

Application of Simplified Waveform in Parallel Imported Vehicle Certification Using CAE Technology

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Abstract. Parallel imported cars, as a structural supplement to the automotive industry, rarely involve manufacturing and are more inclined towards trade. Due to the particularity of its industry, its ability to bear the cost of testing and certification is not as strong as that of traditional automobile manufacturing enterprises. Previously, the China National Accreditation Service for Conformity Assessment (CNCA) implemented a policy of using data review instead of actual testing for destructive testing of parallel imported vehicles, which can reduce their testing costs. Since the cancellation of the data review system in 2024, the cost of parallel imported car certification has increased and the certification declaration has significantly decreased. At the same time, considering the opportunity for CAE, which has been widely used in the field of automotive design, to gradually enter the testing field, the author envisions that if CAE is introduced to replace the destructive testing project of certification testing, the certification cost of parallel imported cars will be greatly reduced, and the constraints of the industry will be lifted accordingly. Therefore, this article aims to study the introduction of CAE into parallel import vehicle certification to replace the certification technology of destructive testing in type testing. The author believes that this is highly forward-looking.

Keywords: Parallel imported vehicle, Product certification, Acceleration waveform, Equivalent simplification, Finite element model simulation.

1. Introduction

The mandatory product certification for parallel imported cars requires a large portion of the certification cost for medium-sized tests, especially for destructive tests such as the three major collisions and the strength of seat belt anchorages. Not only does the testing cost itself be higher compared to other tests, but companies also need to provide test vehicles to support the testing, and the vehicles will be scrapped after the test. All vehicles for parallel imported cars are purchased from the market, so it is equivalent to companies having to bear the cost of several vehicles. Therefore, introducing CAE into real vehicle testing as a substitute for certification and type testing can legally and compliantly reduce cost pressure for enterprises during the type testing stage. For certification agencies and regulatory authorities, it is also a good practice for the national policy of streamlining administration and delegating power.

2. Overview of the mandatory product certification process for parallel imported automobiles

2.1. Certification Mode

China's mandatory product certification (usually referred to as CCC certification) has two modes: mass production and non mass production. Parallel imported cars usually adopt non mass production forms. The certification of single vehicles in non mass production mode is not considered in this article due to its strong targeting of vehicles and the lack of destructive testing in type testing.

The certification mode applicable to parallel imported vehicles is: type test+initial factory inspection (based on factory quality assurance capability review+on-site inspection or testing of product consistency)+supervision after certification (tracking inspection+sampling inspection at production site).

The type test shall be conducted by a qualified testing agency commissioned by the certification body. As of now, CCC has included a total of 185 type test projects and 164 standards based on them. Among them, there are nearly 7 destructive tests on the samples.

The supervision after obtaining the certificate shall be conducted at the customs port by the certification body in conjunction with the laboratory through non mass production verification ("two out of ten") and compliance verification ("one out of ten"). The "two out of ten" and "one out of ten" tests at the port involve a total of 22 experimental projects and are based on 21 standards.

2.2. Certification Process

The process of CCC certification for parallel imported cars basically includes several steps, such as CCC initial certification, VIN addition and COC printing, VIN return, customs declaration, port inspection, offline inspection, etc.

(1) CCC Initial Certification (Certification Body) - Issuing CCC Certificate

(2) Add VIN (Certification Authority) - Certificate Supplement Additional Information, Print COC Certificate

(3) Return VIN Information to Customs (General Administration of Customs) - Enter Vehicle VIN Information into Customs System

(4) Customs declaration (port customs) - issuance of import certificate (customs declaration) for goods

(5) CCC certification verification (certification body) - tracking and supervision (one out of ten, two out of ten)

3. Application Scheme of 2CAE Technology in Parallel Import Vehicle Certification

CAE, Computer Aided Engineering, is the process of using computer software modeling to analyze and evaluate the performance of a vehicle or vehicle system. It can simulate various testing schemes to reduce testing time and costs. At present, more and more automobile manufacturers are incorporating CAE result indicators into supplier product management, and CAE is also involved in E-NCAP and C-NCAP. With the rapid development of technology in the automotive industry, there is also a space for imagination and research to replace some real vehicle inspections with CAE.

