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Study on the doortrim intrusion velocity based on occupant injuries of side impact

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ABSTRACT

In the side vehicle impact, the door intrusion velocity, the door trim panel, the side restraint system and the side living space determined the damage of the dummy. Thus, the door intrusion velocity was closely related to not only the vehicle impact crashworthiness but also the dummy injury in the side impact. Based on the analysis of the movement process of the door during the side impact and the simplification of the door intrusion velocity, the door velocity can be simplified as the acceleration process, the deceleration process and steady process. Then, the timing sequence between the door trim velocity and occupant injury was studied. Afterword, a restraint system simulation model of side impact was established using the MADYMO soft. The sensitivity of the relation between the door trim velocity and the occupant injury was analyzed and it showed that the acceleration process of the door velocity had the most significant effect on the occupant injury.

KEYWORDS

Side impact; Door intrusion; Velocity simplification; Dummy Injury; MADYMO.

INTRODUCTION

The human chest, abdomen and pelvis are the main parts that resulted in fatal or serious injury to the dummy in the side impact. The main factors influencing the occupant safety are the side body structure, the door trim panel, the side restraint system and the living space[1,2,8]. The side body structure determined the intrusion velocity and intrusion displacement of the door trim which had direct contact with the occupant during the side impact and the door intrusion velocity, the door trim panel, the side restraint system and the side living space determined the damage of the dummy[3,9]. In the side impact test, the main contact between the door and dummy was the door trim which had three aspects resulting in the dummy injury: shape, stiffness and movement. However, for the deformation of each door region in the side impact was very different, the intrusion velocity and intrusion displacement of the door trim differed greatly in every contact region. Thus it can be seen that the door intrusion velocity was closely related to not only the vehicle impact crashworthiness but also the dummy injury in the side impact[4,5,6].

Based on the analysis on the door intrusion velocity waveform, the waveform characteristics were extracted and the velocity waveform was simplified. Finally, the restraint system model of side impact was established and the sensitivity of relevant parameters was analyzed in view of the research on the relationship between the door speed waveform and dummy injury through the video and test curves.

ANALYSIS ON THE WAVEFORM CHARACTERISTICS OF THE DOOR INTRUSION VELOCITY

Through a large amount of real vehicle side impact test data, it can be shown that the door velocity waveform corresponding with the middle rib of side ES-Π 50% dummy was as shown in fig.(1)[7]. Taken the beginning of the side impact as the starting point, the whole side impact process could be divided into 3 stages: AB,BC,CD.

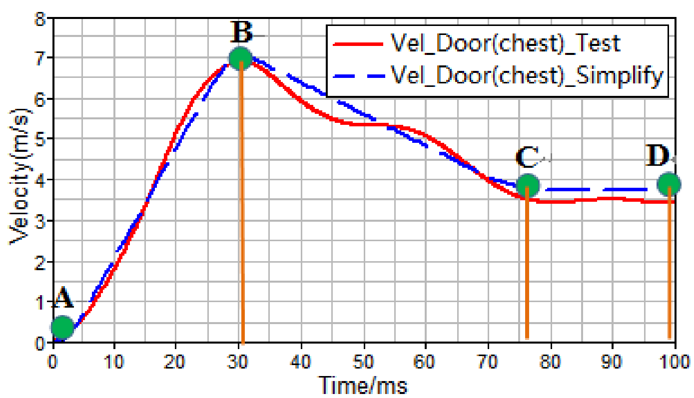


Fig. (1). The intrusion velocity of the door

1) AB stage: MDB (moving deformable barrier) came into contact with the door at point A. The door panel was accelerated under the impact of MDB, while the outer door panel began to buckle from the extrusion of MDB until the door velocity reached a maximum (point B). The door trim came into contact with the seat or/and dummy in the vicinity of point B.

2) BC stage: The door velocity began to decline after point B. In this process of BC stage, the door panels were still being squeezed by the effect of MDB, dummy and seat. The door velocity dropped to the lowest value at point C, at the same time, the intrusion displacement of the door panel reached its maximum.

