PROCESSES. CASE STUDY

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Abstract

The main purpose of crash tests is to enable customers to identify the safety features of the vehicle, according to their needs in terms of passive and active vehicle safety. At the same time, the test results are the basis for the realization of technological advancement in terms of design improvement, the creation of a vehicle with greater resistance to collisions, all in order to raise the level of general safety of vehicles i.e. driver and passenger safety in the passenger cabin.
This paper presents the crash tests, their historical development, the vehicle evaluation system created by EURO NCAP, as well as most aspects of the application of crash tests. An analysis of a particular collision case will evaluate the vehicle safety assessment system through the NCAP system and investigate the need for standardization of methodology and vehicle safety assessment system using crash tests.

Keywords: crash test, collision process, security, evaluation system

1. Introduction

In the early 1970s, many European institutions began to work on developing the procedures necessary to perform tests to increase the passive safety of passengers in vehicles. As a result, in the 1990s, a crash test procedure was developed to protect passengers in the front and side collisions and a partial procedure in pedestrian-vehicle crashes. In Europe and the United States tests for frontal collisions were carried out first, then tests for side collisions and pedestrian-vehicle crashes. The purpose of the first European crash tests was to familiarize the buyer with the safety of the vehicle. The first tests were performed by the German club ADAC. On that occasion, the technique of head-on collision in a solid obstacle was used, after which the results of such crash tests began to be published as public information, to be available to potential buyers. The European New Car Assessment Program - Euro NCAP was developed in 1996, and the initiator of its establishment was the World Automobile Organization - FIA. There are many crash test programs dedicated to providing consumers with approximate information about the safety performance of new and used cars. Such programs are implemented in various testing centers around the world. For markets in Europe, including Russia, these tests are conducted by Euro NCAP. For the North American market, these activities are carried out by the IIHS (Insurance Institute for Highway Safety). Similar organizations exist for other large and significant markets: Asia (ASEAN NCAP), China (C – NCAP), Japan (J-NCAP), Australia (ANCAP) and others. All these organizations conduct crash tests according to well-established methodologies and are often very similar to each other.

A Crash test is a destructive form of testing, usually performed to establish reliable design standards in crash resistance and crash compatibility for various forms of transport or similar systems and components. In other words, crash tests of vehicles are carried out to determine the level of protection that vehicles provide in the event of a collision. Several aspects of safety are checked: passenger safety, child safety,

pedestrian safety, and the operation of safety systems installed in the vehicle. The main goal of the NCAP tests is to increase traffic safety [1].

Since 1997 crash tests are prescribed by the Euro NCAP (New Car Assessment Program) standard. Shortly afterward, the Euro NCAP became a credible factor in assessing vehicle safety parameters and one of the most important factors influencing the improvement of the reliability of new cars. The first test results were presented to reporters in 1999. Since 2003, Euro NCAP has focused its attention and announced the introduction of child protection testing in the car. Research has shown that over 60% of children do not use the protection provided to them. In February 2008 Euro NCAP has introduced the testing of pick-up vehicles for the first time, according to the conclusion that this type of vehicle is not only used for the transport of goods but also used by families.

In 2009, a new assessment method was introduced, with the introduction of additional safety tests for children, passengers and pedestrians, the use of additional safety systems in the vehicle: electronic stability system, automatic speed control system and safety belts control system and the inclusion of grades from these tests in the overall assessment of vehicle safety.

Lately, all major vehicle manufacturers, before putting the vehicle for sale, must perform experimental vehicle collisions. With that, they examine the construction of the vehicles, their deformability, the durability of the passenger cabin in the trucks, etc. This provides a vivid concern for the safety of the person and his life. Some carmakers (vehicle manufacturers), primarily from Asia, are avoiding testing their vehicles in accordance with these safety procedures, making it difficult for these brands to access European markets.

This paper aims to present most types of crash tests, multiple systems for assessing vehicle safety capabilities, and through a case study to identify the need to standardize the procedures of testing and evaluation of vehicle safety.

2. A way of realization and types of EURO NCAP crash tests

The Euro NCAP crash test simulates a collision that usually results in severe or fatal injuries, to see the behavior of the crew, represented by test dolls and the vehicle. The rating system ranging from one to five stars shows the level of protection in a wide range of traffic accidents, as well as the level of protection aimed at pedestrians. All tests are performed with passengers fastened with seat belts, in accordance with the legislation in European countries (ex. [2] Euro NCAP test procedure for BMW Series 3 2012).