As the consumer end of traditional foreign automobile manufacturing enterprises, parallel import automobile enterprises find it almost impossible to obtain inputs such as the vehicle collision acceleration waveform required for CAE. Therefore, this article's exploration of certification technology requires a widely applicable vehicle acceleration simplification method to promote the use of CAE technology in parallel import automobile certification. Considering the universality of technology, this article only explores and studies representative frontal collisions in type tests.

3.1. Equivalent simplification method for vehicle acceleration

In a frontal collision of a vehicle, the acceleration of the vehicle body is one of the important factors affecting passenger injury and also a key input for collision testing. But firstly, the high-frequency oscillation of its waveform curve makes it difficult to directly study its relationship with passenger injury. Secondly, such materials are confidential information of automotive companies, and it is almost impossible for parallel imported car companies to obtain them. So we need a widely applicable acceleration waveform input.

This article is based on a large number of real vehicle collision acceleration waveforms, combined with real vehicle collision test videos for in-depth research and analysis, to find the common

characteristics of the vehicle acceleration waveform during the collision process. By studying the transmission path of force, key points in the waveform are extracted, and the vehicle acceleration waveform is divided into five stages. According to the principle of equal acceleration integration, the waveforms of each stage are linearized, and an equivalent simplification method for acceleration waveform is obtained. And the damage differences of the dummy before and after the acceleration waveform simplification were compared and analyzed through finite element model simulation analysis and pulley collision test to verify the suitability of this method.

The analysis results show that the dynamic response and damage characteristics of the dummy before and after the simplified acceleration waveform are basically the same, indicating that this simplified waveform can be used as input for collision tests.

3.2. Transmission path of force in frontal collision

Based on in-depth research and analysis of the acceleration waveforms and collision test recordings of 30 frontal 100% overlapping rigid barrier collision tests, we found that during the frontal collision process of the vehicle, the transmission path of the impact force is generally: front panel bumper energy absorption box longitudinal beam and vehicle body, as shown in Figure 1.

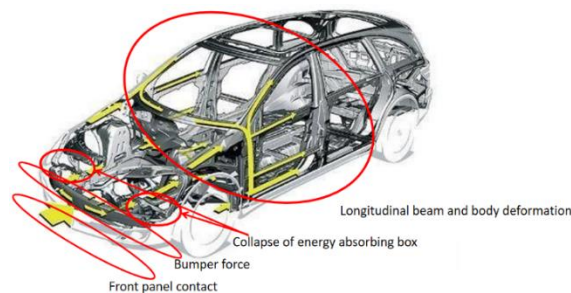


Figure 1. Schematic diagram of the transmission path of collision impact force

(1) Front panel contact. At the beginning of the collision, the front end of the vehicle comes into contact with a rigid barrier, causing deformation of the body skin. The acceleration of the body shows slight fluctuations around 0 g. The vehicle speed remains largely unchanged, and the collision kinetic energy is not consumed.

(2) The bumper is under force. The bumper begins to exert force, the vehicle's acceleration begins to rapidly increase, and the vehicle's speed begins to decrease.

(3) The energy absorbing box collapsed. The front energy absorbing box of the vehicle deforms and collapses, absorbing the impact energy of the vehicle. The body acceleration shows a relatively stable fluctuation state, which lasts for a period of time, and the vehicle's speed continues to decrease.

(4) Deformation of longitudinal beams and body. The longitudinal beam of the vehicle begins to deform, and the acceleration of the vehicle body shows a significant upward trend. At this stage, the vehicle speed will sharply decrease. At this point, the passenger compartment (firewall) begins to deform due to engine compression.