3) CD stage: After point C, the door panels were no longer squeezed and the outer and inner door panels moved together with the vehicle body, so their velocity remained unchanged (such as CD stage). Meantime it showed that the door had already pushed the dummy away and it would no longer do any harm to the dummy through lots of vehicle impact test data. At last, the velocity of the whole test system (including the test vehicle, the dummy, MDB) was reduced to zero under the ground damping.

Through the above analysis the process of the entire side impact could be divided into three phases, namely: AB stage was the initial acceleration process of the impact; BC stage was the door deceleration process; after point C, the dummy was pushed away then the whole side impact was over. Therefore, in order to analyze the relationship between the door intrusion velocity and the dummy injury, the door velocity was simplified to three segments (A-B-C-D) as shown in fig.(1). In the simplifying process, it should be noted at that: (1) the door displacement should remain consistent before and after simplifying the curve, as shown in fig.(2); (2) it needed to consider the effect of the slope of AB and BC segment. Overall, the simplified curve should reproduce the door intrusion velocity and displacement of the vehicle side impact test, and then it could be used for the following study.

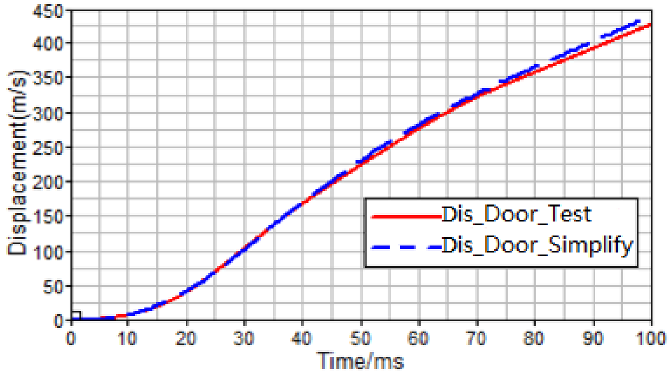
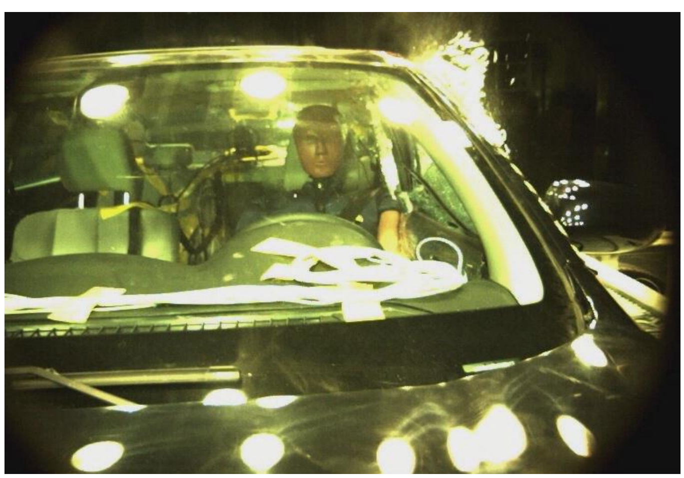


Fig. (2). The intrusion displacement of the door

ANALYSIS ON THE DUMMY INJURY AND THE DOOR INTRUSION TIMING

For a more detailed understanding of the relationship between the generation process of dummy injury and the movement of the door, the injury curves in different parts of the dummy were compared with the velocity curves that were picked up in various parts of the door trim corresponding to the dummy. The dummy injuries included up, middle and lower rib displacement (URD, MRD, LRD), abdomen force (ABF), backplate force (BPF), pelvis force (PF) and T12 force and moment (T12F, T12M).

