CHALMERS

Writing a Handbook of Vehicle Safety Measures

Master's Thesis in the Biomedical Engineering

JING LI

Department of Applied Mechanics
Division of Vehicle Safety
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2012

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ABSTRACT

This master thesis project report is organized by four main sections: Introduction, methods, results and discussion. It is known from the introduction section that road accidents is a big issue at global levels for it is a leading factor for fatalities. The problem in China is serious since the number of vehicles on the roads grows fast, which means it is more likely to be exposed to road accidents but the safety countermeasures and people's safety awareness fail to catch up with the increasing traffic. This project work is done following the methods of literature review, telephone interviews with Chinese people, accident data research, Madymo simulations for common but dangerous situations and hand drawn figures for better demonstration. It is to combine the techniques and the real situations, which are totally different from Sweden, to make the techniques serve more people. Through these methods, the handbook of vehicle safety measures is developed as the result of the master thesis project. Introduction of both active and passive safety systems and their working mechanisms are presented in the handbook. Moreover, results of accident research are given as motivations of vehicle safety measures and Madymo simulations for two typical situations are done to show the potential danger and increase people's safety awareness. Two advanced systems are illustrated to focus on active safety systems which will be the trend of the development of vehicle safety. From the discussion section, it is known that user-centered design method is utilized to make the handbook effective and the challenge of further evaluation of the handbook after distribution is presented as well. What's more, work on the handbook' distribution in China is also done as a part of the project, which will put the handbook into practical use and make Chinese people really benefit from it.

Key words: road accidents, safety countermeasures, safety awareness, active safety, passive safety, simulation, advanced systems

Contents

1 Introduction

1.1 Global situations

Thousands of people are injured and killed on the roads every day. Those people who will never return home do leave shattered families and communities behind. Each year, millions of people spend long time in hospital after road accidents and many are not able to work and live as they used to. It is a global phenomenon that road accidents result in the growing problem of fatalities and injury. WHO (World health organization) predicts that injuries of traffic accidents will rise to the fifth leading contributor to death by 2030 (Fig1) in the global status report on road safety [1]. In addition, WHO also works a lot to monitor activities relating to the Decade of Action for Road Safety in its report for 2012 [2] for injury prevention at global levels. Fig2 from another report demonstrates the regional distribution of 75,000 fatalities in 1999[3]. It points out that road accident in Asia and Pacific area is a more severe problem compared with that in other areas.

TOTAL 2004

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Lower respiratory infections	7.0
4	Chronic obstructive pulmonary disease	5.1
5	Diarrhoeal diseases	3.6
6	HIV/AIDS	3.5
7	Tuberculosis	2.5
8	Trachea, bronchus, lung cancers	2.3
9	Road traffic injuries	2.2
10	Prematurity and low birth weight	2.0
11	Neonatal infections and other	1.9
12	Diabetes mellitus	1.9
13	Malaria	1.7
14	Hypertensive heart disease	1.7
15	Birth asphyxia and birth trauma	1.5
16	Self-inflicted injuries	1.4
17	Stomach cancer	1.4
18	Cirrhosis of the liver	1.3
19	Nephritis and nephrosis	1.3
20	Colon and rectum cancers	1.1

TOTAL 2030

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Chronic obstructive pulmonary disease	7.0
4	Lower respiratory infections	5.1
5	Road traffic injuries	3.6
6	Trachea, bronchus, lung cancers	3.5
7	Diabetes mellitus	2.5
8	Hypertensive heart disease	2.3
9	Stomach cancer	2.2
10	HIV/AIDS	2.0
11	Nephritis and nephrosis	1.9
12	Self-inflicted injuries	1.9
13	Liver cancer	1.7
14	Colon and rectum cancer	1.7
15	Oesophagus cancer	1.5
16	Violence	1.4
17	Alzheimer and other dementias	1.4
18	Cirrhosis of the liver	1.3
19	Breast cancer	1.3
20	Tuberculosis	1.1

Source: World health statistics 2008 (http://www.who.int/whosis/whostat/2008/en/index.html)

Fig1 Leading contributors to death, 2004 and 2030

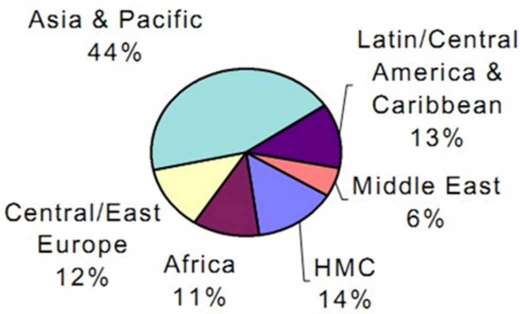


Fig2 Regional distribution of 750,000 fatalities (1999)

1.2 Situations in China

China has been experiencing the fast growth of urbanization and motorization according to such the rapid development in economy. From the year 1980-2005, the overall GDP increased by around 10% per year and the urban population increase by three times with more rural people moving to the city. Meanwhile, the number of motor vehicles increased 18 times with the number of drivers increasing 33 times. Because of the improved motorization and road infrastructure, road transport has kept rising since 1980. The share of passenger/km on highway rose to 53.2% in 2005 compared with 32.0% in 1980. The share of freight/ton • km rose to 10.8% in 2005 compared with 6.4% in 1980[4].

In china, the prevention of injury and death in road accidents turns out to be a big issue. Ministry of Public Security announced that road traffic injury was the leading cause of death for people at the age up to 45 and it is also the cause of losing years of working life. Although road accidents in china is a big problem, the public still pay little attention to safe driving. For instance, roadside observational surveys on seat belt wearing in two cities including Zhoushan and Nanjing in 2005 showed that occupants to a large proportion do not wear seat belts. Table 1 demonstrates the seat belt wearing situation in China [5].

	Driver		Front passenger		Rear passenger		Total	
Interviews	n	%	n	%	n	%	n	%
Always wear	930	70.7	158	27.4	90	23.1	1178	51.6
Sometimes wear	275	20.9	218	37.8	123	31.5	616	27.0
Never wear	110	8.4	201	34.8	177	45.4	488	21.4
Total	1315	100.0	577	100.0	390	100.0	2282	100.0
Observational survey								
Wearing	20,229	56.7	1309	8.8	51	0.5	21589	35.1
Not wearing	13,557	38.0	13551	91.1	10923	99.5	38031	61.8
Pretend/tampering	1873	5.3	16	0.1	5	0.0	1894	3.1
Total	35,659	100.0	14876	100.0	10979	100.0	61514	100.0

Source: NJ & ZH 2006 & 2007 observation and interview surveys.

Table1 Results of from interviews and observations on seatbelt wearing

The objective of this master's thesis project was to write a handbook on vehicle safety measures to be used for public education. By acquiring knowledge of vehicle safety, the public will increase their safety awareness and learn how to use safety systems for self protection. It is hoped that less and less Chinese people will suffer from road accidents.

2 Methodology

2.1 Preparations

A literature review was done to acquire knowledge about the most common and advanced safety systems at present.

The survey (see appendix) was done in two ways, telephone interviews with Chinese people and Chinese accident data research which were used to illustrate the true situation of road traffic and road accidents in China in recent years. The results of the survey point out that there are some typical road accidents which may be prevented by proper vehicle safety measures. Meanwhile, there is also some evidence showing that Chinese people want to be safe in the car but they know little about the function of safety systems, the importance of safety systems or how to use them. Thus, this handbook is needed to educate and increase people's safety awareness.

2.2 How the handbook is organized

The handbook consists of five main parts: 1) explanations on positions of systems' hardware and functions of systems with pedagogic figures, 2) results of typical road accidents analysis, 3) systems' working mechanisms and how people behave following these mechanisms, 4) Madymo simulation of various hazardous situations in frontal collision, 5) introduction of advanced safety systems. All the chosen systems are typical ones including both passive and active safety.

The first part of the handbook is used to give the public awareness of the safety systems. The second part is used to inform people of the need of safety systems. The third part is for teaching people how the safety systems work and how to use them. The fourth part is used to demonstrate the result of unsafe situations which are common in China now. The last part is used to introduce the future of safety systems. The input from Chinese citizens and from non-engineering experts has contributed to the outline of the content, which made it more understandable and acceptable to the public.

3 Results

3.1 Preface

In the preface of the handbook, the background knowledge of vehicle safety including the definitions of passive safety and active safety are given. In addition, the aim of this handbook and its organization are also presented.

3.2 Introduction of morphology, position and function of Safety Systems

The second part of the handbook is divided into passive safety and active safety. For passive safety, the most common airbags (front airbag, side airbag, airbag curtain, knee airbag) in China are shown in hand drawn figures (Fig3-Fig5) with explanations on their storage positions and functions. A reminder of the safety issues related to the deployment of the front airbag is given (Fig6). Seatbelts are also mentioned with some common misuse issues (Fig7) and their impact on safety. Meanwhile, the use of seatbelt adjuster and related misuse issues are also shown in Fig9 and Fig8 respectively. For active safety, night vision systems, frontal collision warning systems, lane departure warning systems, electronic stability systems and adaptive cruise control systems are explained with their functions and human machine interfaces.

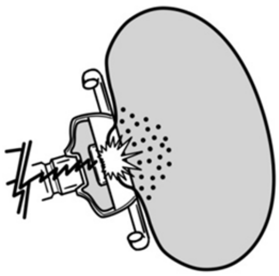


Fig3 Front airbag for driver side

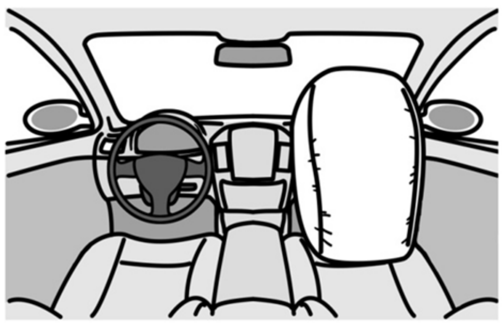


Fig 4 Front airbag for passenger side

Fig 5 Side airbag

Fig 6 Staff at the position where airbags deploy

Fig 8 Extra seatbelt latch

Fig 7 Common misuse of seatbelts

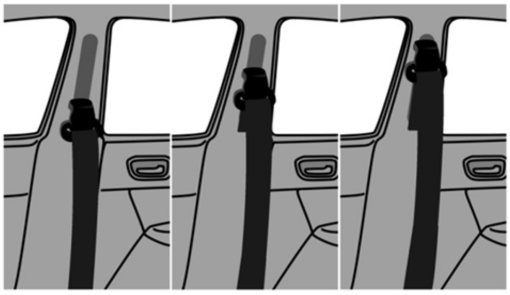


Fig 9 Use of seatbelt adjuster

3.3 Traffic accident statistics and analysis

In the third part of the handbook, Chinese road accident data are presented. It is divided into three parts, city traffic, highway traffic and the use of safety equipments. In cities, there are some obvious issues found from the statistics. Most lethal cases occur at night without any road lights (Fig10), on icy roads and in foggy weather respectively. However, there is also a comparison between city accidents and accidents on highways. Evidence shows that the death rate is higher in highway accidents than in city accidents. And rear-end collision is the most common type of accident on highways (Fig11). The leading cause of this is drowsiness. When it comes to the use of safety equipment, for driver side, seatbelts and front airbags are installed in most vehicles; other airbags are seldom installed (Fig12). Seatbelts are not used a lot [5] but the use of seatbelts and airbags have a large effect on the injury outcome in road accidents (Fig13). There are also some data showing that if adults don't use seatbelts, they will hardly ask their children to use seatbelts or buy child restraints for them. The result of accident statistics analysis points out the need for vehicle safety measures.

