Structural Modelling and Validation of Typical Sedan Used for Pedestrian Injury Analysis in Accidents

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I. INTRODUCTION

Vehicle mathematical models have been set up using different software [1-2]. The computing efficiency of the Finite Element (FE) model is much poorer than that of a multi-rigid model. An ellipsoid model is less precise than a facet model in the description of the vehicle surface. At the aspect of contact characteristic modelling, the contact force under the stress-strain mode depends on both penetration and contact area, considering the shape of the contact surface, which is more accurate than that of force-penetration mode, which simply depends on the maximum penetration.

The aim of this study was to set up a more precise sedan model with the facet surface and contact characteristics of stress-strain mode, and with a force-penetration relationship that was converted to a stress-strain relationship using the mechanical equations and simulations. The vehicle model would be used for pedestrian injury analysis in accidents.

II. METHODS

The vehicle geometry model was set up according to the FE model released by the National Crash Analysis Center (NCAC) of United States. And the surface of the FE model was extracted and re-meshed. Only the frontal parts were kept, to reduce the total amount of meshes and in order to improve the computing efficiency. The frontal parts include the bumper, hood-edge, hood and windshield. Because the stiffness of different locations of the windshield varies, according to a previous study [3], the windshield was subdivided into four regions (Fig.1).

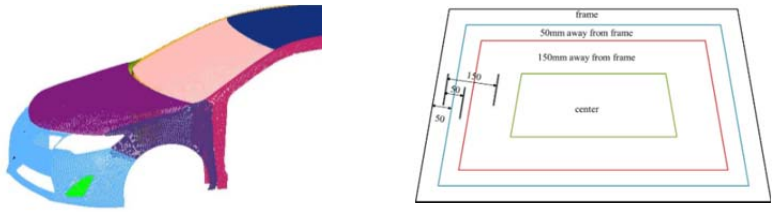

Fig.1. Geometry model of sedan and windshield subdivision

Force Model Converting

In order to obtain the contact characteristics in the form of stress-strain relationships, the force-penetration relationship obtained from the impact tests need to be converted. The conversion method could be explained and summarized by the simple contact model flow chart in Fig. 2. First, a simple contact model involving a facet ball and a facet plate was set up without defining the contact characteristics. The thickness of the facet plate was set to 1, that is L=1. Then, the relationship of contact area (A) and penetration (ΔL) could be obtained by conducting an impact simulation of this model. Together with the mechanical equations,$\sigma = F/A, \varepsilon = \Delta L/L$, the relationship of stress-strain could be derived in the form of the $\sigma - \varepsilon$ curve, which was then used as an input in the simulation to output the force-penetration curve 2. Finally, curve 2 was compared with curve 1 to judge if the simulation results accorded with curve 1, which was original test data. If the result was rejected, the $\sigma - \varepsilon$ curve would be adjusted based on the difference between curve 1 and curve 2. In this study, the contact characteristics of bumper, hood-edge, hood and windshield with the stress-strain mode were obtained by this method, as is shown in Fig.2.

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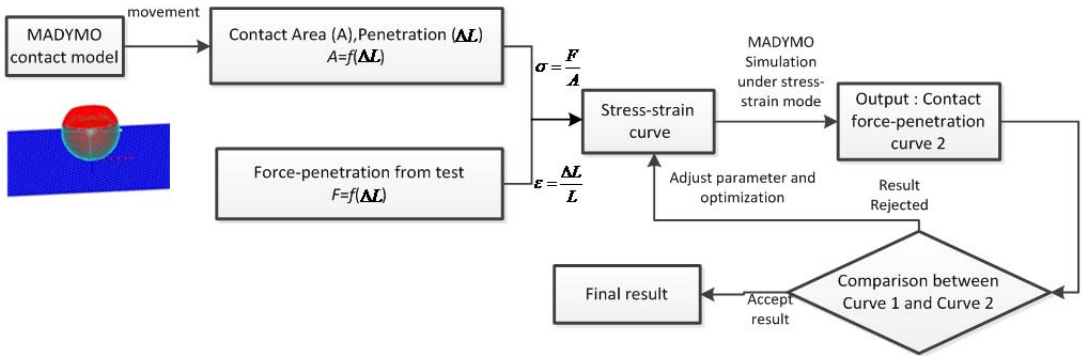

Fig. 2. Flow chart of converting force mode.