The purpose of the head-on collision test [3] is to simulate the most common type of road collision, with severe and fatal injuries to the driver and passengers and the damages to vehicles. Simulate a car collision with another car of a similar mass. This evaluation is a serious test of the car's ability to experience a head-on collision while keeping the passenger cabin free of deformation (Fig. 1).In the case of a head-on collision, kinetic energy is absorbed by deformation of the bumper, by the front of the vehicle, and in the

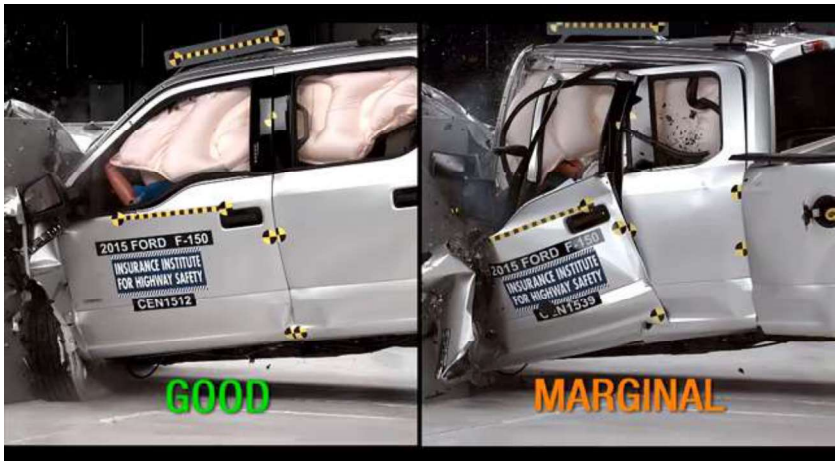

Figure 1. The condition of the passenger cabin after a head-on collision [10]

case of stronger collisions, by deformation of the front of the passenger compartment. Certain structural elements (drive unit, wheels) limit the length of the deformation. Therefore, during the construction of the vehicle, it is necessary to provide sufficient space for moving the front skeleton and the drive unit (to provide appropriate deformation zones), to minimize the displacement of the partition sheet and instrument panel and, generally the disturbance and damage in the passenger space.

The data from this test is the basis for assessing the safety of passengers in the front seats of the car. If the cabin remains free of deformation, the likelihood of injury to passengers is minimized, while airbags and seat belts are used at the same time. Euro NCAP encourages carmakers to install belt tensioners and airbags to reduce the energy transmitted to the front passengers during a collision. Because the protection systems in most cars cannot prevent the knees from hitting the instrument panel, Euro NCAP stimulates the production of cars that do not have solid parts in the zones where the passengers' knees can hit in the event of a collision.

According to the frequency of occurrence and the consequences, the side collision [3] is the second traffic accident in a row. The boot structure of the vehicle is not sufficiently resistant, i.e. it is significantly less resistant compared to the front part of the vehicle, due to which only a small part of the impact energy can be absorbed. As a result of this fact, the consequences are severe deformations of the vehicle and the high risk of severe injuries to the people (driver and passengers in the side-hit vehicle). The side collision test is the basis for the development and mandatory installation of side airbags in newer vehicle models.

Across Europe, about 25% of serious and fatal injuries occur inside collisions [1]. Many of these injuries occur when the car crashes into the side of another car, or into another obstacle, such as a tree, post, or a lamppost.

For these reasons, Euro NCAP has developed a special set of tests to [3] analyze the car's resistance to side impact in a pillar. These tests are designed to encourage carmakers to develop and incorporate passenger head protection. Air headbands, or air curtains, serve to protect the passenger's head and upper body from passing through an open window. Given the fact that the obstacle is relatively narrow, its penetration into the cabin is great, and the likelihood of severe consequences for the crew in the vehicle is high. Without built-in protection, the driver's head could hit the pillar too hard, causing fatal consequences. Airbags allow people to survive in such situations.

One of the elements increasingly being insisted on in traffic is child safety. The safety capacity of the vehicle in terms of child protection is assessed during the realized front and side collision of the cars, with dolls that replace children being 1.5 and 3 years old. The 2009 Child Safety Assessment [3] is part of the overall assessment of the vehicle, and primarily assesses the behavior of the child seat in a collision, as well as some other elements such as the simplicity of mounting the child seat, guidance on why and how to turn off the airbag, etc.