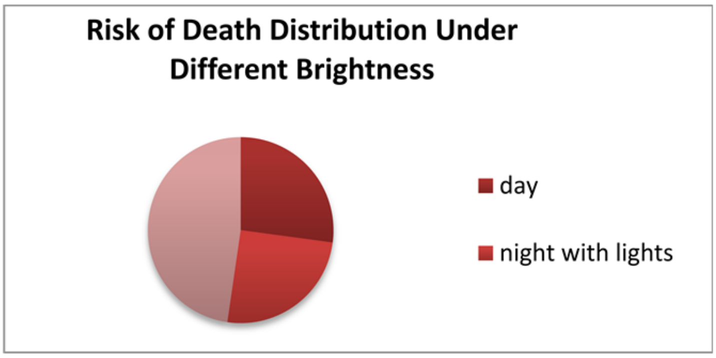


Fig 10 Risk of death distribution under differet brightness

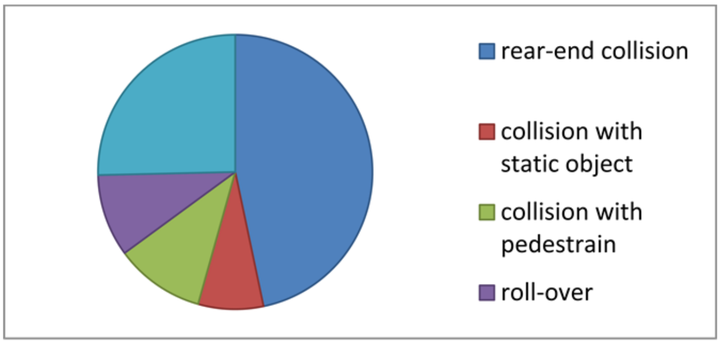


Fig 11 Distribution of the numbers of accidents on highway

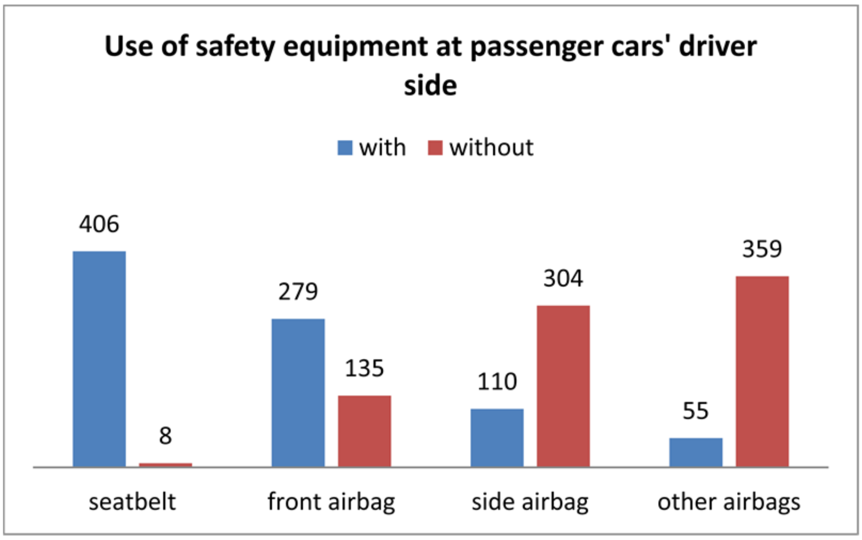


Fig 12 Use of safety equipment at passenger cars' driver side

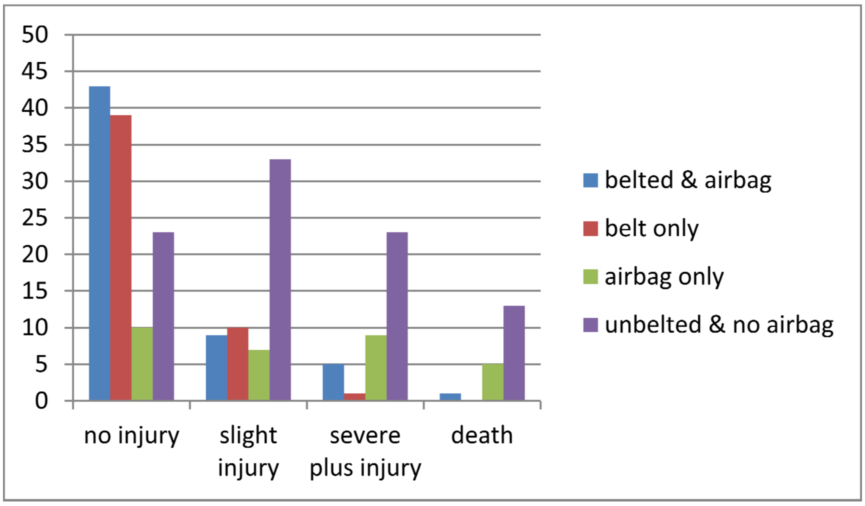
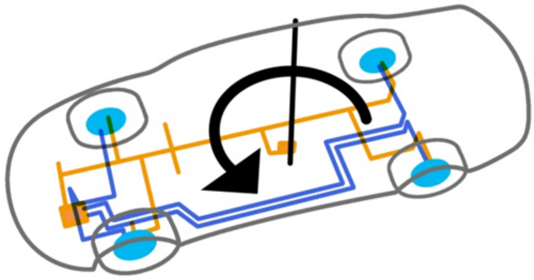


Fig 13 Distribution of degree of injuries according to the use of seatbelts and airbags

3.4 How the systems improve safety in driving

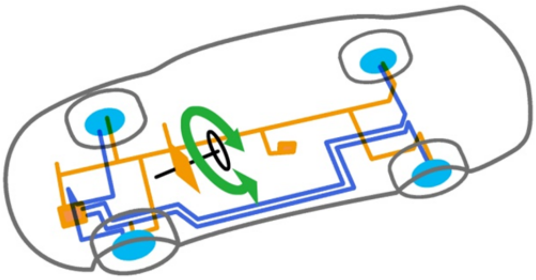
The fourth part describes active safety and passive safety. In the active safety section, night vision system, frontal collision warning system, lane departure warning system, electronic stability system and adaptive cruise control system are chosen as examples. They are most common and needed systems according to the accident research section. How these systems work to prevent crashes and how people interact with these systems is illustrated in pedagogic stories and figures, which makes the handbook more attractive. Electronic stability system is presented as an example (Fig14, explained by figures). The passive safety part is divided into frontal crash, side crash, roll-over, rear-end crash and child restraints. For each type of crash, it is described how passive safety systems work together to protect people. Figures are also included for better understanding. In addition, whiplash test in C-NCAP and child restraint are presented in this part. Whiplash testing is an additive part in the coming version of C-NCAP 2012 and child restraints are also new and popular nowadays for Chinese people.

1



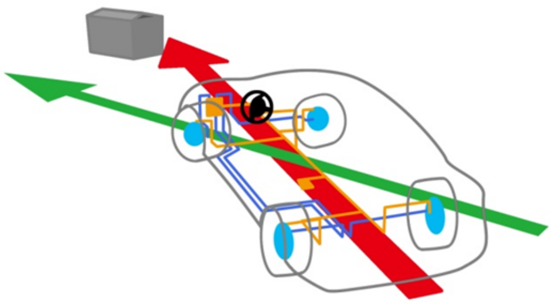
Yaw sensor is used to detect the true steering situation of the vehicle, as the black arrow illustrates.

2



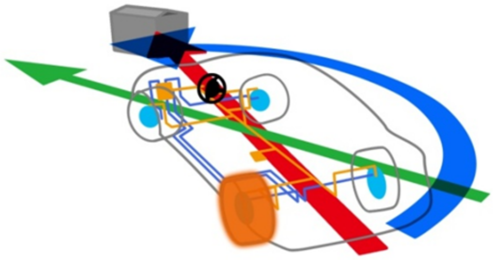
Steering angle sensor is used to detect how much the driver wants to steer, as the green arrow illustrates.

3



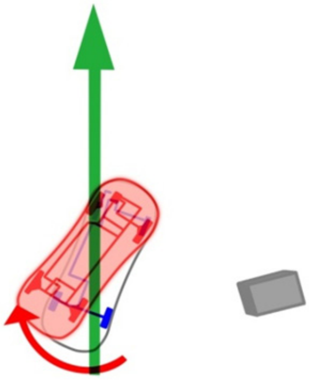
The desired direction is shown with green arrow and the true direction is shown with red arrow. This indicates lack of steering response.

4



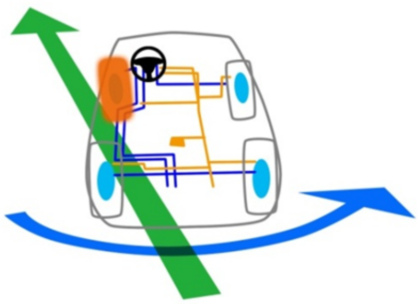
The system puts brake force on the rear-left wheel, making the vehicle turn left and thus obtain the desired steering response.

5



When turning to the opposite direction after finishing turning left, over steering may happen and the vehicle may drift to the left.

6



The system puts brake force on the front-left wheel, making the vehicle turn right against the drift force. This system is used for the vehicle's stability.

Fig 14 Decomposition figures of the process how a car avoids colliding with the box with use of Electronic Stability System

3.5 Simulations for dangerous situations

In the fifth part of the handbook, simulation animations of various situations are presented to show the kinematic characteristics. An unbelted rear passenger is involved in a frontal collision at the impact speed of 50km/h. A front passenger with a kid standing in front of him during the frontal collision at the same impact speed is simulated (Fig15-Fig16). Although these situations are dangerous, they are very common in China and people have no idea about what will happen under these circumstances. Thus, the simulations are displayed to tell them what will happen and how dangerous it is.