3.3. Equivalent simplification of acceleration waveform

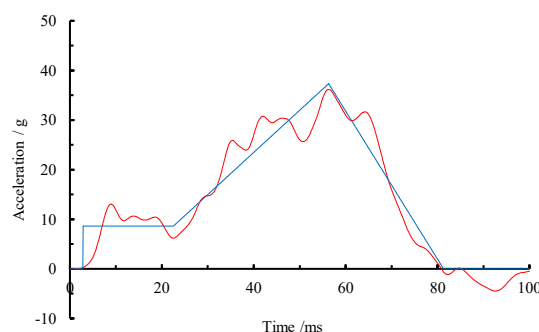


Figure 2. Equivalent Simplified Results of Vehicle Acceleration Waveform

Referring to the transmission process of force path during vehicle collision, we divide the body acceleration waveform into 5 stages and simplify each stage equally based on the principle of equal acceleration integration. Taking the collision condition of a 100% overlapping rigid barrier on the front of a certain vehicle model as an example, the equivalent simplified acceleration waveform is shown in Figure 2.

(1) Front panel force stage (0-A): During this process, the body acceleration is approximately 0 g. In the simplification process, a horizontal line with $Y=0$ is used instead. The duration of this stage is calculated based on the rigid frontal collision deformation energy stiffness (K_{w400}) of the vehicle [7], with time 0 as the starting time and the time when the body displacement is 25 mm as the ending time. The expressions for the acceleration Acc_A and time T_A at the end point A are shown in equations (1) and (2):

$$\int_0^{T_A} V(t) dt = 0.025 \quad (1)$$

$$Acc_A = 0 \quad (2)$$

Among them, $V(t)$ is the actual vehicle speed.

(2) Bumper - Energy absorbing box force stage (A-B). Usually, the stiffness of the bumper is relatively high, and its contribution to energy consumption through deformation is minimal. Therefore, in the early stage of the bumper's stress stage, the vehicle's acceleration rapidly increases in a short period of time (A-A'). With the transmission of force from the bumper, the energy absorbing box begins to collapse, and the acceleration shows a stable fluctuation state with an approximate constant value, which lasts for a period of time. Therefore, the body acceleration waveform at this stage is replaced by a square wave. The starting time of the square wave is T_A , the ending time is T_B , and the square wave acceleration is Acc_B . The expressions for each parameter are shown in equation (3):

$$Acc_B \times (T_B - T_A) = \int_0^{T_B} a(t) dt \quad (3)$$

Among them: $a(t)$ is the actual vehicle acceleration, and T_B is the last trough moment of this stage. If the actual body acceleration waveform at this stage does not fluctuate significantly or is an approximate straight line, this moment is the moment of contact between the rigid barrier and the engine.

(3) Longitudinal beam stress stage (B-C). The energy absorption box collapsed completely, and the collision force reached the longitudinal beam. At the same time, the engine made contact with the firewall under the action of the collision force, causing the passenger compartment to be compressed and deformed. Due to the high stiffness of the longitudinal beam and engine, the acceleration of the vehicle body increased at a large slope and reached its peak at this stage. Therefore, a triangular wave was used to simulate the actual acceleration of the vehicle. The starting acceleration of the triangular wave was Acc_B , the starting time was T_B , the peak acceleration was Acc_C , and T_C was the moment when the actual acceleration waveform of the vehicle reached its peak. The expressions for the acceleration parameters of the triangular wave are shown in equation (4):

$$\frac{1}{2} \times (Acc_B + Acc_C) \times (T_C - T_B) = \int_{T_B}^{T_C} a(t) dt \quad (4)$$

(4) Longitudinal beam bending deformation stage (C-D). At this point, the longitudinal beam of the vehicle undergoes bending deformation, and the body acceleration decreases until it drops to 0 g. During this process, there may be a situation where the longitudinal beam stops collapsing and the acceleration is not 0 g. In this case, the deceleration rate of the acceleration curve significantly slows down and there is a small fluctuation, which can be seen as a clear turning point from the acceleration waveform. In the stage of longitudinal beam collapse and energy absorption, the acceleration of the vehicle decreases rapidly, so triangular waves are still used in this stage. The starting acceleration of the triangular wave is Acc_C , and the starting time is T_C . The simplified waveform parameter expressions are shown in equation (5).

$$\frac{1}{2} \times Acc_c \times (T_D - T_C) = \int_{T_n}^{T_D} a(t) dt \quad (5)$$

(5) Collision completion stage (D-E). In this stage, the acceleration of the vehicle fluctuates around 0 g and gradually approaches 0 g. Therefore, this stage can be simplified as a horizontal straight line with Y=0.