In assessing the safety of pedestrians in the event of a car crash, several tests are performed for adults and children pedestrians. Due to the difficulties of specifying a single and clear methodology for assessing vehicle safety in a pedestrian impact, special situations are used and assessed [3]: the impact of the bumper on the lower part of the legs, the edge of the cover from the engine compartment on the upper part of the legs and the cover of the motor space on the child's head or the adult pedestrian.

The leg protection of the pedestrian is given by the specially designed bumpers, which are deformed when hitting the leg. The test vehicle receives a higher safety rating if the injury is in a lower part of the leg, or a larger area of the leg is affected (i.e. less force per unit area). The upper part of the legs is protected by removing unnecessary hard parts from the front edge of the engine cover. To protect the pedestrian's head, the upper part of the cover of the engine compartment should be flexible, i.e. it should be able to repel the pedestrian's head.

The consequences of the traffic accident during the so-called rear collision, vehicle body deformities, and injuries to people in the passenger compartment are the smallest compared to the other two types of accidents. In this type of impact, the risk of injury to the passenger's neck and spine is greatest. Although the mechanism of injury is not entirely clear, this type of injury is difficult to diagnose and very difficult to treat. Well-designed seats and headrests have a significant impact on protection against such injuries. The Euro NCAP tests [3] assesses several of their characteristics, seat quality and strength, head restraints, the ability to easily adjust and fix them in the desired position, and overall integrity.

The assessment is based on the geometric aspects of the driver's and front passenger's seat, the shape and size of the headrest, the proximity of the driver's headrest and the dynamic performance of the seat and headrest. The dynamic performance of the seat and headrest is determined so that the seat is mounted on rails and tested on small, medium, and large force strikes. This test has been included in the testing program in 2009.

In addition to driver safety, vehicle occupants and pedestrians, the new vehicle safety assessment systems focus on active vehicle safety. This includes an assessment of the technical systems responsible for assisting the driver and active safety technologies, which play a major role in preventing accidents or injuries.

Since 2012, there has been a legal obligation for carmakers to install electronic vehicle stability systems (ESP). As part of the overall vehicle safety assessment [3, 4], the existence of such vehicle systems is also assessed.

Euro NCAP positively grades vehicles that have an alarm for passengers who do not use the seat belt. The signal must be unambiguous and indicate which of the passengers is not wearing a seat belt. The loudness of the signal, its duration, the position of the visual warning and whether all passengers can see the warning are evaluated. This criterion carries one point.

Euro NCAP rewards vehicles with speed limiters. Having systems that limit speed can bring one point, and systems that warn that the maximum speed has been exceeded can bring half a point.

3. Systems for vehicle safety evaluation

Carmakers have no obligation to produce safe cars, but organizations such as Euro NCAP allow consumers to get an objective assessment of the safety of the vehicles available on the market. As a result, vehicle manufacturers have gone from being dissatisfied with vehicle testing in the late 1990s to purposely testing their vehicles and accepting results as the basis for undertaking vehicle design improvements to achieve a higher level of safety.

Euro NCAP [5] has created and is using a 5-star vehicle safety rating system to help consumers more easily identify vehicle safety requirements compared to their requirements and expectations. The number of stars with which one vehicle is rated shows how well the vehicle has met the test requirements, but also how much safety equipment the vehicle has.

Given the fact that vehicles are constantly improving, so do test procedures undergo changes, and new procedures are introduced, so in addition to the number of stars, it is important to know the year of testing the vehicle. The current vehicle safety assessment system dates to 2009.

In IIHS [6], the nonprofit and non-governmental organization that implements the NCAP vehicle safety assessment program for the U.S. market, the assessment system is focused on analyzing aspects of vehicle resistance to collision: crashworthiness (small overlap front – driver side, small overlap front – passenger side, moderate overlap front, side, roof strength, head restraints & seats), crash avoidance & mitigation (front crash prevention – vehicle to vehicle, front crash prevention – a vehicle to pedestrian), child seat anchors. The evaluation system is composed of an evaluation of several criteria and sub-criteria, with descriptive remarks - good, acceptable, marginal, and (poor). With the development and technological advances of the vehicles, the evaluation system of this institute is also changing and is being upgraded with the introduction of new criteria and sub-criteria.

GLOBAL NCAP [7] implements the SAFER CARS FOR AFRICA and SAFER CARS FOR INDIA programs, which aim to provide safer vehicles in (this geographic location). The assessment of vehicle safety is extremely simplified and aimed at assessing the protection of the crew in the event of a head-on collision (performed with the same procedure as in the EURO NCAP - crash test) and assessing the level of protection of child passengers. The rating system consists of a maximum of five possible stars, showing the number of points scored out of the maximum number of points.