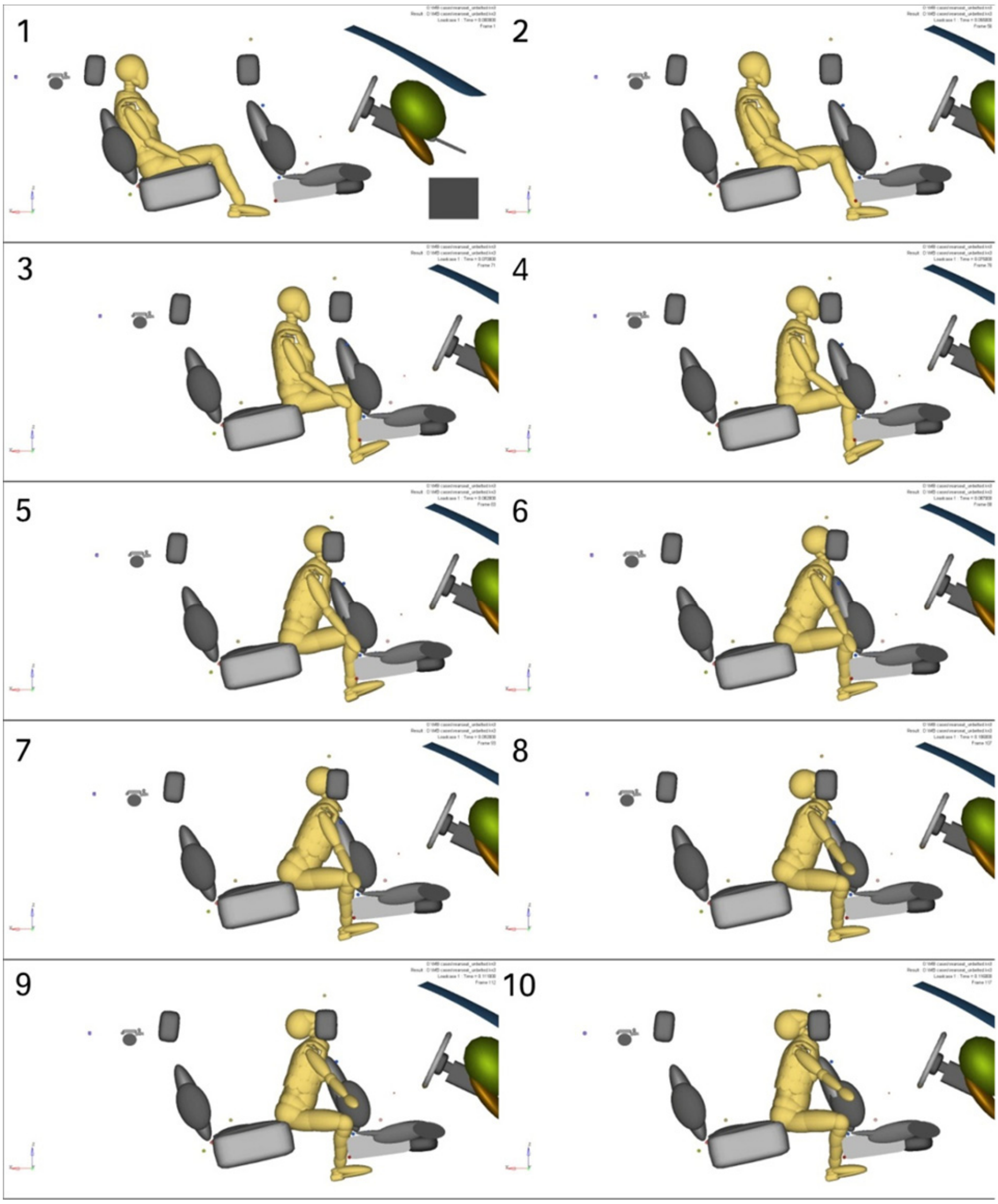


Fig 15 Unbelted rear passenger (Hybrid III 5% female dummy) in frontal impact, impact speed=50km/h. There are much hurt on adult's neck and lumber.

Fig 16 Front passenger (Hybrid III 50% male dummy) with a standing kid(Hybrid III 3 year old dummy)in frontal impact, impact speed=50km/h. There are much hurt on adult’s head and neck and on child’s head, neck and chest.

3.6 Introduction of advanced safety systems

In the last part of the handbook, two advanced systems, eye-tracking system and cooperative system are introduced. Eye-tracking system can be used for detecting drowsiness and distraction/inattention to assist divers to drive safely. Eye-tracking can also work with other active safety systems to reduce false warnings. Cooperative systems make use of wireless communication to send, receive and deliver information and give warnings. Two communication methods, vehicle-to-vehicle and vehicle-to-infrastructure are illustrated. Typical situations where the system can work with higher resolution compared with other active systems are also presented (Fig17). Moreover, Cooperative systems is a technology that the Chinese government will promote. With the rapid development of communication technology in China, cooperative systems have a particularly good potential.

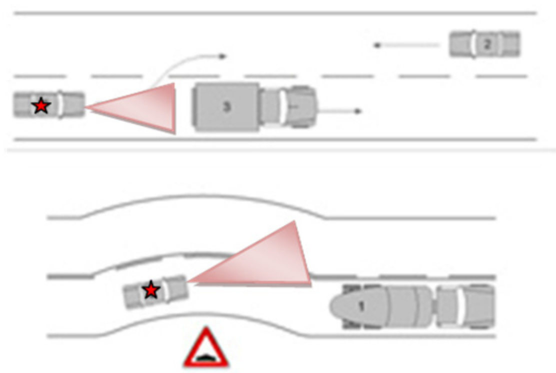


Figure 17 Higher resolution in blind spot detection compared with front sensor.

4 Discussion

4.1 User-centered design

This handbook has a user-centered design and all the development work was done with the users in the center of focus. The design work followed the steps below:

1. Mapping of the target reader categories and their needs and preferences
   - Surveys with users conducted before the design
   - Information gathering about the structure and content
2. Empirical testing of how general public perceives the handbook
   - Focus on ease of understanding and ease of learning
   - Testing the prototype with actual users
3. Iterative design
   - Upgrade of the handbook design, testing and evaluation
   - Allow complete rethinking of the design at an early stage

Main users of the handbook are comparatively advanced car owners in China. They are more relevant to both active and passive safety systems. This group of people are mostly at the age from 35 to above, they are educated according to the education level at that time. Thus, it is important that how the systems are illustrated in an understandable way for these users and what they want to know. Surveys and interviews are used to get ideas and the iterative design is used to get an interaction with the target group. However, the final usability evaluation of the handbook will be a challenge after they have been distributed. Further work should be done on this issue.

The software Madymo was selected for this study since it is relatively easy to learn and runs with short computation time. The software offers very good animation outputs, which is essential for the users to know the situations. The detailed body loading was not included, however not in focus in this application. That's why more advanced finite element software was considered too time consuming to use.

4.2 Distribution

When it comes to distribution of the handbook, cooperation with CATARC (China Automotive Technology and Research Center) has been established. CATARC is the most influential vehicle safety organization in China and will be an ideal partner to work with. They have a range of offices in cities all over China. They are well known to the Chinese public and people in China have confidence in the organization. Thus, success in getting the certification both on the handbook and the cooperation from CATARC means that the handbook will reach more readers and help more people in their daily life.

5 Acknowledgement

Most figures are drawn by Qian Liu aiming at the better illustration and People from CATARC and Autoliv China also help a lot for the accident research section and Madymo simulation section respectively. Ola Boström, Mats Svensson and Yong Chen offered the technical support. Liling Yuan contributes a lot on language modification of the whole handbook.

6 Reference

[1] World Health Organization. "Global Status Report on Road Safety." Available: http://www.who.int/violence_injury_prevention/road_safety_status/2009/en/index.html. [2009].

[2] World Health Organization. "National plans for the decade of Actions for Road Safety 2011-2020." Available: http://www.who.int/roadsafety/decade_of_action/en/index.html. [2012].

[3] G D Jacobs and Amy Aeron-Thomas. "A Review of Global Road Accident Fatalities." TRL Annual Research Review 1999. Available: http://www.transport-links.org. [2000].

[4] Shengchuan Zhao. "Road Traffic Accidents in China." IATSS RESEARCH Vol.33 No.2.Available: http://worldcat.org/issn/03861112. [Sep.3, 2009]

[5] Virgina Routley, Joan Ozanne-Smith, Dan Li, Min Yu, Jianyue Wang, Ming Wu, Junhe Zhang, Yu Qin. "Attitudes to seat belt wearing and related safety features in two cities in China." International Journal of Injury Control and Safety Promotion, Vol. 16, No.1, March 2009.

7 Appendix

7.1 Questionnaire of the survey/telephone interview to users in China

20 participants at the age between 30 and 45 are chosen for the telephone interviews, since they are the target user group who are more likely to possess the advanced vehicles installed with more intelligent systems due to their economic levels and social status, and who concern more about the safety features of vehicles. According to their education and similarities, the survey is done to get ideas on how much they know the safety systems, what they want to know, the feedback on the draft of the handbook and etc respectively. The handbook is designed to meet the needs of the target group and hopefully to satisfy the public, more age groups. The questionnaire is divided into two sections. One is used to locate what to write and the other is used for the modification of the draft of handbook.

Section1:

1 Suppose that you select a car to buy. What feature of a car is the one you most concern about? Put features below in the descending order.

a)Price b)Dynamic performance c)Power d)Safety e)Size f)Fuel consumption g)Looking

P.S: This question is given to get how much the public care about the safety issue.

2 Please tell me what you know about safety systems? What types of systems have you used?

3 Do you know how the systems (those they know) work to protect you?

4 Do you know what active safety systems are and what they are used for?

5 There will be a handbook of vehicle safety measures. What do you want to learn from this handbook?

Section 2:

1 Please tell me your overall feeling of the handbook? Is it a good reading or a bad reading? Is it useful for you or useless for you? Is it easy to understand or complicated to understand?

2 Please tell me the weak points of the handbook which you think should be improved?

3 Is there anything thing more that you want to know and that is not covered in the handbook? Is there anything redundant or useless in the handbook?

4 Besides the handbook, what types of education materials you think are needed and applicable for the further steps?

7.2 Handbook—First version

2012 First Version

HANDBOOK OF VEHICLE SAFETY MEASURES

AUTOLIV

CATARC

Jing Li Master Student Chalmers

Ola Boström PhD Director of Integrated Safety Autoliv Research

Mats Svensson Professor Applied Mechanics Chalmers

Yong Chen PhD Accident Researcher Autoliv China

Qiang Chen PhD Director of Road Traffic Research CATARC

Contents

1 Preface

With the continuous improvement of living standard in China, buying and driving a car seems to have become necessary in people's life. Cars can carry people to their dreaming places with offering the freedom on both space and time. It can be used as fast and independent transport for daily commute on weekdays. It can also be used on a road trip for the family to enjoy the nature on weekends. However, safety is the foundation of a happy and fulfilling life. Thus, it is the goal and wish for all vehicle safety related staffs to offer a safe car and safe driving environment.

Vehicle safety consists of active safety and passive safety respectively. Active safety is used to prevent crash with use of active safety systems such as frontal collision warning system. Passive safety is used to reduce injuries with use of passive safety systems such as airbags when crashes cannot be prevented.

In this handbook, firstly the location and function of each safety system are introduced to give readers a cognitive feeling about them. Secondly, accident statistics study is brought in with relative figures to explain why we need safety systems. Thirdly, since the importance of the systems is known, their working mechanisms are given to show how these systems work to save lives. Fourthly, computer simulations of hazardous situations are added to point out the problems caused by lack of safety awareness in order to arouse the public.

Lastly, two advanced safety systems are introduced on the future of vehicle safety.

This handbook is dedicated to all the individuals who drive, ride or love vehicles. We hope that everyone can drive safely and live happily!

