Parameters influence of windshield curvature on pedestrian head injuries based on reverse engineering

H G Zhao¹, H J Shi², C S Li³ and N Yang⁴,⁵

¹ Shandong Tianhong Judicial Expertise Center, Weihai, Shandong Province, 264209, China.
² Taizhou customs, Taizhou, Shandong Province, 318000, China.
³ Network Center, Harbin Institute of Technology, Weihai, Shandong Province, 264209, China.
⁴ School of Automotive Engineering, Harbin Institute of Technology, Weihai Shandong Province, 264209, China.
⁵ Automotive Engineering Research Institute, China Automotive Technology and Research Center Co.Ltd., Tianjin 300300, China.

*Corresponding author’s e-mail: ynhelen@126.com

Abstract. With the development of the automobile industry, the problems of traffic accidents has attracted more and more attention, and many countries are also attaching importance to pedestrian protection. In the collision process of vehicle and pedestrian, the head of pedestrian is very easy to collide with the engine cover and windshield of the car, which causes fatal damage. In this paper, the curvature of four kinds of automobile front windshields is studied by reverse engineering and simulation experiments. By using reverse engineering software to dispose the scanned point cloud data, a smooth surface is derived, and finite element software is used to establish the model of the pedestrian head impactor hitting the windscreen of the car, and finally the simulation processing is carried out. Simulation results show that Head Injury Criteria is positively correlated with the transverse curvature of the front windshield and negatively correlated with the longitudinal curvature.

1. Introduction

According to statistics, the collision between the head of pedestrian and the engine cover or windscreen is one of the main causes of pedestrian death in today's world traffic accidents[1]. In order to better protect pedestrian in accidents, the research on the collision performance of windscreen is significant to the pedestrian protection design in cars.

Reverse engineering is a kind of methods based on the available physical model, which could construct the concept of design and adjust reconstruction model characteristic parameters. The method can make full use of the various advantages of the technology of D/ACM, and finite element analysis, error analysis and a series of subsequent operations can be carried out on the model after this is constructed. The current development of reverse engineering has been more mature. Qi Xiuli studies the tracking algorithm, which uses simple curve to fit an unordered set of points on a plane[2]. Wang Chuantao, Yang Jianxi and others optimize NURBS method, and propose a method used to express the unity of the conic and free curve, and this method can be used to accurately describe the free curve.
surface and elementary curve surface in the same mathematical form[3]. In the model accuracy evaluation aspect, Jin Tao and others analyse various sources of error in reverse engineering, discuss how to control error, and advance the model accuracy evaluation method on this basis[4]. These researches provide technical support for the application of reverse engineering in various fields. In this paper, we collect the data of automobile windshield glass surface according to reverse engineering technology, so as to establish the finite element model of head impacting windshield glass and conduct simulation. The relationship between curvature and Head Injury Criteria (HIC) is obtained by analysing the simulation results.

2. Materials and method

2.1. Data collection of reverse engineering

Due to the complexity of the front windshield glass surface, in order to obtain a higher measurement speed and protect the glass surface from damage, the non-contact data acquisition method is adopted[5]. Based on the rapid contour vision measurement technology[6], the Tiandyuan 3d scanner was selected, which is shown in figure 1. By projecting grating on the surface of the windshield glass and shooting the distorted grating image with two cameras, the 3d contour of the windshield glass can be measured.

![Spatial digitizer](image1)
![Windscreen pre-treatment](image2)
![Calibration block](image3)

Figure 1. Spatial digitizer. Figure 2. Windscreen pre-treatment. Figure 3. Calibration block.

Before scanning, the windshield glass surface needs to be wiped clean and sprayed with the developer, and sprayed again after air drying. In this way, the front windshield glass surface presents a good diffuse reflection body, which can effectively improve the serious defects of the windshield glass reflection, make it easier to be scanned, and obtain high-quality point cloud data. Due to a large surface area of the front windshield glass, the data of the whole part cannot be measured at one time. The mark points can be posted and spliced together, as shown in figure 2. The image acquisition system consists of a CCD camera and an image acquisition card, which is used to complete data acquisition. Among them, camera calibration can achieve the calibration of the system by shooting images of calibration blocks at different positions, as shown in figure 3. With the help of a scanner, the windshield is scanned step by step and then stitched together to form a complete point cloud.

2.2. Point cloud processing

Point cloud is the data collected by 3d data collector, which can contain more comprehensive physical quantities, such as 3d coordinates, size and normal vector of discrete points. Due to a large amount of data contained, it is necessary to pre-process the point cloud data before starting to construct the surface. Redundant data can be reduced by means of de-noising, filtering[7,8], alignment and combination, and simplification, and effective information can also be retained[9].

The point cloud data, scanned by the scanner, is imported into Geomagic Studio, as shown in figure 4. The external solitary point is deleted, as shown in figure 5. After filtration, the deviation can be seen, and the point cloud deviation can also be seen through the colour. The curvature priority is set as the middle. When noise points are reduced, the parameter is free-form surface shape and the smoothness is adjusted to the size of the difference. Due to the vibration during scanning, some point cloud data has large errors (yellow part in figure 6). During processing, the point cloud data in yellow part is deleted in figure 6. The places with poor quality of triangular mesh of surface are selected and deleted, and the
empty places are completed by filling function, in order to complete the mesh of point cloud, as shown in figure 7. After optimization of edges, relaxation, creation of popularity and simplification, surface pieces are generated in the module of accurate surface, which are used to form the surface. After adjustment, the surface consists of 16×8 surface pieces, as shown in figure 8. The surface, after being fitted and merged, is shown in figure 9, and the surface is saved as an IGES file finally.