Otherwise, the organizations that implement NCAP protocols regularly publish crash tests for all newer vehicles (after 2000), with an assessment of the safety of the specific vehicle model. The rating for some older models or used vehicles can also be checked.

4. Comparative analysis of the security of NISSAN NP300 vehicle available on the African and European market

The research aims to evaluate the procedure for performing the crash test and the various systems for assessing vehicle safety. This is achieved by analyzing the mechanism of occurrence and development of the collision and its consequences, in a simulated reciprocal head-on collision of both vehicles and simultaneously with the analysis of grades from the NCAP program, obtained from two different organizations. Both vehicles are from the NP300 model, of the manufacturer NISSAN, one intended for the European market of used vehicles sub-model NAVARA, produced in 2015, the other best sold pick up for 2019, intended for the African market of new vehicles, sub-model HARDBODY. The vehicles have approximate dimensions and mass. An essential element that distinguishes the two vehicles is the market for which they are intended, they differ consequently according to the constructive solutions, the materials used, the deformability, the performance of the seats with the backrest, etc. The European vehicle has collision prevention systems, and electronic stability control system, unlike the African one that does not.

Figure 2. Analysis of NCAP ratings of both vehicles

The first vehicle was evaluated according to the 2018 evaluation methodology from the SAFER CARS FOR AFRICA program, while the second was evaluated with four stars according to the EURO NCAP tests from 2018. The conditions under which the crash test is performed, which is the basis for evaluating vehicles destined for the African market, are identical to the head-on collision test under the EURO NCAP system. The difference is in the rating system. However, clearly from fig. 2, by analyzing the vehicle safety ratings and crew injury risk zones, it can be concluded that different assessment systems lead to a single and reliable conclusion that the vehicle intended for the European market has far better performance in passenger protection and children passengers in relation to the vehicle intended for the African market.

Figure 3. Crash test of new vehicle NISSAN NP300 Hardbody and used NISSAN NAVARA NP300

The validation of the results is confirmed by the analysis of the mutual frontal collision of the two vehicles realized at a collision speed of 56 (km / h) with a 40% overlap of the front surfaces.

The NISSAN NAVARA NP300, a used vehicle intended for the European market, as a result of the crash test, is damaged in the front engine part, while the cabin part remains undeformed. The kinetic energy from the impact is absorbed by the front bumper, the front skeleton, the front cover, the drive unit, and the front wings of the vehicle, while the partition sheet between the engine compartment and the cabin remains undeformed and almost fixated. The integrated passenger seat system, seat belts, and airbags are activated and perform their intended function, thus preventing serious injuries to front-seat passengers and keeping the children rear-seat passengers safe and unharmed.

The NISSAN NP300 Hardbody, a vehicle intended for the African market for new vehicles, suffers dramatically more damage than the first vehicle. The deformities in the second vehicle greatly affect the cabin area and cause severe damage to the roof and front doors. The instrument panel and the partition sheet move and exert additional pressure on the driver and front passenger. The kinetic energy of the collision causes damage that reaches the rear seat in the passenger compartment. The passenger restraint system is activated, but the effects of passenger protection are almost non-existent. Passengers in the front seats and child passengers in the child seats, due to the high intensity of the restorative forces, move forward, and due to the collapse of the cabin, make contact with the interior of the vehicle. As a result of the collision, the passengers in the vehicle suffered very serious and potentially fatal injuries.

The double standards of the manufacturers regarding the safety of the vehicles intended for different vehicle markets are visible. It seems that the choice between the European NISSAN NAVARA NP300 and the African NISSAN NP300 Hardbody is a choice between life and death.

5. Conclusion

Thanks to the results of crash tests, potential buyers can get adequate information about the safety of various car models. This fact motivates carmakers to work to improve vehicle performance in terms of passenger and pedestrian safety. Experience shows that the implementation of crash safety tests is expedient and results in a significant reduction in the number of victims in traffic accidents and damage to vehicles participating in them.

It is very important to standardize the various crash tests, by creating a clear and unambiguous methodology for performing crash tests and establishing a single system for assessing vehicle safety capabilities. In this way, the unification of the obtained results will be achieved, their comparability,

increased trust by the users, as well as opportunities for better cooperation between the different organizations that implement NCAP programs.

Such results would be the basis for establishing clear criteria, systematized in certain standards, for the acceptance of new vehicles in terms of passenger and pedestrian safety.

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