DOI 10.15302/J-SSCAE-2019.03.022

Development Path of Anthropomorphic Test Device with Chinese Physical Signs

Liu Zhixin , Wu Yongqiang, Ma Weijie

China Automotive Technology and Research Center Co., Ltd., Tianjin 300300, China

Abstract: Automobile safety is an important factor that affects public transport safety, and the anthropomorphic test device (ATD) is a core technology that ensures vehicle safety. However, the design of existing ATDs cannot be used to adequately evaluate the safety of vehicles for Chinese passengers, and China does not possess the core ATD technologies. Major problems restrict further development of automobile-safety technologies in China. In this paper, through research on the development trend and key ATD technologies in China and the world and by considering China's technical status, a development path for ATDs with Chinese physical signs is proposed to further improve the standards system for automobile safety in China. Development of ATDs in China will promote its high-end equipment-manufacturing industry and standards innovation. It also provides practical significance and long-term strategic values for developing China as an innovative country and enhancing its international competitiveness.

Keywords: automobile safety; anthropomorphic test device (ATD); Chinese physical signs; standards system

1 Introduction

With the continuous growth in car ownership in China, the road traffic safety situation has increasingly become serious. At present, the death rate in 10 000 vehicles in road traffic accidents in China remains at two to four times that in developed countries such as in Europe and the United States. Traffic safety has become a serious public safety problem that threatens economic and social development. Automobile safety technology, as an important factor that affects road traffic safety, has become the focus of attention of the government, society, and automobile industry.

Passenger protection is the ultimate goal of vehicle safety technology, which is closely related to traffic accident analysis, vehicle safety design optimization, vehicle safety performance tests, and verification. An anthropomorphic test device (ATD) is a measuring instrument that is directly used to evaluate the damage degree of the impact on the human body and to evaluate the safety of vehicles. Therefore, ATD is a core technological requirement that supports vehicle safety.

On the one hand, China's early automobile safety standards are mainly directly based on foreign standards, which for a short time solved the problem of whether or not China's automobile safety technical constraints are present. Therefore, for a certain period of time, the safety technical standards have effectively addressed China's public transport safety problems. However, in recent years, contribution in the improvement of safety technology to reduce traffic safety is no longer as significant as that in previous years. One of the main reasons is that the ATD used in automobile safety standards was developed based on human characteristics in Europe and America, which leads to the problem that the existing automobile safety design cannot optimally protect Chinese drivers [1–3]. On

Received date: May 16, 2019; **Revised date:** May 25, 2019

Corresponding author: Liu Zhixin, professor level senior engineer from China Automotive Technology and Research Center Co., Ltd. Major research field is automobile safety. E-mail: liuzhixin@catarc.ac.cn

Chinese version: Strategic Study of CAE 2019, 21 (3): 103–107

Cited item: Liu Zhixin et al. Development Path of Anthropomorphic Test Device with Chinese Physical Signs. *Strategic Study of CAE*, https://doi.org/10.15302/J-SSCAE-2019.03.022

the other hand, the ATD and its related technical standards are monopolized by the United States, and the core technology is restricted by other countries. If the United States imposes a technological blockade, China will face an embarrassing situation of no ATDs available. In particular, at present, China holds the largest automobile market in the world, and this amplification effect has become particularly significant.

In this paper, the core issues that affect the progress of China's automobile safety are analyzed, and the necessity and feasibility for testing ATD with Chinese physical signs is studied. A development path for this type of ATDs is preliminarily proposed to further improve China's automobile safety standards system. Developing vehicle ATDs that use Chinese physical signs and formulating the corresponding standards are not only conducive to eliminating the situation where the core technology is "dependent on others," but also to emphasizing the dominance of China's technical standards through the core strength of China's standards, which are supplemented by China's market advantages.

2 Analysis of automobile safety standards

ATD represents the "weight" of safety standards. The ATD used in domestic standards has been developed according to European and American human bodies. It remains questionable whether the "weight" of European- and American-based vehicle safety can provide the most effective protection for Chinese drivers and passengers.