2 Introduction of morphology, location and function of Safety Systems

2.1 Passive safety systems

2.1.1 Airbags

Front airbag at driver side

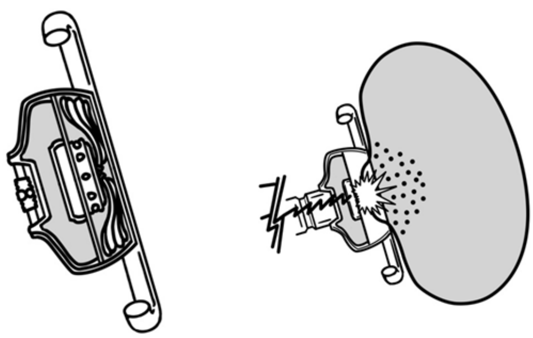


Fig1 Front airbag at driver side

Front airbag at driver side is folded and stored in the center of steering wheel. When the vehicle is involved in high speed collision, the airbag deploys to protect driver's head and chest from direct and violent collision with the steering wheel (Fig1).

Front airbag at passenger side

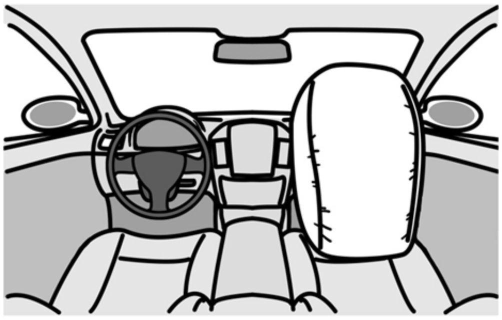


Fig2 Front airbag at passenger side

Front airbag at passenger side is folded and stored under the right part of the dashboard. When the vehicle is involved in high speed collision, the airbag deploys to protect the front passenger's head and chest from direct and violent collision with the windshield and other vehicle interiors (Fig2).

P.S: Don't leave any stiff stuff on the right part of the dashboard, like perfume bottles or other decorating objects (Fig3), to avoid being hurt by them as they will be projected towards you and your companions with the deployment of the airbag.

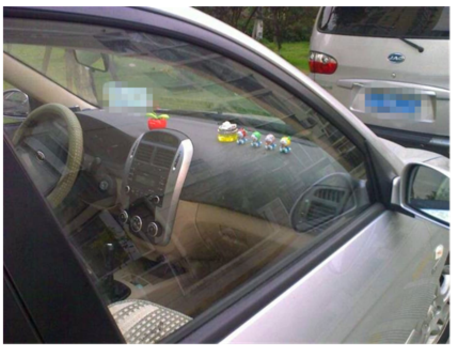


Fig3 Stuff in the way where the airbag deploys

Side airbag

Fig4 Side airbag

Side airbag is folded and stored at the side of the seat back. When the vehicle is involved in a side collision or roll-over, the airbag deploys to protect occupants from direct and violent collision with the vehicle door and other interiors. According to different protection objects, side airbags can be categorized into the thorax airbag, the abdomen airbag, the bottom airbag and their combinations (Fig4).

Airbag curtain

Fig5 Airbag curtain

Airbag curtain is folded and stored at the side of vehicle roof. When the vehicle is involved in side collision or roll-over, the airbag curtain deploys to protect occupants' heads from direct and violent collision with car body (Fig5).

Knee airbag

Fig6 Knee airbag

Knee airbags are folded and stored under the steering wheel and under the glove box respectively at driver side and passenger side. When the vehicle is involved in high speed collision, the airbag deploys to protect the driver and front passenger's knee from direct and violent collision (Fig6).

2.1.2 Seatbelts

When the vehicle is involved in collision or urgent brake, seatbelt pretensioner will work to limit the expansion of belts to restraint the occupants in their seats. Seatbelts are used to protect occupants from moving forward too much to collide with vehicle interiors or be thrown out of the vehicle in serious situations due to the inertia. Correct method of wearing the seatbelt is shown in Fig7.

Fig7 Correct way of wearing seatbelt

Fig8 Wrong way of wearing seatbelt

Fig8 shows the most common wrong methods of wearing seatbelts: the left one indicates that the horizontal belt stays too high on the abdomen and cause much pressure on it (organs in abdomen are not protected by skeletons and compared with chest and bottom, abdomen is more vulnerable); the middle one indicates that vertical belt cannot restraint occupants as expected because it slides over the left shoulder of occupant; seatbelt wore in the way shown in the right figure cannot restraint the occupant well and will cause much pressure on the abdomen and may result in injuries of internal organs. Occupants who wear the seatbelt in the wrong way cannot be protected effectively as expected. Thus, it is necessary for occupants to know the correct way of wearing the seatbelt.

Besides, typically, there is an adjuster in the seatbelt system (the shaded part in Fig9), which is used for adjusting the height of the upper fixation point of the vertical belt. If the belt is fixed too high, it will slid over the occupant’s neck; if the belt is fixed too low, it can slid over the occupant’s shoulder. Too high or too low position will make occupants uncomfortable and be exposed to potential hazard. Thus, we suggest that occupants adjust the upper fixation point to the proper height (referring to the correct method of wearing the seatbelt), for the best comfort and protection.

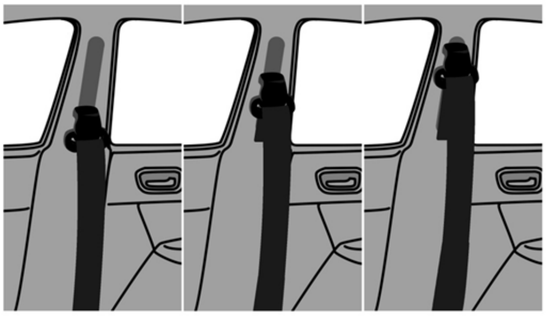


Fig9 Seatbelt adjuster

In addition, some drivers who lack of safety awareness take some irrational measures in order to escape from the punishment from the police and the disturbance from the safety system. Some examples are given below. Fig10 indicates that the fixation point of vertical belt is stuck with an added object. Fig11 indicates that the seatbelt buckle is fixed with an additional tongue. These manipulations do have side effect on safety.

Fig10 Misuse of seatbelt 1

Fig11 Misuse of seatbelt 2

2.2 Active safety systems

2.2.1 Night vision system

Fig12 Night vision system based on FIR camera

Night vision systems which make use of near infrared sensor or far infrared sensor are designed for helping drivers to see the road ahead under the dark circumstances (e.g. villages without street lamps) to avoid accidents.

2.2.2 Frontal collision warning system

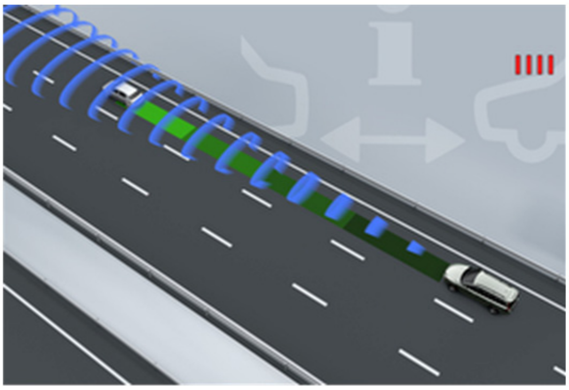


Fig13 Fontal collision warning system

When the driver is involved in drossiness, distraction/inattention or sudden brake of the front car at the high speed, if the distance between the vehicle and the car ahead falls below a limit and the driver fails to respond in time, frontal collision warning system will start to work reminding the driver of the dangerous situation. It, for instance, uses alarms and in severe and urgent situations the system will intervene on the brake to prevent the crash.

2.2.3 Lane departure warning system

Fig14 Lane departure warning system

When the car is driven on the road with obvious lane marks and the driver changes lane by mistake due to his fatigue or distraction, the lane departure warning system will be engaged to send out the reminding signals (visual, acoustic or vibration of the steering wheel) in order to alert the driver to concentrate on driving and adjust speed and steering to avoid accidents.

2.2.4 Electronic stability system

Fig 15 Electronic stability system

Electronic stability system is the force control system. Generally, when vehicles go across the corner or icy roads at the high speed, the vehicle' heading direction can be out of control due to lack of steering or over steering. It will cause accident. In this case, electronic stability system is used to keep the vehicle on the right track and in the right direction by adjusting force distribution and brake on the certain wheel.

2.2.5 Adaptive cruise control system

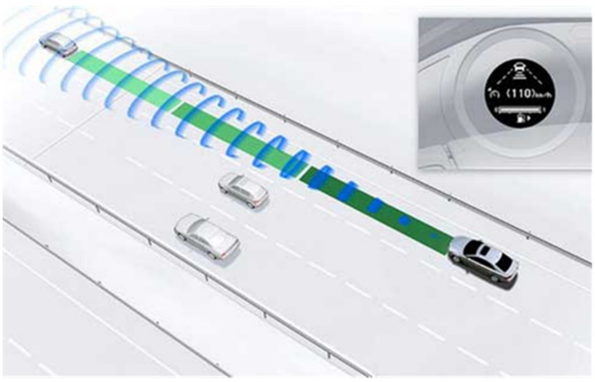


Fig16 Adaptive cruise control system

At the high speed, when there are no cars in front, adaptive cruise control system will intervene on the throttle automatically and make the vehicle to maintain a certain speed; when another vehicle appears in front, the system will adjust the speed to make the vehicle maintain a certain distance from the car in front. Adaptive control system will not only improve driving experience but also help to reduce fuel consumption. In addition, automatic following function is good for improving safety.

3 Traffic accident statistics and analysis

Fig17 Highway accident, CIDAS, 200908057

In order to help readers to know the real situations of traffic accidents happened in China and the existing hazard, the section of traffic accident statistics and analysis is produced. Moreover, accidents indicate the trends of vehicle safety products since all the products are developed for preventing accidents or reducing injuries. On the other hand, it is definitely hoped that people can improve their own safety awareness by acknowledging the problems. It is pursued that everyone can drive safely and live happily.

3.1 City traffic situations

3.1.1 Death distribution due to the illumination condition

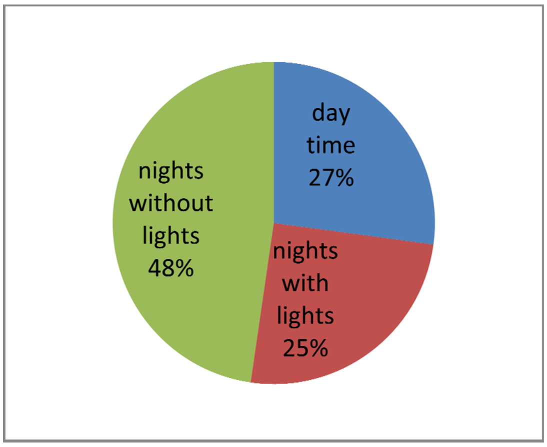


Fig18 Death distribution according to the illumination condition

According to traffic accident statistics annual report 2010 in China [1], Fig18 indicates the death distribution due to illumination condition. It shows that in every hundred people died in road accidents, there are 48 of them died at night without street lamps, 27 died at day time, and 25 died at night with street lamps. There is evidence showing that the reason for this kind of accidents is usually low visibility due to darkness. These accidents include collisions between vehicle and stationary object, another vehicle, cyclists, motor cyclists or pedestrians. However, It is common that in most countrysides and suburbs in China where there lacks of street lamps and roads

[1] 《中华人民共和国道路交通事故统计年报（2010）》

are shared by vehicles and pedestrians. Vulnerable road users like pedestrians, cyclists and etc. are easily exposed to injuries when they collide with vehicles. Thus, accidents caused by lack of illumination require attention. Night vision system which is mentioned in the previous section can serve to improve driver's vision and this will be further discussed in the coming section.