From the comparison before and after simplifying the acceleration waveform of the vehicle body, it can be seen that the trend of the simplified waveform is basically consistent with that of the original waveform. Among them, the peak value of the original acceleration waveform is 36.18 g, the peak value of the equivalent simplified acceleration waveform is 37.33 g, and the error is 3.2%. In addition, by integrating, the velocity and displacement of the simplified acceleration waveform can be obtained from the original waveform. The comparison results are shown in Figures 3 and 4. The error in vehicle speed before and after simplification is 0.3%, and the error in displacement is 1.0%.

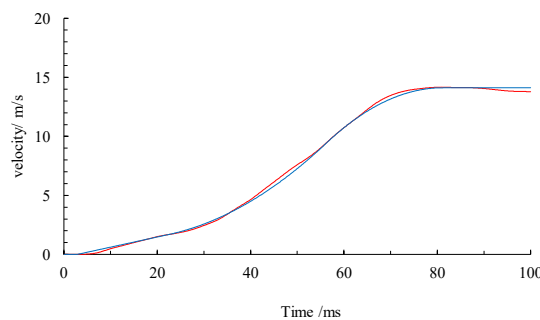


Figure 3. Speed comparison before and after simplified acceleration waveform

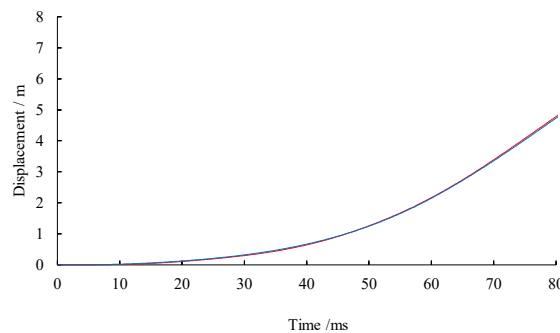


Figure 4. Comparison of displacement before and after simplification of acceleration waveform

4. Comparative analysis of dummy injuries in finite element model simulation

In order to verify the accuracy of the waveform simplification method, this article borrowed a certain domestic brand vehicle model to establish a finite element model of the constraint system for experimental simulation analysis. The finite element model of the constraint system is shown in Figure 5.

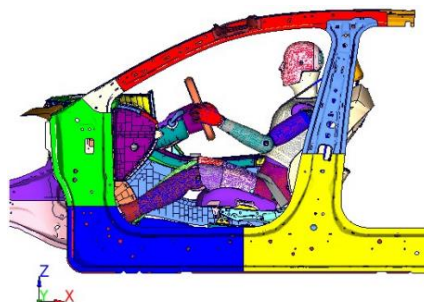
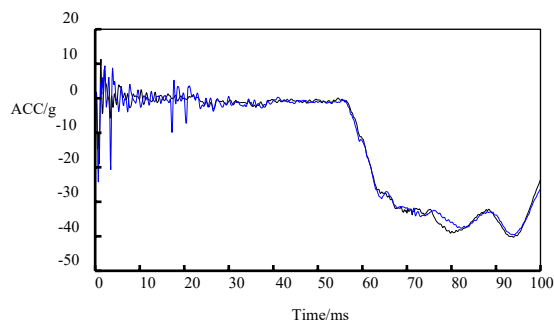


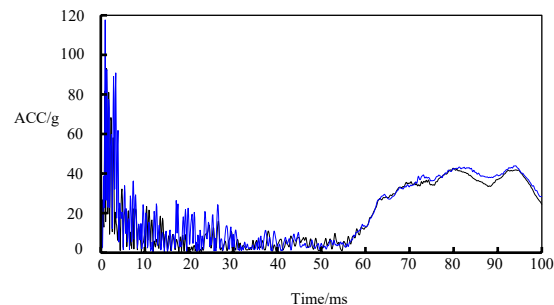
Figure 5. Finite element model of constraint system

This model is based on a calibrated finite element model of the entire vehicle collision. The front row constraint system is selected, and the component systems involved in the mechanical response in BIW are extracted for grid processing. The remaining parts are weighted with mass points. This model utilizes Hypermesh software for pre-processing, establishing meshes, materials, contacts, connections, and boundary constraints. LS-DYNA solver is used for calculation, and Hyperview is used for post-processing of the results. The airbag modeling adopts particle method, and the seat belt is established using finite element method. The dummy is the Hybrid III 50th percentile finite element dummy from OASYS company. The total number of grids in this model is about 2.11 million, and the input waveform curve is the body acceleration curve obtained from the 100% frontal rigid barrier collision test of the actual vehicle, which is applied to the finite element model body.