(a) 30ms



(b) 68ms

Fig. (3). The movement response of the dummy in the side impact test

From the image analysis from the high-speed camera in the front of the vehicle, it could be seen that MDB came into contact with the door at the moment of 0 ms(corresponding to point A of the door intrusion velocity curve), meanwhile the door began to accelerate (corresponding to AB stage of the door intrusion velocity curve); at 30 ms or so (corresponding to point B of the door intrusion velocity curve), the door trim came into push the dummy movement; From the high-speed video, it also could be known that the impact the door trim dashed against the dummy mainly focused on the period from 29 ms to 76 ms (corresponding to AB stage of the door intrusion velocity curve) and the dummy was pushed away at the time of 68ms. Then the whole impact was almost over.

As shown in fig.(4), taken the dummy rib injury as an example, the door began to come into contact with the dummy ribs at the time of TB'(31ms) and the ribs was accelerated for the door's intrusion, also the rib deformation was increased quickly. Until the moment of TC' (50ms) that the rib had the same velocity as the door, the dummy rib deformation reached the maximum. Then the dummy began to separate from the door and its rib deformation started to fall down.

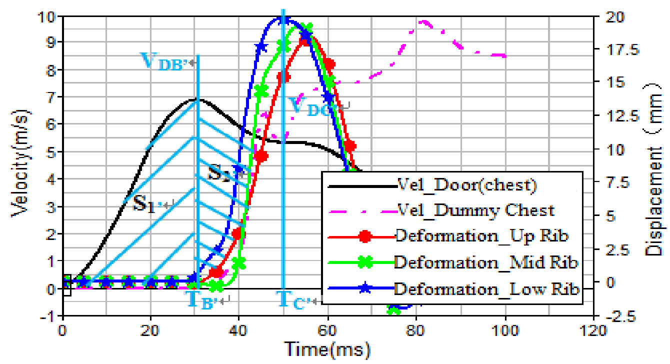


Fig. (4). The curves of dummy ribs deformation and door (chest) velocity

It were the corresponding relations between the door intrusion velocity and the other parts injury curves of the dummy as shown in fig.(5) to fig.(7). It could be known that the starting time of the dummy injuries basically concentrated at the moment that the door intrusion velocity was at the most (point B), and the peak value of the dummy injury always occurred when the dummy reached the same velocity as the door. Basically, the dummy injuries were concentrated in the decelerating stage (BC). But the initial time of the pelvis injury appeared in the accelerating stage of the door intrusion velocity (AB), which was due to the some thickness energy-absorbing foam block in the position of the door corresponding to the dummy pelvis that made the contact between the door trim and the dummy pelvis ahead. Anyway the max the pelvis force still occurred in the BC stage.