3.1.2 Accidents in bad weather

According to traffic accident statistics annual report 2010 in China, more than 3500 accidents happened on the icy roads and caused fatality of more than 5600 people in 2010. In the north part of China in winter, vehicles usually suffer from icy/slippery roads, which increases the chance of accident. Slow and careful driving is most common and effective way to prevent this kind of accident. Besides, the electronic stability system could be used to control the vehicle to avoid crash intelligently.

In addition, rainy and foggy weather are also common in some cities in China. Under these weather conditions, low visibility introduces much trouble to driving. According to the statistics, there are more than 27000 accidents caused by rainy and foggy weather in 2010, causing significant loss on property or even lives. Some active safety systems with radar sensor (almost invariant to different weather) could work in these situations and help prevent crashes. Further discussion on these systems is given in the coming section.

3.2 Highway traffic situations

3.2.1 Accidents and injuries

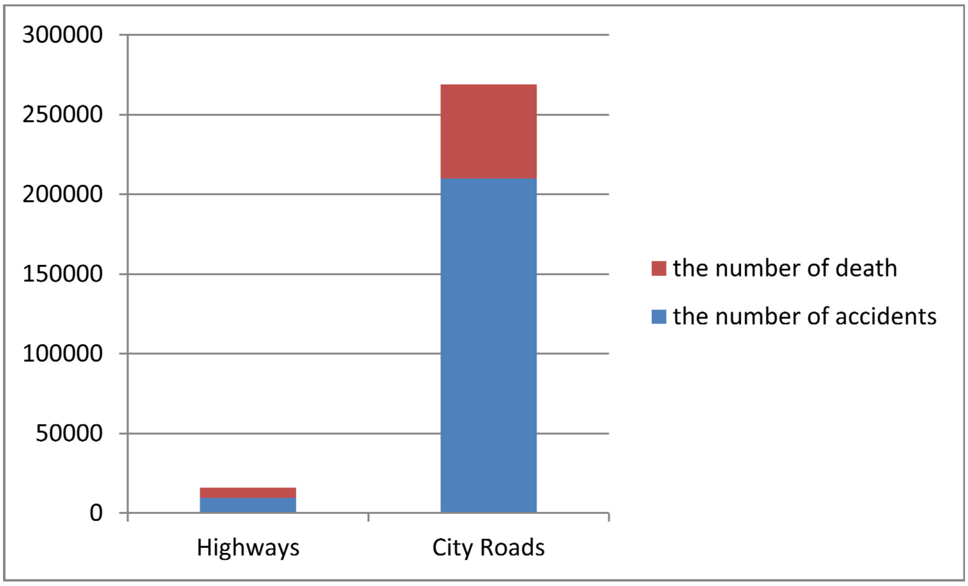


Fig19 Relationship between accidents and deaths on different roads

Fig19 indicates that it has higher risk of death on highway but the numbers of accidents and fatalities on city roads are much higher than those on highway.

3.2.2 Accidents' distribution due to their types

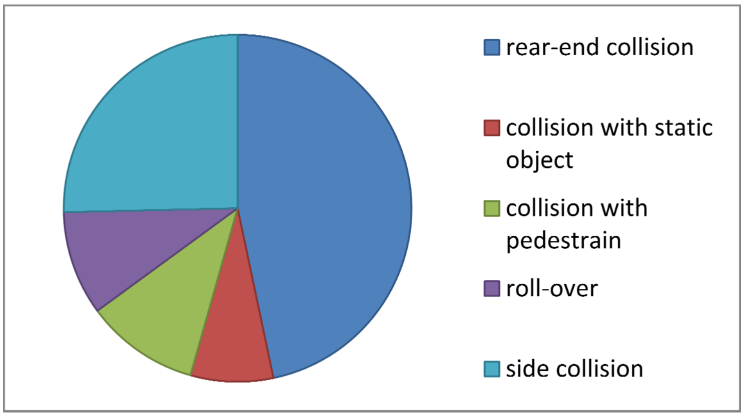


Fig20Accidents' distribution due to their types

Fig20 is accidents' distribution due to their types and the number of accidents in each type. From the figure, it is shown that most common accidents on highway are rear-end collisions, side collisions, collisions with pedestrians, roll-overs and collisions with stationary obstacles. And rear-end collisions are the most frequent accidents on highways. Moreover, when it comes to reasons for highway accidents, drossiness is proved to be the most common contributor to rear-end collisions.

3.3 Installation and use of passive safety systems

3.3.1 Passive safety systems at driver sides of passenger cars

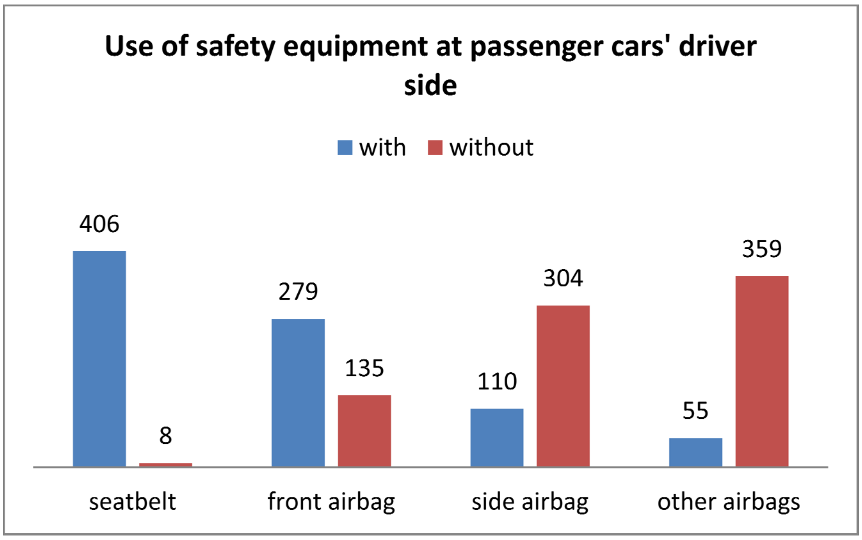


Fig21 Use of safety systems at driver sides of passenger cars

Passive safety products are developed and produced many years earlier than active safety products. Accident analysis based on 414 cases of passenger car accidents from 2005 to 2010(Fig21) shows that seatbelts are nearly installed at all passenger cars' driver sides; front airbags are installed at most passenger cars' driver sides; side airbags, airbag curtains, knee airbags and etc. are installed at few passenger cars' driver sides. However, airbags and seatbelts are well known as the most popular and effective countermeasures to reduce injuries. Since the data above is only for driver sides of passenger cars, it can be roughly inferred that vehicle safety is able to be improved in China.

3.3.2 Use of seatbelts and injuries in accidents

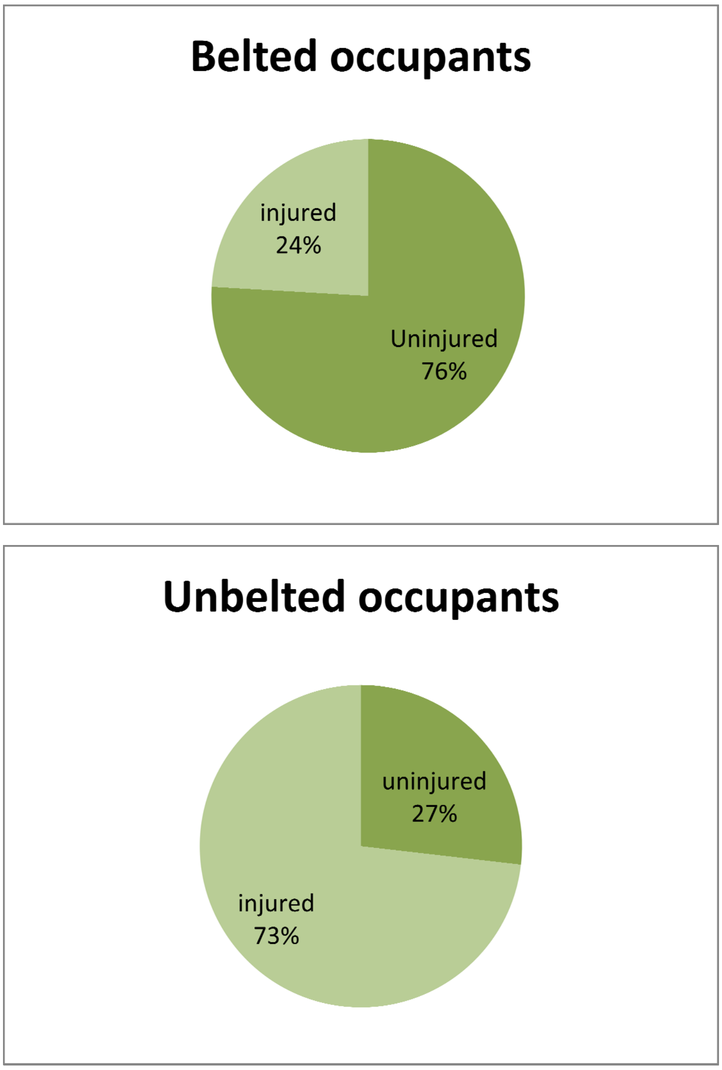


Fig22 Injuries for belted and unbelted occupants respectively

Fig22 illustrates the injuries for belted occupants and injuries for unbelted occupants in accidents. For unbelted occupants, 73% of them are exposed to injuries in accidents and injured occupants are rather more than the uninjured; for belted occupants in accidents, the uninjured are fairly more than the injured. Thus, wearing the seatbelt is an effective way to reduce injuries in accidents.

On the other hand, some studies on Chinese driving behavior and psychology[2] point out that the use of seatbelts in China is decreasing and rear seat passengers seldom wear seatbelts. It is to say that people haven't realized the importance of wearing seatbelts and the protection they offer. There are also some data showing that if the adult is not used to wearing the seatbelt, it's unlikely for him to help his kid to wear the seatbelt or buy him the child restraint. The potential hazard exists in these situations.

4 How the safety systems improve safety in driving

4.1 Active safety systems

4.1.1 Lane departure warning system

This is a true story of my own. When I went back to China for the summer vacation in 2011, I heard that my close friend's mother had lost her life in a road accident. After one month since her mother had died, I met my friend and knew the details of the accident.

It happened on the highway. After lunch, the car set out from Xi'an to Yulin. Two hours later, perhaps due to the lunch or the warm sunshine, all the occupants felt sleepy. My friend's mother fell asleep in the rear seat and even the driver looked too tired to open his eyes. In this case, the tragedy came. The car kept heading to the right. At the moment it almost hit the boundary fences, the driver suddenly woke up with the immediate steering. It took

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[2] Virginia Routley, Joan Ozanne-Smith, Dan Li, Min Yu , Jianyue Wang, Ming Wu, Junhe Zhang and Yu Qine." Attitudes to seat belt wearing and related safety features in two cities in China" International Journal of Injury Control and Safety Promotion, Vol. 16, No. 1, March 2009, 15–26

some hard time to stop the car. But unfortunately, my friend's mother was thrown out of the car by the rear windshield onto the freeway divider during the sharp steering. After that, she was sent to the nearest hospital but still lost her life because of the severe injuries.