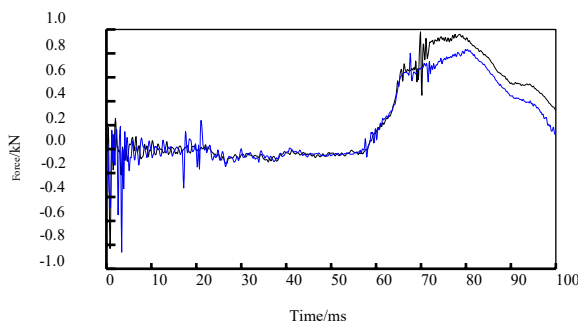
This article uses the finite element model to simulate the frontal 100% overlapping rigid barrier collision conditions under the two waveforms described in Figure 2, and compares and analyzes the damage situation of each part of the driver in the two calculation results. The comparison of the damage results of each part of the dummy is shown in Figure 6.



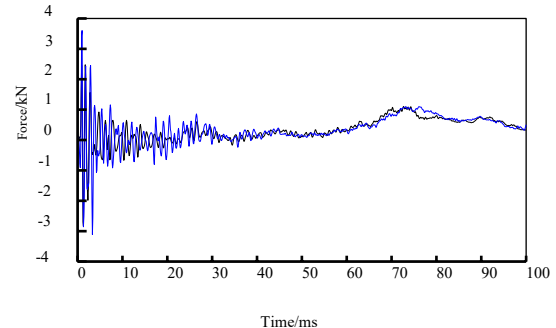
(a) Head X-acceleration



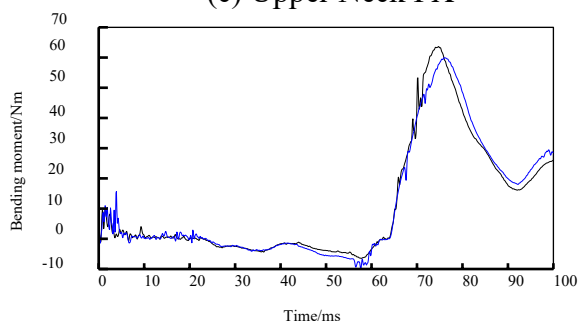
(b) Head Composite Acceleration



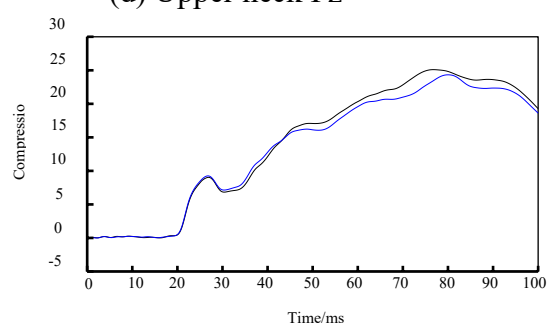
(c) Upper Neck FX



(d) Upper neck Fz