![Figure 4. Point cloud.](image1)

![Figure 5. Single point selected.](image2)

![Figure 6. Checking the deviation.](image3)

![Figure 7. Mesh surface.](image4)

![Figure 8. The surface after the surface pieces adjusted.](image5)

![Figure 9. Fitted surface.](image6)

2.3. Building finite element model

2.3.1. Establishment of finite element model of windscreen. Without considering the laminated glass composition efficiency, this paper establishes the overall model of the two-layer shell element, in order to simulate the windscreen through the equivalent method. This model is connected by the shell element with the same thickness and density[10]. In the equivalent model, the upper shell element can be used to simulate the brittle failure of the glass. When the upper shell element fails, the lower shell element can represent the PVB layer of the original windshield glass and the glass layer on the compressed side, and this shell element will not fail. The material of selected glass layer is No. 24, and that of PVB layer is No. 123, both of which are elastoplastic, as shown in table 1.

![Table 1. Equivalent laminated glass parameters.](image7)

Finally, the boundary constraint of the windscreen finite element model is created to make the model boundary fixed.

2.3.2. Establishment of the model of pedestrian head impactor hitting windscreen in automobile. The head impactor is introduced into the finite element model of windscreen, and the relative position is adjusted to give the impactor a certain speed. Then the gravity is applied to the whole model to simulate the real situation. Since the glasses and PVB layer are connected together, the bonding properties are applied to the model. Finally, the head impactor is not set to pass through the windscreen when the
former hits the latter. The established finite element model of four pedestrian head impactors hitting the windshield glass of the car is shown in figure 10.

![Figure 10. Pedestrian head impactor hits the windscreen model of car.](image)

3. Result

The established finite element model is imported into LsDyna, and the simulation results are obtained through calculation. The calculations are viewed with HyperGragh.

The acceleration curve of the model can be easily obtained, and then the value of acceleration can be converted into the value of HIC by software. The acceleration curve of surface 1 is shown in figure 11.

![Figure 11. Acceleration - time curve of the impactor on impact in surface 1.](image)

CATIA was used to obtain the curvature of transverse and longitudinal interface curves at the impact points of four surfaces. The curvatures of surface 1 are shown in figure 12 and figure 13.

![Figure 12. Section curvature curve of longitudinal impact point in surface 1.](image)

![Figure 13. Section curvature curve of transverse impact point in surface 1.](image)

The corresponding values of curvature and HIC are shown in table 2.
Table 2. Corresponding values of curvature and HIC.

| Surfaces       | Surface 1 | Surface 2 | Surface 3 | Surface 4 |
|----------------|-----------|-----------|-----------|-----------|
| Transverse curvature (mm⁻¹) | 670.539   | 761.427   | 621.755   | 706.174   |
| Longitudinal curvature (mm⁻¹) | 436.456   | 392.735   | 467.718   | 439.837   |
| HIC             | 2481.66   | 2686.92   | 2217.13   | 2465.04   |

The measured curvature value and the HIC value obtained from the simulation experiment are put into Excel to make the scatter diagram. The relationship between HIC and curvature is shown in figure 14 and figure 15.

![Figure 14](image1.png)  ![Figure 15](image2.png)

Figure 14. Relationship between transverse curvature and HIC.
Figure 15. Relationship between longitudinal curvature and HIC.

It can be seen from the chart analysis that HIC is positively correlated with transverse curvature and negatively correlated with longitudinal curvature.

4. Conclusion
In today's traffic accidents, it is one of the important causes of pedestrian’s injury and even death that pedestrian’s head hits the windscreen of car. In this paper, the principle of reverse engineering is used to collect data on the surface of automobile windshield glass to obtain the fitting surfaces, and then a finite element model is built in Hypermesh for simulation and analysis, so as to obtain the images of curvature and HIC. By analysing the scatter diagram obtained from HIC values and curvatures, it can be seen that HIC is positively correlated with transverse curvature and negatively correlated with longitudinal curvature. According to the results of the current research, the transverse curvature can be reduced and the longitudinal curvature can be increased in the manufacturing process of windshield glass, so as to reduce the head damage caused by windshield glass.

References
[1] Zang, M.Y., Song, Z.L., Yang, Z.G. (2014) Finite element model of windshield glass for pedestrian protection analysis. Journal of south China university of technology, 42(04): 143-148.
[2] Qi, X.L. (2007) Research on tracking algorithm of curve reconstruction. Journal of huaihua university, 03: 19-21.
[3] Wang, C.T., Yang, J.X., Zhang, L.P., Su, C.T. (2009) NURBS surface reconstruction technique in reverse engineering. Journal of He’nan university of science and technology, 30(02): 19-21+110.
[4] Jin, T., Kuang, J.Y. (2001) Precision evaluation of inverse product model. Mechanical engineering, 02: 3-4.
[5] Wu, J.C. (2010) Key steps and key techniques of reverse engineering. Scientific and technological information, 09: 512-518.
[6] Sun, C.K., Ye,S.H. (2001) Laser measurement technology. Tianjin University Press, Tianjin.
[7] Shi, F.Z. (2001) Computer-aided geometric design and non-uniform rational b-spline. Higher Education Press, Beijing.

[8] Xie, W.S., Meng, G.F. (2005) Curve reconstruction based on filtering and smoothing. Journal of Tianjin university, 07: 654-658.

[9] Hu, X., Xi, J.T., Jin, Y. (2004) Reverse engineering scattered point cloud data automatic segmentation and surface reconstruction. Journal of Shanghai jiaotong university, 01: 62-65.

[10] Liu, Q., Liu, J.Y., Miao, Q. (2011) Simulation and experimental verification of damper glass under impact load of pedestrian head. Journal of automotive safety and energy conservation, 2(02): 128-133.