III. INITIAL FINDINGS

Based on the method introduced above, the contact characteristics for each part of the sedan front-end were converted from the force-penetration mode to the stress-strain mode. All the validations were based on the EEVC requirements [4] and all the force-penetration of the test curves were also cited from reference [3][5]. Fig.3 shows the validation results of each part of the sedan's front-end. Finally the sedan model with the facet surface and more precise contact characteristics was obtained.

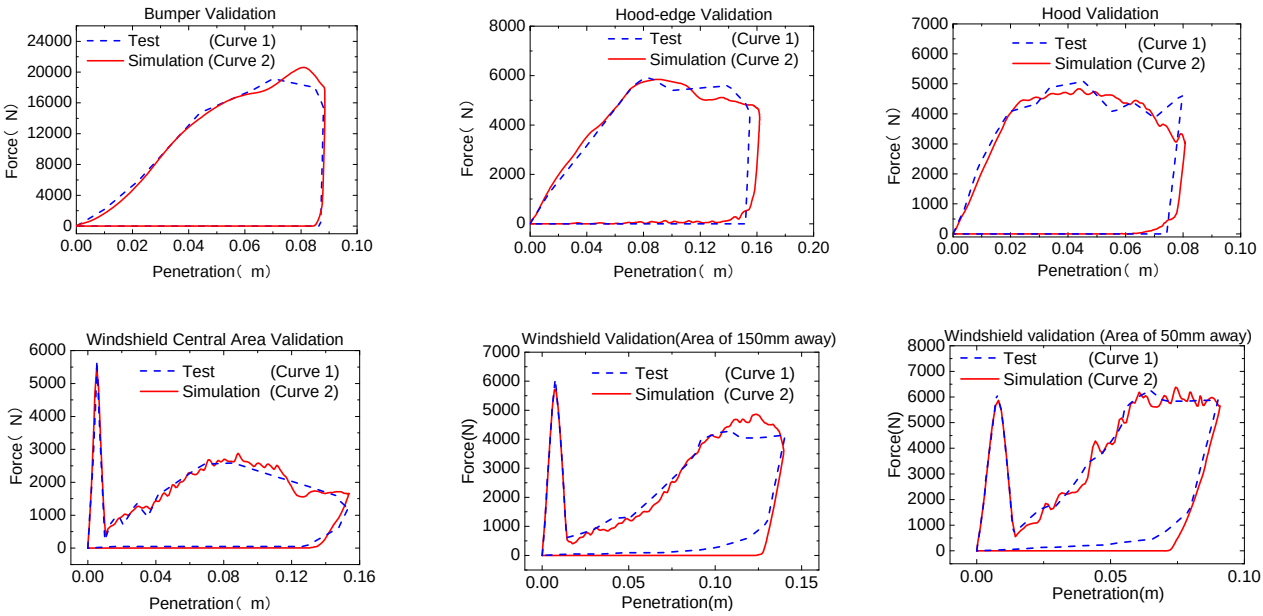

Fig.3. Force-penetration response of each part of sedan's front-end.

IV. DISCUSSION

The method was proven to be useful in converting the contact characteristic mode, with the aim of improving the contact force calculation, considering both the area of contact surface and penetration. While, the contact characteristic of the windshield area is different from other parts, it will crack after the initial impact load, generating the first peak of contact force. As the impact load continues, the cracked glass and the connecting layer continue sustaining the subsequent load. Thus, in this study the two different phases were considered separately using the combined contact mode. In the first phase, the force-penetration mode was adopted, and in the second phase the stress-strain mode was used. By this means, the validation results of each part of the windshield were as good as the others. Finally the precise sedan model could be used for pedestrian injury analysis in accidents. Due to the limitation of the European Enhanced Vehicle-Safety Committee (EEVC) test data, the large deformation should be avoided in the future simulation of this model.

V. REFERENCES

[1] Bourdet N. et al., Int J Crash,2013. [2] Untaroiu C.D. et al., Safety Science,2010. [3] Van Rooij L et al., ESV, 2003. [4] EEVC Committee, EEVC Working Group 17 Report, 1998. [5] Yang J. et al., Technical report, 2007.