Drowsiness, lane departure and the sharp steering deprived a person of her valuable life and also deprived a family of their happiness. However, can this accident be prevented and how?

Lane departure warning system could work in this situation. It can detect lane marks (white lines, yellow lines, dash lines and etc.)

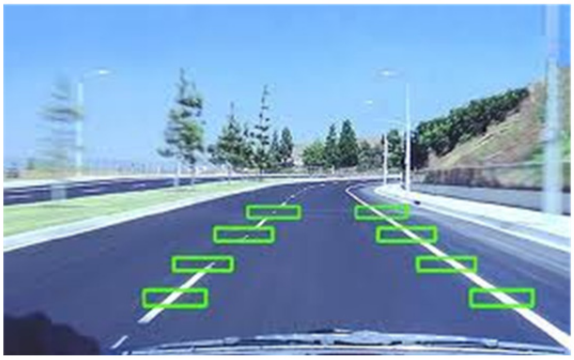

Fig23 Lane recognization

with camera sensors installed in the front of vehicle to determine whether a vehicle changes lane. If the vehicle changes lane by mistake, lane departure warning system will send out signals to alert the driver to concentrate on driving and prevent crash. For instance, when the driver feels sleepy, the vehicle could be out of control. It cannot keep its track and will head to the road border. In this scenario, the driver won't turn on the turning light because he doesn't intend to steer. Lane departure warning system works: 1) when the velocity of the vehicle is above around 60km/h[3], 3) when the vehicle keeps heading to the road border, 3) when the driver doesn't engage the turning light, the system will consider this situation as the lane departure. When lane departure occurs, the system will send out acoustical signals, visual signals or cause the vibration on the steering wheel (according to different products) to alert driver. After receiving such signals, the driver stares at the road, discovers the potential hazard and adjusts vehicle's heading direction and velocity in time to avoid accident. However, if there were the departure warning system installed in the car that my friend's mother rode or if her mother wore the seatbelt, things might be different.

4.1.2 Frontal collision warning system

The example taken below is caused by the driver's distraction.

When the truck ran on the highway, the driver got a SMS message. When he looked down reading and texting, bad things happened.

At the moment the driver stared at the cell phone, the car alarmed. When he fixed his eyes on the road to check what happened, he found that the car was moving towards the stones. He suddenly stepped on the brake and the car just stopped in front of them. Because of reading message, the driver neglected the road construction sign. If the car had kept going without being braked in time, roll-over would occur.

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[3] Visvikis, C., Smith, T. L., Pitcher, M., & Smith, R. (2008). Study on lane departure warning and lane change assistant systems. Transport Research Laboratory.

Why did the car alarm? Could it be able to see the obstacles?

Drivers are easily involved in the fatigue and distraction after a long time driving. Distraction such as texting illustrated in the example above may lead to collisions. Frontal collision warning system can work in this situation to effectively improve safety. When the system is engaged, the radar sensor sends out rays and receives the returned ones (long range radar can detect around 250 meters) and after the calculations, the relative speed and distance are received. When the vehicle falls into the distance limit/safety distance, the system will remind the driver of the potential crash. The reminders can be visual signals like the red light on the front window (Fig24)

Fig24 Human interface for frontal collision warning system

or auditory signals like "tick tock" due to different manufacturers. After receiving the reminder, the driver realizes the hazard and focuses on driving with decreasing speed, braking or changing lane to avoid crash. In urgent situations when the driver fails to take effective measures timely to prevent the crash after the alarm, the system will automatically intervene on the throttle or the brake to avoid collision.

4.1.3 Electronic stability system

Electronic stability system combines the function that helps the driver maintain steering control while braking and the function that helps the driver escape from sliding. Electronic stability system is the so-called force adjustment system. By adjusting the force on the certain wheel, the system keeps the vehicle stable. Take a case for instance to explain the system' working mechanism. This case demonstrates that a car runs on the highway and suddenly there is a big box falling down from the front truck's compartment and lying on the way of the car. In order to avoid colliding with the big box, the driver turns left (he drives on the right lane).

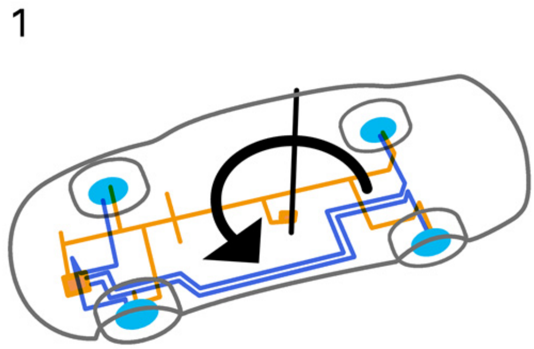

Fig25-1

Yaw sensor is used to detect the vehicle's steering performance, shown with black arrow in Fig25-1.

2

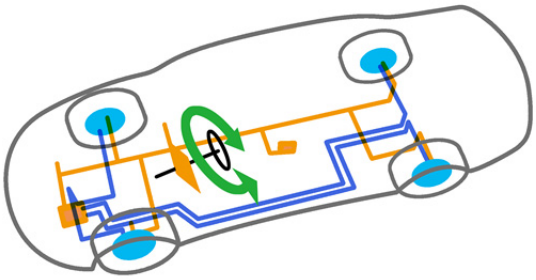

Fig25-2

Steering angle sensor is used to detect the driver's steering expectation, shown with green arrow in Fig25-2.

3

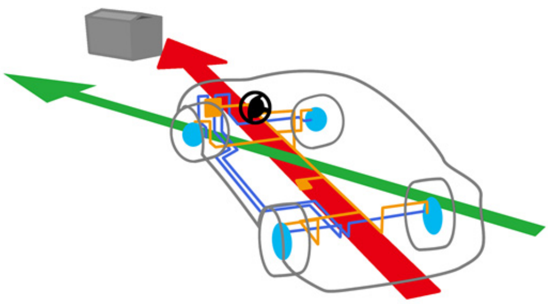

Fig25-3

Steering angle sensor detects the driver's steering expectation (shown with green arrow in Fig25-3), and yaw sensor detects vehicle's actual steering (shown with red arrow in Fig25-3). It is lack of steering response.

4

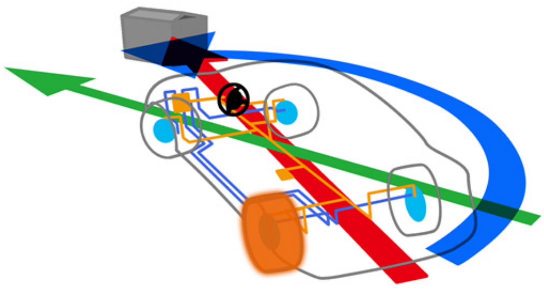

Fig25-4

When the vehicle lacks of steering, electronic stability system exerts the brake force on the rear left wheel (the orange wheel in Fig25-4) to offer the vehicle the force to turn left (shown with blue arrow in Fig25-4). In this case, the vehicle can reach the desired steering response.

5

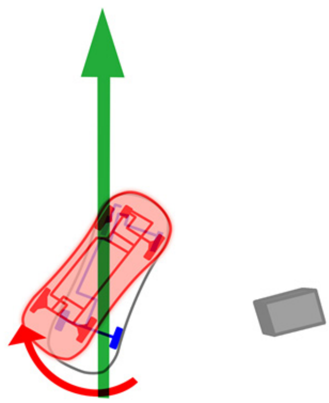

Fig25-5

It is for keeping the left lane that the driver turns left. Typically, after this maneuver, the driver needs to steer back immediately to make sure that the car won't collide with the boundary fences at the left side. If the driver turns too much when adjusting the direction, the car will drift to left (shown in

Fig25-5). At this moment, the car body is not stable and easily exposed to be out of control.

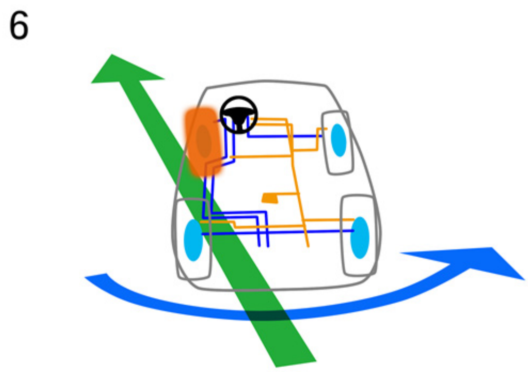

Fig25-6

However, the electronic stability system is used to offer the front left wheel the brake force and makes other wheels keep running. In this case, the force of turning right for the rear part of the car is produced (shown with the blue arrow in Fig25-6) to overcome the drifting force and make the car stable.

Electronic stability system can not only work in the situations given above, but also work on icy/slippery roads to improve the stability and safety of vehicle.

4.1.4 Adaptive cruise control system

Adaptive cruise control system is nowadays widely used in active safety field and the following story helps explain its working mechanism.

A father drove a car to Beijing for sending his daughter to the university. What he drove was a new car installed with the adaptive cruise control system. On the highway, the father pushed down the button next to the screen of dashboard and there was a sign shown. Then the system reminded the driver of setting the limit of speed and the limit of range respectively. Then the father set the speed limit to 100km/h and the range limit to 60 meters due to the speed limit of the highway and his own experience. After that, the adaptive cruise control system started to work.

At the beginning it is easy and relaxing to drive since the father’s car was the only one on the road. He just needed to hold the steering wheel without stepping on the throttle and the car could keep a constant speed under the automatic control from the system. After a while, more and more cars appeared. The system switched to the other mode. Instead of keeping a set speed, the system detected the nearest front vehicle, the relative speed and the relative range with it and then turned to follow it at the set range. In this process, the only thing that the driver did was still holding the steering wheel. The vehicle speeded up with the front one speeding up and vice versa. It was a very smooth driving.

However, when everyone talked about the adaptive cruise control system excitedly, the front car was suddenly braked! The father felt much too nervous and thought that the disaster would occur! No one could imagine that the thing was not like what they had speculated. The adaptive cruise control system insisted on keeping the set range and made the car keep decreasing the speed. The driver found they survived and hurried to stop the car. A disaster was removed.

The father drove the rest road to Beijing all by himself without feeling so tired. Reading the fuel meter, he found that the fuel consumption was reduced by 3%[4] compared with the common value.

This is the adaptive cruise control system that can not only improve the vehicle's dynamic performance and safety but also reduce the fuel consumption. In addition, the system won't limit driving. When the driver changes lane, steps on the brake, use the manual gear shift, or at the speed below the certain value (typically 30km/h[5]), the system will stop controlling the vehicle. Besides, the driver can deactivate the system by "on/off" button on the dashboard. It is very flexible to use the system.

4.1.5 Night vision system

In this case, a girl lost her boyfriend. At a summer night, they planned to encamp in the suburb after one day's trip. They tried to find a camp place. It was too dark for them to see the road since there were no street lamps. When they crossed the road, the boy was collided by a car and badly hurt. The driver and the girl hurried to send the boy to the hospital. But he failed to survive since it took long to arrive at the hospital in the city and he was injured severely. As the driver said, he turned on the front lights at that moment but the range of the lights was limited and he didn't see the boy. He added that

[4] T. Alkim, G. Bootsma, & P. Looman, "De Rij-Assistent; systemen die het autorijden ondersteunen. Studio Wegen naar de Toekomst (WnT), Directoraat-Generaal Rijkswaterstaat", Delft, 2007. – Project Report in Dutch

[5]A. Vahidi and A. Eskandarian, "Research Advances in Intelligent Collision Avoidance and Adaptive Cruise Control", IEEE Tans. On Int. Transp. Syst., Vol. 4, No. 3, 2003 – ''Review'' Journal Paper

although he didn't drive so fast, the crash could not be prevented when he saw the boy.