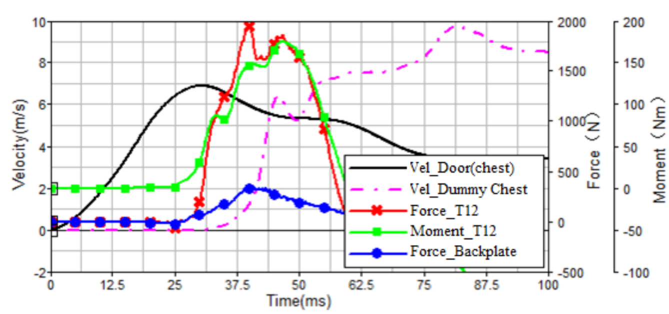


Fig. (5). The curves of dummy injuries and door (chest) velocity

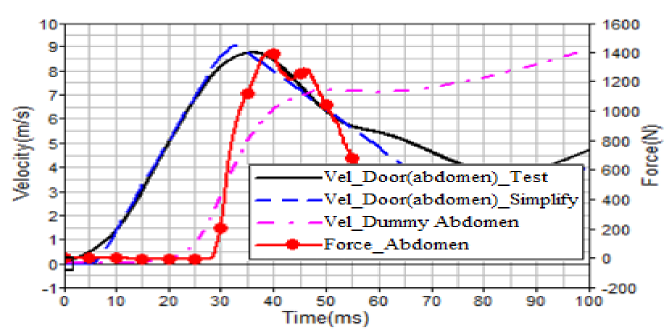


Fig. (6). The curves of dummy injuries and door (abdomen) velocity

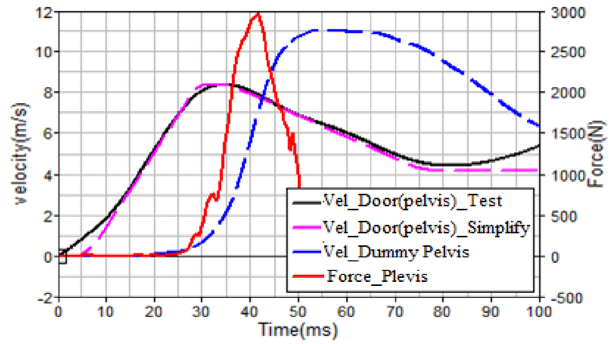


Fig. (7). The curves of dummy injuries and door (pelvis) velocity

Besides, as shown in fig.(3), S_1 that integrated the door intrusion velocity curve from the initial time to the time TB represented the door's deformation under the impact of MDB and was equal to the living space between the door trim and the left of the occupant, so it determined the initial contact time between them. S_2 stood for the shaded area under the curve that was calculated by subtracting the dummy velocity curve from the door intrusion velocity curve. S_2 decided the amount of the door's intrusion into the dummy and directly dictated the extent of the dummy injury.

STUDY ON THE EFFECT OF THE DOOR INTRUSION VELOCITY ON THE DUMMY INJURIES

In order to analyze the effect of the door intrusion velocity on the dummy injury, the restraint system simulation model of the side impact was established in MADYMO software as shown in fig.(8). The model was validated with the real vehicle impact test data for the following study[10].

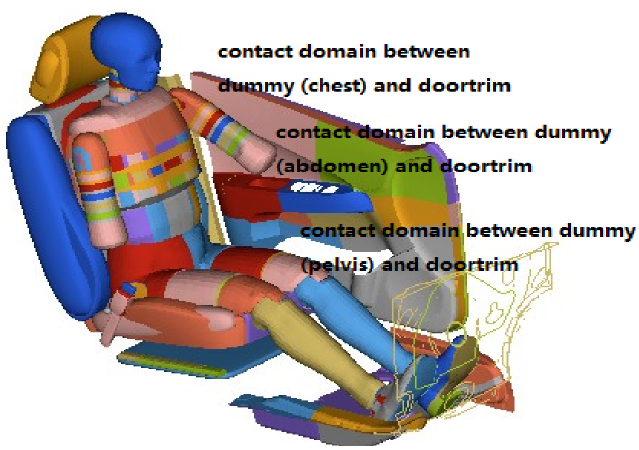


Fig. (8). The restraint system simulation model of the side impact

After simplifying the door intrusion velocity, the complex velocity curve in the real vehicle impact can be represented by several characteristic parameters, and thus the parameterization of the vehicle movement could be realized. The simplified door intrusion velocity can be replaced by the parameterized acceleration curve, as shown in fig.(9), in which A_1 denoted the slope of the accelerating stage of the door velocity and A_2 denoted the slope of decelerating stage.