2.1 Existing automobile safety design cannot optimize the protection of passenger safety in China

As a key technology that measures vehicle safety, ATD directly affects vehicle safety design. It has a "technical weight" effect. However, in the field of vehicle crash safety, the ATD used in China is still used abroad, which is designed according to the main size of a 50th percentile adult male in the United States. At present, all vehicle safety designs in China consider this ATD as the ideal protective device. However, considerable differences exist between the Chinese and American human body in terms of external (such as height, weight, muscle density, and mass distribution) and internal characteristics (dynamic response and biomechanics). For example, compared with medium-sized men in the United States, the corresponding male dummies in China are 3.48% shorter and 13.55% lighter. The proportion of the upper arm of medium-sized men in China is 4.14% shorter than that of medium-sized men in the United States, and the knee height at a sitting posture is 12% shorter. Significant differences also exist in the biomechanical properties, which directly affect the tolerance limit of a human body as well as the evaluation index and limit in a dummy (also called ATD) test. By considering the chest as an example, the thickness of a rib dense tissue in Chinese people is significantly smaller than that in Americans, which shows that the breasts of Chinese people are more vulnerable to the same collision than those of American people. This difference shows that the automobile safety design based on the "European and American human body" cannot actually protect the "Chinese human body." In other words, because of the inaccuracy in "technical weight," the "American weight" cannot truly be used to ensure China's automobile safety.

2.2 Overseas technology monopoly: Core technology is controlled by other countries

The ATD, which measures the "weight" of a vehicle crash safety standard, is exclusively monopolized by the United States. The lag in the research on ATD in automobile crash test in China reveals that all ATDs and their vulnerable parts mainly depend on imports. Not only are the ATDs expensive and the supply cycle long but also the development cost and cycle of independent brands are limited by other countries. To break this monopoly and take the initiative, speeding up the development of ATD and its safety standards system is imperative, which should be an important strategic measure for China to go forward from a big automobile country to a powerful automobile country.

At present, China has the largest automobile market in the world with 200 million cars and 400 million registered drivers. With such huge car ownership, all vehicle safety designs are designed to protect "Europeans and Americans" rather than "Chinese," which requires more prominent benchmarking to address the problems exposed by foreign ATD vehicle safety design benchmark with the increase in car ownership.

3 Necessity and feasibility of developing ATDs with Chinese physical signs and their standards

3.1 Necessity analysis

The European and American human signs are quite different compared with the Chinese physical signs in the

DOI 10.15302/J-SSCAE-2019.03.022

corresponding Chinese human body in terms of both external and internal characteristics. These differences significantly affect the vehicle safety design as well as directly affect the restraint system and safety performance evaluation index. The main differences are divided into three aspects.

3.1.1 Dynamic response difference

The Hybrid III 50-percentile dummy is designed according to the size of a 50-percentile human body in Europe and America. Its height and weight are 1.76 m and 78 kg, respectively. It greatly differs from a Chinese human body (height = 1.69 m and weight = 69 kg), and its dynamic response is different. A computer simulation analysis shows that obvious differences exist between the damage response of the Chinese human dummy and that of the Hybrid III dummy in a vehicle crash test. Therefore, the direct use of Hybrid III dummy test evaluation can lead to the development of an occupant restraint system that cannot achieve the best protection of a Chinese human body. In the field of rail transit and aerospace, developing the best protective measures for Chinese human body is also difficult by testing and evaluating using European and American dummies.

3.1.2 Difference in mechanical properties

The differences between the European and American human bodies and Chinese human bodies not only affect the dynamic response of the two bodies under stress. Research shows that obvious differences exist in the skeletal structure and body shape, which result in differences in the mechanical properties between them and affect the mechanism of human injury and tolerance limits. Morphological statistics shows that some characteristic parameters of the human body, including the height, weight, and age, have important effects on the size and shape of a human skeleton, such as the cross-sectional area of the ribs, width and thickness of the thoracic cavity, height and width of the pelvis, and cross-sectional area of the upper and lower limbs, with the change in the body size. The results of the simulation and cadaveric tests show that these geometric differences affect the location and severity of human injuries during accidents. Simultaneously, large differences exist in the material parameters between the Chinese and Western populations. Studies show that the pelvic-bone mineral density is higher and the vertebral-bone mineral density is lower in Eastern women than those in Western women. Therefore, the tolerance of a human body to external stress changes with the change in the material parameters.