The thing has passed for many years and with the development of vehicle safety, night vision system was born.

The girl in the story drives a car installed with the night vision system now. She tells, "This night vision system is based on far infrared sensor to detect the thermal radiation. According to different temperature, living bodies and the environment can be divided and shown in the image by the calculations in the data processing unit." In Fig26 for instance, compared with the environment, humans and the animal are the thermal source with high temperature and radiate much heat to be captured by the far infrared sensor, thus they are shown with bright component in the image; the background is the thermal source with low temperature and radiate little heat, thus it is shown with comparatively dark component in the image. According to the contrast, living bodies are recognized in advance.

Fig26 Human interface for night vision system

At night and especially at dark places, this system is very important since the range of car lights is usually around 50 meters but the range of far infrared sensor is around 300 meters. Night vision system based on far infrared sensor acquires better contrast in the image than other night vision systems. In addition, night vision systems which are commonly integrated with the function of pedestrian detection will alert the driver when there are pedestrians in front.”

4.2 Passive safety systems

4.2.1 Frontal collision

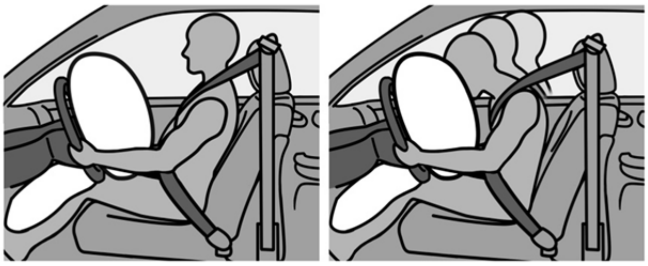

Fig27 Decompositions of the driver behaviors in frontal impact

In the frontal collision, when the sensor in vehicle detects the impact and determines that the impact meets the requirements of airbag deployment (simple scraping won’t cause injuries and the airbag won’t deploy), the control unit immediately transmits the firing current to the airbag system. Firing current makes the chemicals in the gas generator involved in chemical reactions to produce gas. After that, the airbag is inflated and deployed. The front airbag at driver side comes out from the steering wheel and the knee airbag comes out from lower part under the steering wheel; the front airbag at passenger side comes out from the right part of dashboard. The whole process for the deployments illustrated above will be finished within 25 milliseconds(less than a blinking). That is to say, when the collision occurs, airbags are deployed first and then occupants interact with airbags for buffering (Fig27). In addition, the best protection is offered when seatbelts and airbags are used at the same time. During the collision, when the control unit transmits the firing current to the airbag system, it will also send out the signal to the seatbelt system. Pretensioners work with limiting the expansion of the vertical belt. In the frontal collision, the occupant's upper body tends to move forward because of the inertia and the seatbelt can keep him in the seat preventing him from being thrown out.

Under the protection of seatbelts and airbags, the process can be concluded as follows: occupants move forward to the certain extent with the restraint of seatbelts and interact with the deployed airbags. Airbags and seatbelts are effective countermeasures of passive safety systems.

4.2.2 Side collision and roll-over

Fig28 Passive safety systems in side impact

In the side collision or the roll-over, side airbags and airbag curtains are deployed (Fig28) and their working mechanisms are as similar as those of the airbags used in the frontal collision. Side airbags and airbag curtains are used to prevent occupants' sides (heads, arms, chests and bottoms) from directly colliding with vehicle interiors to reduce injuries.

4.2.3 Rear-end collision

Rear-end collision is the most common accident on highway. But the rear-end collision demonstrated here indicates the low speed rear-end collision in the city traffic. Suppose that when a guy drives on the road, a pedestrian crossing the road appears in front of his car and he brakes immediately. But the car following his fails to stop in time and collides with his car. At this moment, the guy's back and hip are pushed forward by the interaction with the seat back but his head stays in the original position according to the inertia and then collides with the seat pillow (see Fig29).

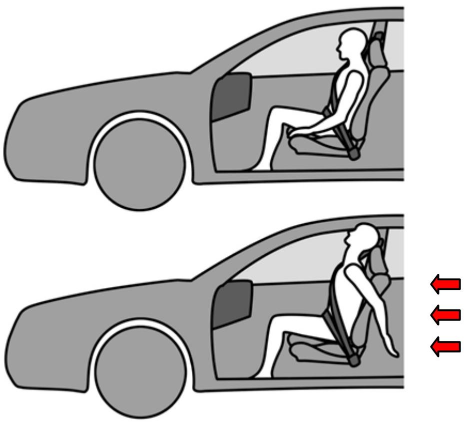

Fig29 Whiplash in the low speed rear-end collision

This phenomenon is so-called whiplash. In this case, the driver's neck will be easily hurt because of the flexion and extension. Someone may ask “why the head doesn’t move forward with the neck and back instead of such the relative motion on the neck (the upper neck stays behind with the head and the lower neck moves forward with the back)?” It is because of the flexibility of neck. Compared with other skeletons, neck is much more flexible. However, this feature of neck leads to the whiplash in rear-end collisions.

Why whiplash can draw attention of the public? It is not due to the injury itself but its consequences which are really horrible. Sometimes, people will suffer from such the hurt for their whole lives.

Fig30 Consequence of whiplash

C-NCAP in 2012 （http://www.c-ncap.org.cn/C-NCAP/index.htm） includes a new role for whiplash assessment, which indicates the importance of this kind of injury and how much attention people pay to it.

There are two main countermeasure principles for the whiplash prevention below. They are both mechanical design based on mechanics. The first design (Fig31) is: when the impact occurs, the seat back moves forward pushing the heading forward to make it keep the same motion as the neck and the back to avoid whiplash.

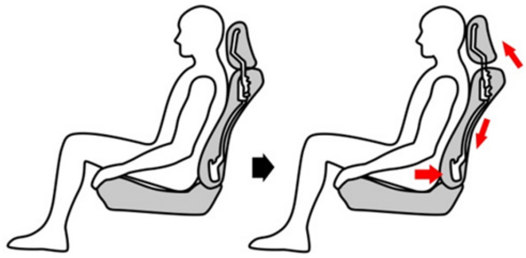

Fig31 countermeasure principle 1 for whiplash

The second design (Fig32) is: when the impact occurs, the seat back moves backward making the back of person move backward to keep the same motion as the neck and head.

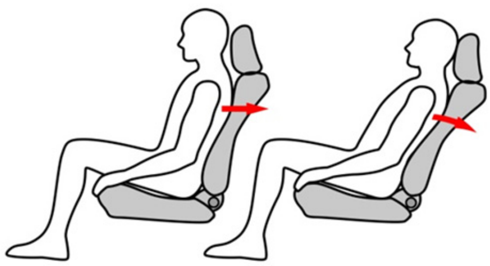

Fig32 Countermeasure principle 2 for whiplash

4.2.4 Child restraint system

Child restraint systems mostly refer to additional seats and cushions for kids. Child seats consist of the forward-facing and rear-facing ones; cushions or boosters consist of the independent and integrated ones.

Why rear-facing seat?

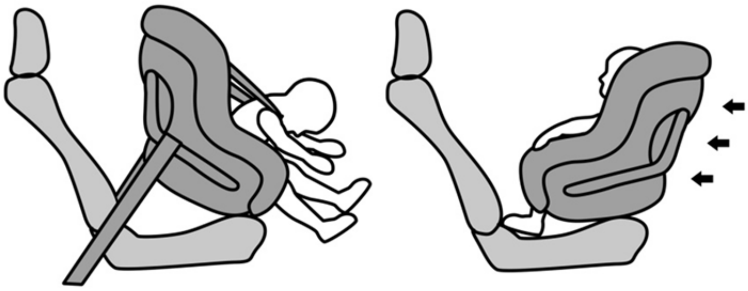

Fig33 Child restraint 1

Kids are not small adults. They don’t differ from adults only due to the size but the growth of organs, skeletons and etc. To the kids under the age of three, they have proportionally larger and heavier heads, which means their necks are easily exposed to injuries because of the motive force from the head; their spins and ribs never develop well to protect the organs inside and they have more exposed abdomens, which indicates higher risk for lap belt. If kids sit in the forward-facing seats when they are involved in the frontal collision, the car will be stopped by the collision and the kid’s body will be restrained by the seatbelt but the head will move forward violently according to the inertia and without any restraint(Fig33). In this case, the neck will suffer from the relative motion and get injured. If the kid sits in the rear-facing seat in the front collision, the kid’s back will undertake most of the force from the impact(Fig33). The bigger size and more stiffness of the back than the neck will be helpful for reducing the injuries.

Why boosters?

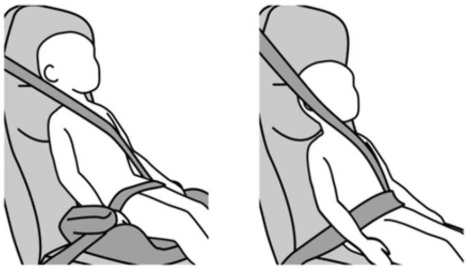

Fig34 Child restraint 2

Due to the limit of size, elder kids are not fit for rear-facing seats. But compared with adults, they are still too short to sit on the seat directly and to be protected well by the seatbelt(Fig34). In this case, the seatbelt will cause much pressure on his neck and belly, which may produce injuries. Boosters are needed. It is used for boosting kids and ensuring that they can be protected by seatbelts properly. Besides the good protection, boosters can also make kids feel comfortable when he wears the belt.

There are two more types of child restraint systems. One is forward-facing seat, see the left in Fig35. Besides the functions of boosters, it can also protect kids in the side collision. The other one is the integrated booster, see the right in Fig35. With the integrated booster, it’s no need to buy extra ones and it is easy to use as well.

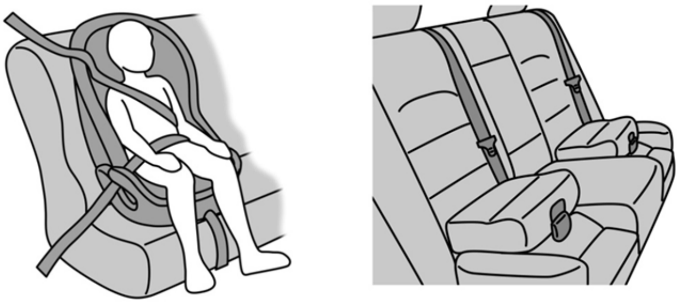

Fig35 Child restraint 3

There is evidence showing that child restraint systems contribute a lot to reduce injuries of kids in road accidents.