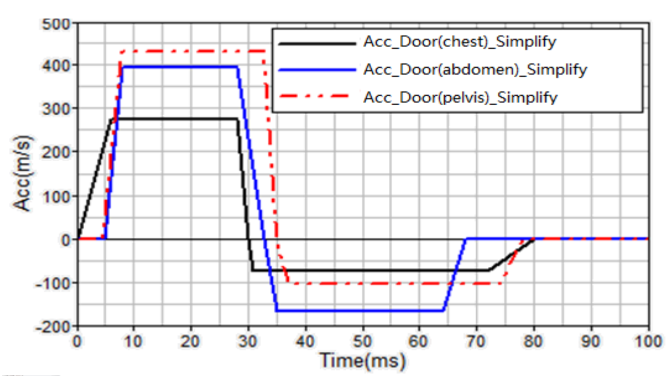


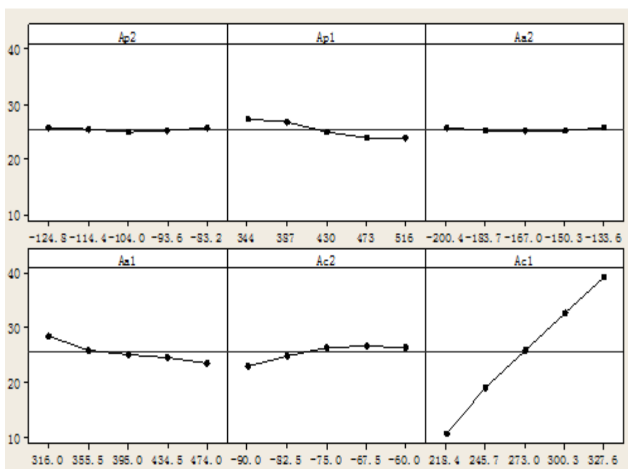
Fig. (9). the simplified acceleration curves of the door

Therefore, in this paper the design variables included: the accelerations at the positions of the door corresponding to the dummy chest, abdomen and pelvis(A_{c1},A_{c2},A_{a1},A_{a2},A_{p1},A_{p2}). The range and level of every design variable was as shown in table1.

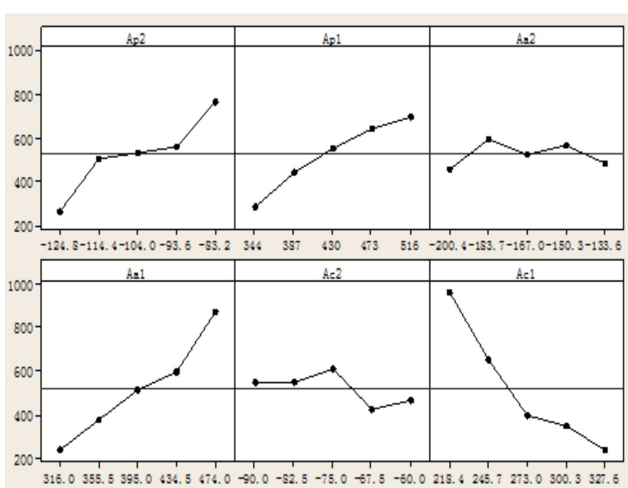
Table 1. the range of the design variables

	Name	Initial value	Parameter range	Levels
Design variables	A_{p2}	-104	-10%~+10%	5
	A_{p1}	430	-10%~+10%	5
	A_{a2}	-167	-10%~+10%	5
	A_{a1}	395	-10%~+10%	5
	A_{c2}	-75	-10%~+10%	5
	A_{c1}	273	-10%~+10%	5

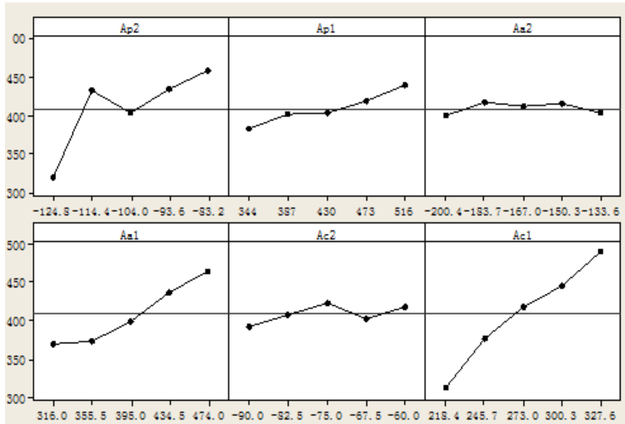
In this paper, taken the occupant injury criteria of side impact required in the version of CNCAP-2012 as the target, so the responses mainly included the up, middle & lower rib displacement, abdomen force, backplate force, pelvis force and T12 force& moment. As shown in fig.(10), it was the main effect diagrams of the dummy injuries. As can be seen from the figure, (1) the major effect factor in the dummy rib deformation was the A_{c1} in the position of the door corresponding to the dummy chest and the other factors looked negative effects; (2) A_{c1},A_{a1} and A_{p1} were the main effect factors affecting the force and moment of T12 and their correlative degree with T12 injuries was A_{c1}>A_{a1}>A_{p1} ;(3) For the backplate force the Ac1 was the main effect factors and For the abdomen force the Aa1 was the main effect factors; (4) for the pelvis force, the Ac1 was the greatest effect factor, followed by the A_{p1}.