(e) Neck My



(f) Chest compression

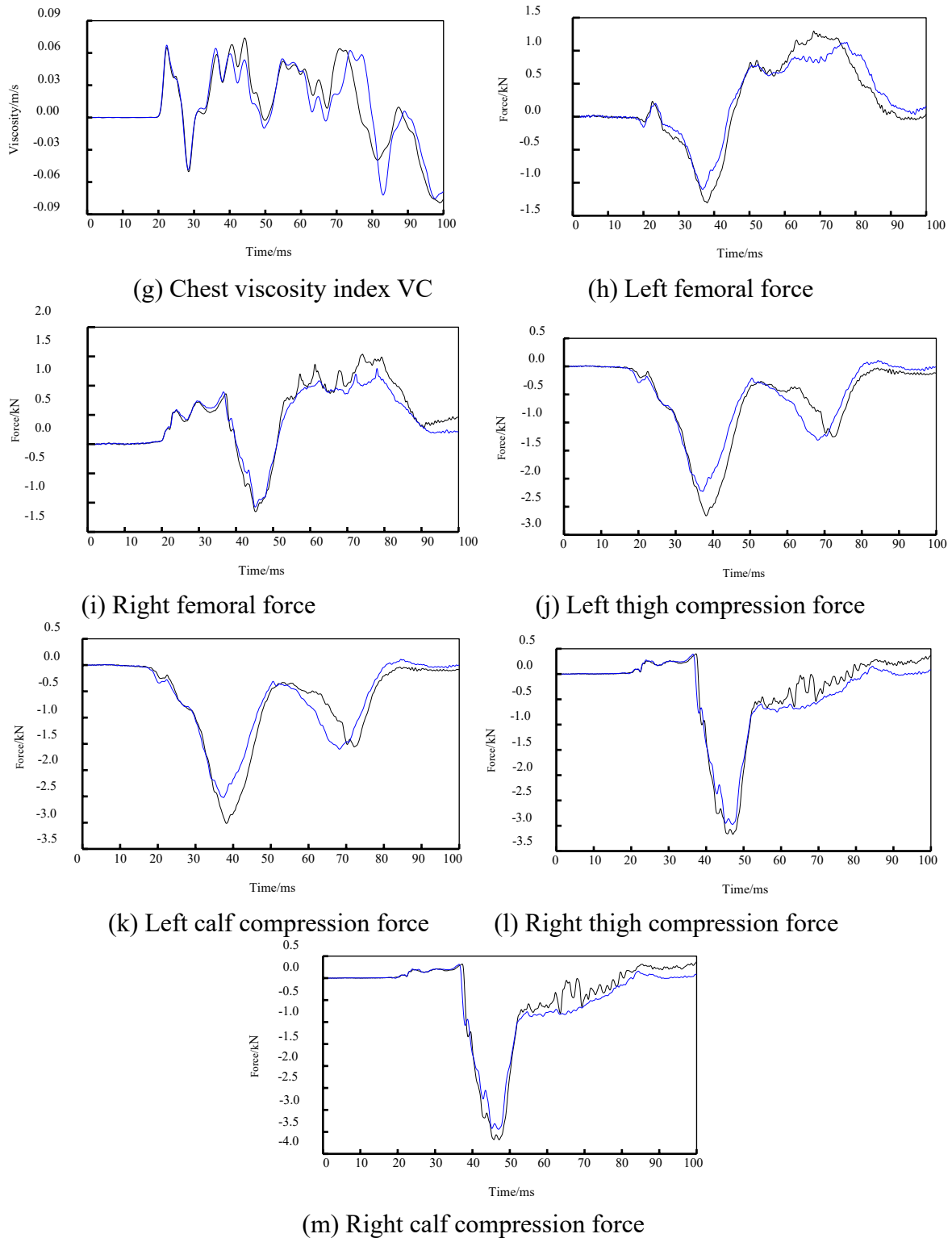


Figure 6. Comparison of Dummy Damage Simulation Results under Two Different Accelerations

At the same time, a comparative study was conducted on the dynamic response of the dummy model in the simulation results of the finite element model under two different accelerations, as shown in Figure 7. Among them, the red model represents the dynamic response of the dummy under the original acceleration waveform, and the blue model represents the dynamic response of the dummy under the equivalent simplified acceleration waveform.