5 Computer simulations for dangerous situations

5.1 Computer simulation of the unbelted rear seat passenger in frontal collision

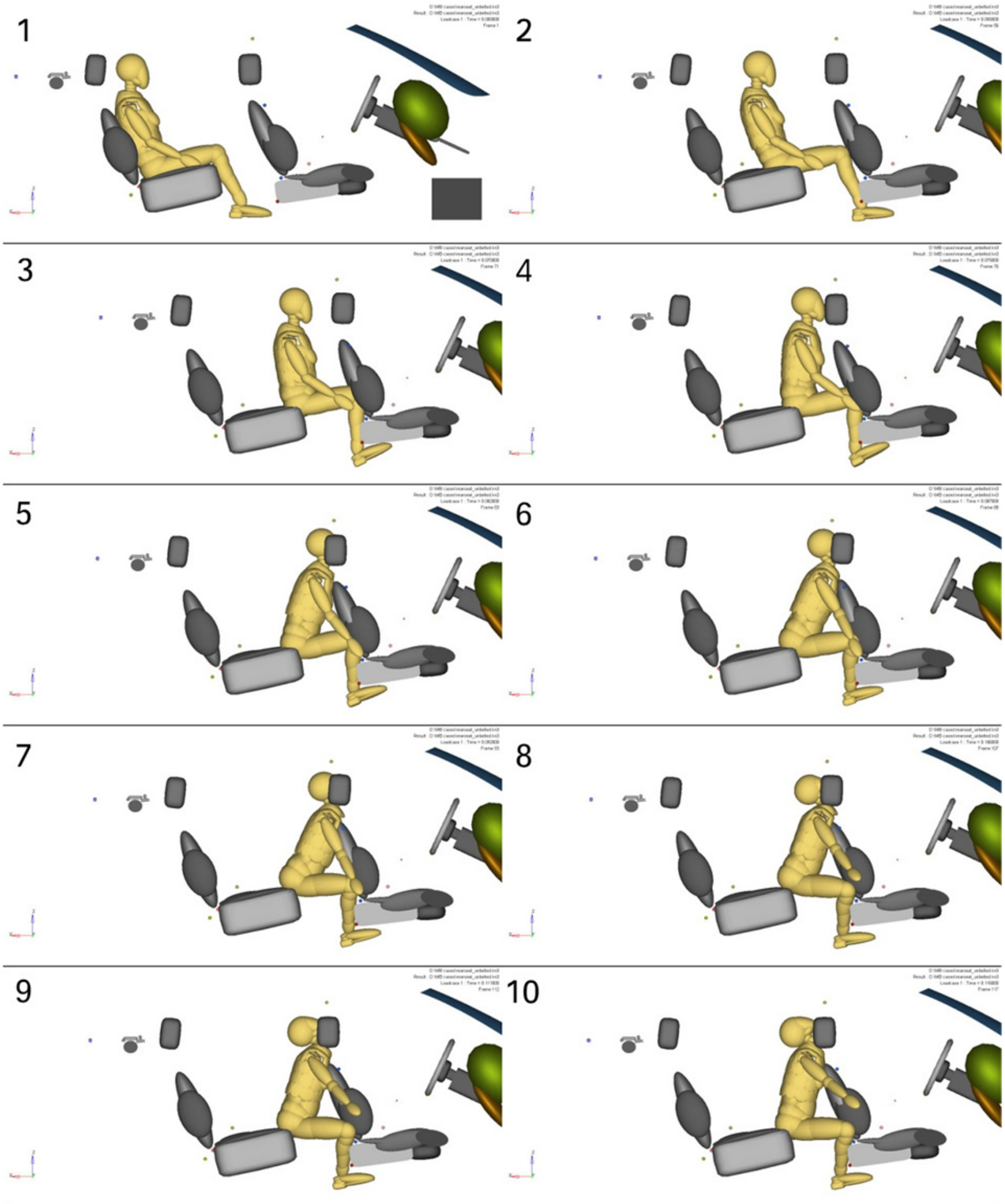

Fig36 Unbelted rear passenger in frontal impact, impact speed=50km/h
There are much hurt on adult's neck and lumber.

The computer simulation demonstrates that the unbelted rear-seat passenger is involved in the frontal collision at the impact speed of 50km/h. As is shown in the process decomposition figures, it is hazardous that the cervical spine and the lumbar spine are injured seriously. According to the accident analysis section, rear seat passengers in China hardly wear seatbelts. It is a potential contributor to injuries.

5.2 Computer simulation of the adult and kid in abnormal postures in front seat in frontal collision

The computer simulation presents that the adult sits in the front seat with the kid standing in front of him. This situation is very common in China, especially in taxis. The process decomposition figures (frontal collision at impact speed of 50 km/h) indicate how hazardous it is. In these postures, the adult's legs, head and neck and the kid's head and chest are easily exposed to injuries caused by compression. Furthermore, when it happens at the high speed, the airbag will deploy and cause the serious injury on the kid's head.

6 Introduction of advanced safety systems

6.1 Eye-tracking system

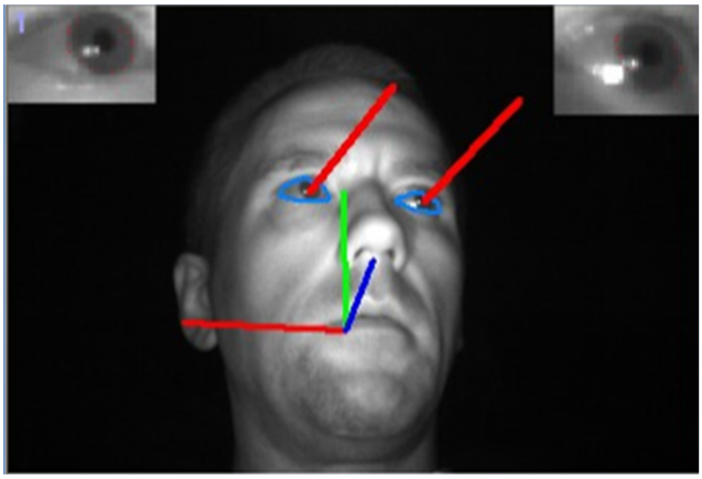

Fig38 Eye tracking

Eye-tracking system consists of two main parts: the camera sensors and the image processing unit. The camera sensors are used to capture the image of the eye and the image processing unit is used to position the eye fixation and the eyelid for eye movement analysis. It can be determined by the eye movement analysis whether the driver is distracted and whether the driver is involved in drowsiness. The system determines the distraction due to eye fixation and the time eyes keep fixing on the certain position. Generally, if the driver concentrates on driving, he will have his eyes on the road; if the driver is distracted by the non-driving related things e.g. reading SMS, he will keep looking down for a short period. When the driver is distracted, eye-tracking system may send out signals to remind him. The drowsiness is determined by the eye blinking frequency and the time each blink lasts. Generally, if people feel sleepy, their eye blinking changes. When the driver is determined to be in drowsiness, the system will send out signals to remind him of a rest to avoid accidents.

The accident data in the previous section indicate that drowsiness is a leading factor for highway accidents. Eye-tracking system is now a popular topic in active safety field due to its function. It can also work with other active safety systems to reduce false alarms and improve safety.

6.2 Cooperative system

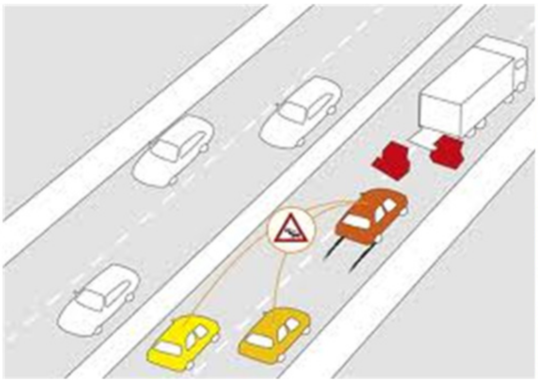

Fig39 Vehicle to vehicle communication

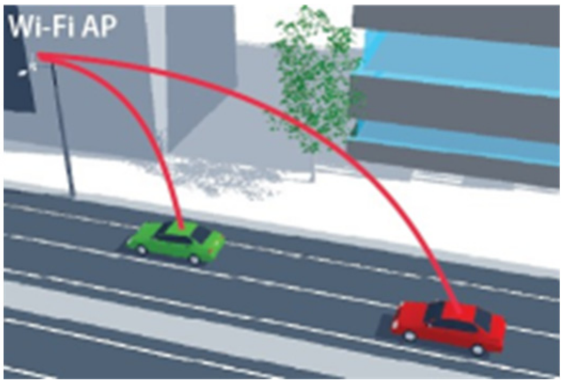

Fig40 Vehicle to infrastructure communication

Cooperative systems are applications based on wireless communication between vehicle and vehicle or vehicle and infrastructure. The transformed information includes the speed limit of the road, the spot of traffic accident, the spot of traffic congestion, the spot of construction, information for assisting changing lanes and information for assisting steering. The information can come from neighboring vehicles or the infrastructures on the road sides. Receiving the information, drivers get to know the traffic situations, escape from the traffic congestion and the locations where accidents occur and they can also reduce the speed when they are alerted by the cooperative systems. The system makes trip smooth.

Some situations that the cooperative systems can performance well are introduced below:

1 If the target vehicle needs to overtake the truck by occupying the reverse lane (Fig41, marked vehicle is the target vehicle), the front truck will stop both of the driver's eye sights and the front sensors of the vehicle. Thus, the driver fails to see the car on the reverse lane and so does the front sensor. In this case, when the driver changes lane, crash may happen. However, with the cooperative systems, the target car can receive the information from the truck ahead that there is a car on the reverse lane and it's impossible for lane change. Otherwise, the target car can receive the information from the infrastructure to inform the driver of the car on the reverse lane.

Fig41 Blind spot on the reverse road

2 When the accident happens near the road corner, the frontal collision warning system fails to detect it due to the limit of angular resolution. In this case, if there are cooperative systems, the second crash can be prevented.

Cooperative systems can work well for potential accidents caused by blind spots on roads like corners and ups and downs. Meanwhile, cooperative systems can also use wireless communication to send out emergency signals for in-time rescue. Cooperative systems are the sign of the coming age of vehicle networks.

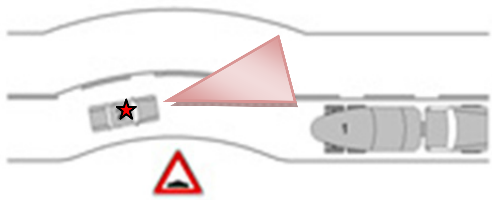

Fig42 Blind spot caused by the limit of regular resolution

7 Conclusion and acknowledgement

Most common and advanced safety systems nowadays are presented in this handbook. It is hoped that readers can get to know the safety systems at overall and detailed levels. It is also hoped that reading the handbook can help readers to improve their safety awareness. In addition, it is planed that the handbook can teach readers how to use the safety systems to benefit from them. Nevertheless, only a handbook is not enough and more and more relevant multimedia materials will come. All vehicle safety related staffs will devote themselves to enhance safety.

However, I want to give my great thanks to Autoliv, Chalmers University of Technology, CATARC (China Automotive Technology and Research Center) for technical support. And I also want to give many thanks to Ola Boström, Mats Svensson and Yong Chen who supervised me in this project. Besides, thanks should be given to my friend Qian Liu who drew most figures used in the handbook. Sincere thanks to those who offer suggestions and help to improve the handbook!

"Why we work together is all for your safe driving!"

Author: Jing Li