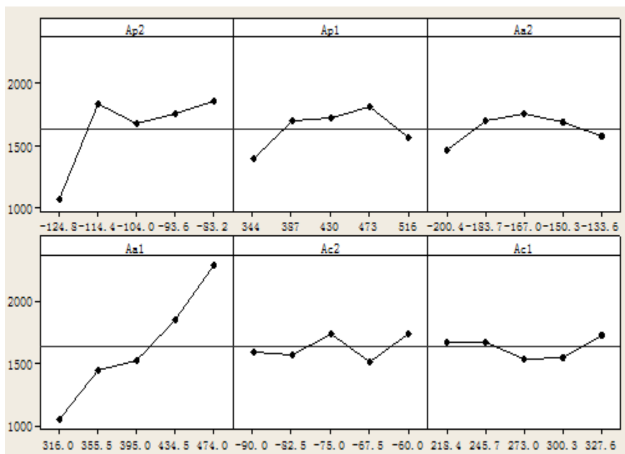
(a) Rib Deformation



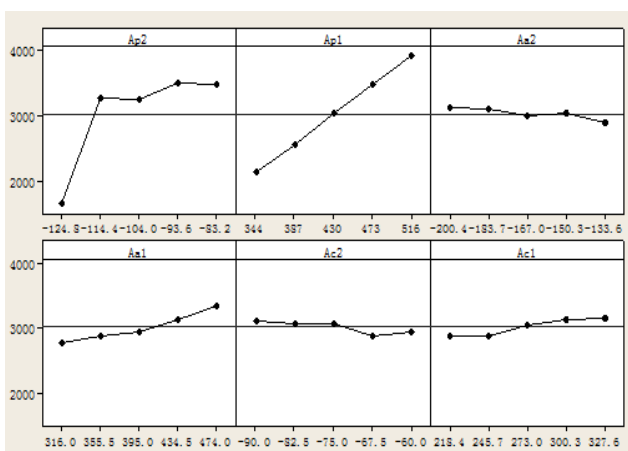
(b) T12



(c) Backplate



(d) Abdomen



(e) Pelvis

Fig. (10). the main effect diagram of dummy injuries

CONCLUSIONS

In this paper, the velocity waveform of three parts in the door corresponding to the dummy chest, abdomen and pelvis was analyzed and simplified and it could be simplified as the accelerating stage, the decelerating stage and constant stage. And generally the door intrusion velocity had a direct impact on the dummy injury only in the accelerating and decelerating stages. The sensitivities of the characteristic parameters of the simplified velocity waveform were analyzed, so it found that the slope of the accelerating stage of the door intrusion velocity had the significant effect on the dummy injuries. Through analyzing the simulation data, the mainly possible causes could be: (1) the accelerating stage (AB stage) of the door intrusion velocity had a great influence on the initial time (TB') of the contact between door trim and dummy while the initial contact time usually occurred near the position (B point) of the door intrusion maximum speed. Thus, the change of the slope of the accelerating stage (AB stage) would bring about the tremendous variation of the contact velocity ($V_{db'}$); (2) the change of the slope of AB stage may also lead to the great difference of the relative intrusion displacement between the door and the dummy (s_1); (3) during the side impact, since the movements of the dummy chest, abdomen and pelvis were pathologically influence each other, it was found that there was a time difference between the peak of the pelvis acceleration and the peak of the rib acceleration and this time difference played an important influence on the dummy injuries. Therefore, in the next step how these possible factors such as the contact time and velocity, the separating time and velocity and the difference time among the dummy parts could influence the dummy injuries was for the further research.

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