3.1.3 Limited trunk biofidelity

Although the current biological characteristics of the chest of the dummy are based on the frontal impact response data of the human chest, the biofidelity of the bionic structure of the dummy's chest still suffers from limitations. For example, the bionic structure of the chest rib of the dummy is quite different from that of the human rib. It can only reflect the response of the human body in a large area of blunt impact. However, it cannot accurately reflect the force characteristics of the human body in a small area of impact and in lateral or oblique impact. In addition, the spine of the dummy is simulated using the whole rigid structure and rubber lumbar spine, which can only reflect the characteristics of the human body when bending in a large range. At the same time, research shows that the lumbar spine of the human body is bent forward in a sitting posture, whereas that of the existing dummy is bent backward, which leads to inconsistent upper body dynamic response between the dummy and a real person.

To more effectively reduce the casualty rate of drivers in traffic accidents, fully ensure the safety of people and property, promote sustainable development of China's automotive industry, and improve the core competitiveness of China's automotive industry, researching, developing, formulating, and popularizing collision test dummies and their standards are particularly important in consideration of the Chinese physical characteristics. These activities are essential.

3.2 Feasibility analysis

ATD was first used in the military field. After more than ten years of development, ATD was gradually applied to automobile, aviation, sports, and medical fields. From enterprise-led to government-led, ATDs were continuously developed, which emphasized the applicability in a region, e.g., Americans are now more obese and aging. Thus, they are gradually developing ATDs for obese and elderly populations. In 2000, China began to develop dummies, which are designed more for imitation and exploration and only to create a look without considering the external and internal characteristics of the Chinese people.

Although some foundations and preliminary explorations have been made on the ATD development in China, corresponding success has not been achieved. The root cause lies in the lack of relevant top-level design, clear

design objectives, and general planning, which resulted in the disadvantage of separate struggle, lack of in-depth research, and repeated research. In this condition, the popularization and application of the dummy has not been fundamentally solved. From key technology research to research and development and design, from production and manufacturing to performance verification and to standards settings, resources are distributed in different institutions and need to be fully coordinated and integrated to complete the development of ATDs with Chinese physical signs. Its root lies in the lack of a government-led organization to coordinate the industry.

A working group was jointly set up in China by the China Automobile Technology and Research Center and automotive enterprises, universities, and scientific research institutes. The establishment of the working group is helpful for providing full utilization of the resources in the whole industry and the technological advantages of the different research fields. The research and development of ATDs and their standards system that conform to Chinese characteristics is very significant, which can also help enhance China's international competitiveness and standard voice in the field of automobile safety.

4 Developing technological path for ATDs with Chinese physical signs

The development of ATDs in China is a systematic project that involves technical complexities and has interdisciplinary characteristics. Simply imitating the existing ATDs from abroad cannot fundamentally solve the problem. This project will fully rely on the advantages of the Chinese ATD Working Group, strictly follow the new product development model of a highly integrated intelligent technology and high-end development of manufacturing industry, and realize overall development goal for high-quality and intelligent ATD series with advanced technology, standards applicability, and market irreplaceability in the future.

The preliminary development technology scheme of the ATDs with Chinese physical signs includes the following five aspects.

4.1 Development ideas

First, the ATDs should have Chinese characteristics, conform to Chinese physical signs, and satisfy Chinese external-size and internal biomechanical-response characteristics. Second, we need to transcend technology, innovate in succession to innovation, consider coherence with foreign ATDs and their standards, and solve existing technical problems of ATDs. Third, we need to find a new method to meet the requirements of new test conditions in relation to the actual situation of road traffic accidents in China.

4.2 Development principles

(1) Government-led and open cooperation: Provide full responsibility as the leading player in the government, strengthen open cooperation, mobilize the interest of all parties, participate in multiple ways, follow market rules, ensure implementation of various tasks, and achieve win–win situations among all parties.

(2) Objectives should be clear and practical: Set realistic and feasible goals according to the national conditions; actively promote innovation and development of technology, application, management, and system; continuously improve the operational efficiency and technical cooperation level of the working group, and promote coordinated development of ATD development projects.

(3) Step-by-step implementation of the master plan: Develop short- and long-term research tasks by combining the goals and tasks of the Chinese ATDs, formulate the framework of a master development plan, follow the trend in technology transformation to the industry, and concentrate on implementing key breakthroughs.