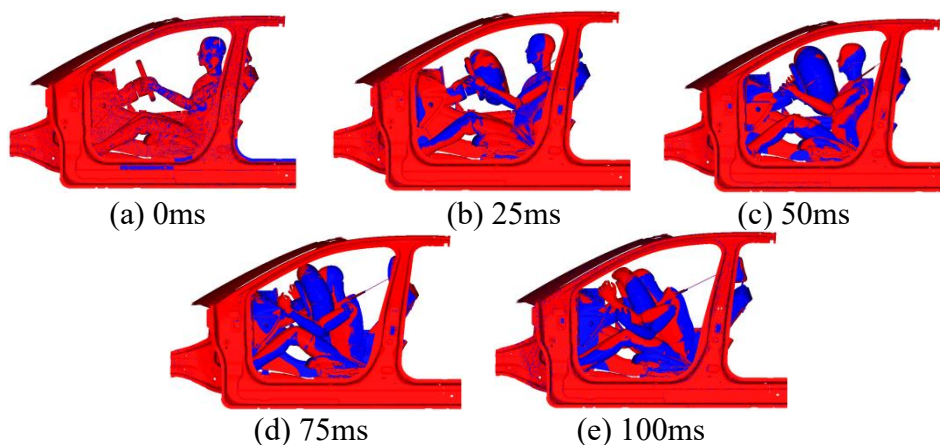


Figure 7. Comparison of Dynamic Response of Dummies under Two Different Accelerations

From Figure 6, it can be seen that under the two collision conditions before and after simplifying the acceleration waveform, the damage trend of each part of the dummy model is basically consistent, and the overlap rate is relatively high. Meanwhile, from the dynamic response diagram of the dummy model in Figure 7, it can also be seen that under the two accelerations, the dummy's motion posture during the collision process has a high degree of agreement. This indicates that the acceleration waveform obtained by the waveform simplification method proposed in this paper can better replace the actual vehicle acceleration waveform.

5. Conclusion

The rapid growth of the volume of imported cars in our country, the higher the degree of data exchange and sharing among regulatory departments and technical service agencies in the industry, the more it can promote the healthy development of the imported car industry.

In order to ensure the legality and compliance of registered vehicles, the Vehicle Management Office of the Traffic Management Bureau usually needs to verify the consistency of vehicles during the registration process, and eliminate social problems such as illegal modifications.

Domestically produced cars can undergo vehicle information verification through announcements and other channels, but parallel imported cars, as a non mass-produced vehicle, do not have announcement information available in China. Therefore, the filing parameters of CCC certification have become the main data reference for traffic management departments to verify the filing parameters of vehicles during vehicle registration and inspection. The update and improvement of certification technology not only save time and cost for enterprises, but also upgrade the informationization and systematization of data exchange and sharing between certification technology service agencies and government regulatory departments, which is a good practice of digitalization in political research cooperation.

According to verification, the simplified waveform test results can maintain good consistency with the original waveform test results, solving the obstacle that parallel import automobile enterprises cannot provide body collision waveforms as CAE inputs, and improving the possibility of introducing CAE into parallel import automobile certification. At the same time, this article explores the introduction of CAE certification technology, which provides new ideas for the development and regulation of the industry.

References

- [1] HUANG J, WANG J. The Occupant Injury Analysis of the Character From Acceleration Curves on Dummy during the Vehicle Crash Process [J]. AUTOMOTIVE TECHNOLOGY, 2010, (1): 30-34.
- [2] WANG F, ZHAO Q J, YUE Z Y, et al. Compatibility of car-to-car frontal crash based on full width deformable barrier test [J]. J Automotive Safety and Energy, 2015, 6 (1): 30-36.

- [3] YANG Y S, LIU Z X, WU Y Q, et al. Study on Vehicle Crash Dual-trapezoids Curve Construction Based on Characteristic Parameters Extraction [C]// The 14th International Forum of Automotive Traffic Safety, 2017.
- [4] WANG B, BAO W. Application of Equivalent Dual-trapezoidal Waveform Analysis Method in the Structure Optimization Design in Frontal Crash [D]. Automobile Science& Technology, 2013, (6): 49-55, 62.
- [5] MA Z X, ZHU X C. A Study on the Equivalent Dual-trapezoids Deceleration Curve Used in Sled Test for Frontal Crash Simulation [J]. Automotive Engineering, 2008, 30 (5): 411-415.
- [6] MA Z X, ZHU X C. An Analysis on the Sensitivity of Main Dummy Injury Criteria to Equivalent Dual-trapezoid Deceleration Curve [J]. Automotive Engineering, 2009, 31 (2): 166-169.