(4) Innovative optimization and coordinated development: Provide full responsibility for the guidance and coordination role of the working group to promote technological application, business model, industry application standards, and institutional innovation as well as promote sound and rapid development of ATDs in China.

4.3 Overall objectives

The planning is divided into long- and short-term planning. The long-term planning takes approximately 10 years, whereas the short-term planning takes approximately 3 years. The first stage is aimed to complete the research of key technologies and methods, including traffic accident and injury research, standards analysis of Chinese body-shape parameters, improving and optimizing resources in various fields, preliminary understanding of key technologies of the ATD development, and forming the overall process of ATD development. The goal is to innovate for the inheritance according to the following: (1) to optimize the sitting posture of existing dummies and

DOI 10.15302/J-SSCAE-2019.03.022

(2) to establish dummy models that conform to the characteristics of traffic accidents in China. The second stage is designed to improve the ATD development and standards research, including Chinese human biomechanics research, material bioequivalence technology, sensor information fusion technology, bionic structure design technology, simulation model development technology, and related standards research. The goals are as follows: (1) to achieve the development of a sitting dummy, (2) to improve the dummy model in line with the characteristics of China's traffic accidents, and (3) to develop dummies applicable to both active and passive safety tests. The third stage aims to complete the demonstration promotion and standards application, including research on the ATD test evaluation method, demonstration promotion and application, and formulation of standards and regulations. The goal of this work is to realize the application of standards to dummy serialization by (1) realizing the development of China's crash dummy serialization and (2) realizing the application of automobile safety test regulations and evaluation rules.

4.4 Development system

The development system, i.e., safeguard and operation management system, is coordinated at four levels: technological, platform, policy, and security. The technological level develops from three fields: ATD development, standards research, and demonstration application. The platform layer includes three platforms: key technology research, standards research, and application promotion platforms, as well as a big data center and a test and evaluation center. The policy level is supported by three levels: national innovative development strategy, commission from the Ministry of Industry and Information Technology, and commission from the National Standardization Management Committee. The security layer is divided into policy, technical, organizational, and supervision guarantees.

4.5 Key tasks

The basis for choosing the key tasks is as follows: (1) serving the strategic needs of the country and guiding the development of the industry, (2) providing forward-looking and basic support services for cross-industry development, (3) providing cross-domain common basic modules, intermediate formation, and common platform for product development of different enterprises, and (4) integrating superior resources and cooperation by specialized sectors.

The first batch of key tasks for ATD development includes five common key technologies, i.e., road traffic accident research in China, injury biomechanics of Chinese bodies, bionic structure and advanced manufacturing, sensor and signal fusion technology, and new alternative material technology. It also includes three platforms, i.e., a key technology research platform, a standards research platform, and an application and promotion platform, as well as two major centers, i.e., a big data (accident, injury, test, and material data) center and a test evaluation (calibration test, bio-simulation evaluation, and test evaluation) center.

5 Conclusions

There is a critical need to develop a "Chinese ATD" and its standards. It is an important measure to ensure the safety of drivers and solve the problem in which the core technology is controlled by other countries. ATD is a system engineering that features technical complexity and interdisciplinary characteristics. Integrating resources, jointly tackling key problems, and conducting extensive research are essential. The research content belongs to the public service platform in the field of transportation, and the government should pay more attention to and support it. The development of ATDs that conform to China's physical characteristics should be promoted at the national level, and the establishment of their standards system should become an important strategic measure for developing China from a big to a powerful automobile powerhouse.

References

[1] Zhang J H, Yang J, Jin X, et al. Differences of anthropometric dimensions between Chinese and American and the effects on drivers' injury risks in vehicle frontal crash [J]. Journal of Automotive Safety and Engergy, 2016, 7(2): 175–181.

[2] Jesse R. Finite element moldeling of the human head and the biomechanical basis of head injury criterion (HIC) [R]. Changsha: 2nd International Forum of Automotive Traffic Safety, 2002.

[3] China Automotive Technology and Research Center Co., Ltd. China new vehicle evaluation rules (C-NCAP) (2018) [EB/OL]. http://www.C-ncap.org. Chinese.