Study on the Relationship between Side Rigidity of the Car and Passenger injury in Side Impact

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Abstract - Based on ECE R95, a side impact simulation model has been established. Using MADYMO6.2.1 software, a series of simulation has been done to research the relationship between side rigidity of the car and passenger injury in side impact. It has been found that the most serious part of passenger injury is pelvis and lower thorax during first impact, increasing the side rigidity of the car is beneficial to the passenger protection.

Keywords: Side Impact　Side rigidity of the car　Passenger injury

1 Introduction

With the development of automobile industry, gross retain of automobile is ascending ceaselessly, velocity of the car is advancing continuously, traffic accident is appearing continually. Side impact accident of the car occupies about 26 percent among total accident of the forms of front impact, side impact, rear impact and roll, and occupies about 30-40 percent among the accident causing death and serious injury[1]. In China, because the grade crossing is master kind of urban road traffic crossing, the occurrence probability of side impact accident is highest, and occupies about one third. Its lethality is only inferior to front impact's lethality, but its injury rate is first.

The side of car is the relatively unsubstantial part of car body, the space between passenger and intensively penetrative impactor has only 20-30cm distance and only a door partition, so passenger injury caused by side impact is more serious than other kinds of impact.

Based on ECE R95[2], a side impact simulation model has been established. Using MADYMO6.2.1 software, a series of simulation has been done to research the relationship between side rigidity of the car and passenger injury in side impact.

2 Simulation Model of Side Impact

When side impact of the car occurs, doors and pillars will deform in the action of impactor, passengers inside the car will suffer load from the action of impact at the time, this collision course belongs to first impact. The deformation of doors and pillars increases on, a collision takes place between passengers and component inside the car by inertia effect, this collision belongs to second impact. During side impact, due to very finite side space beside the passenger, it will cause casualty for passengers because of oversize deformation of side of the car. Therefore, if increasing side rigidity of the car won't make oversize damage for passengers during first impact, it's an effective measure to improve safety of side impact of the car.

In order to calculate expediently, side of the car can be regarded as a whole in the action

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of first impact, that is to say the rigidity of side structure of the car can be predigested to a uniform total rigidity. By increasing or decreasing the integer rigidity step by step, discuss the relationship between side rigidity of the car and passenger injury.

According to requirement of ECE R95，apply MADYMO6.2.1 software, use geometric position relation of ellipsoid and plane, to describe geometric figure of all bodies in simulation model. The model includes vehicle body structure, MDB, seat, and dummy, as shown in fig 1.

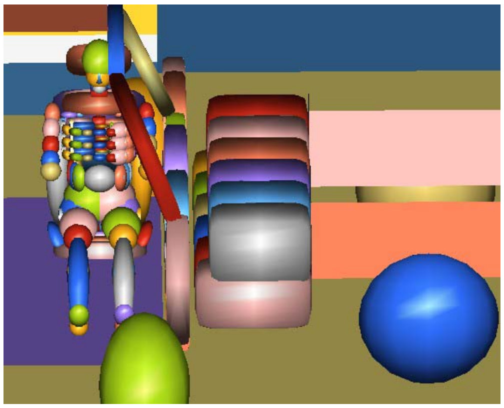

Fig 1 Side Impact Simulation Model

Vehicle Body Structure: select a car, read its geometric figure and position from CAD. It's important to read data of side structure, A pillar, B pillar, front and back door, sill and top rail of roof etc., predigest other parts, then modeling them by planes or ellipsoids.

Mobile Deformable Barrier--MDB: Define structure size of the MDB and rigidity of front impactor according to requirement of ECE R95 strictly, adjust its initial position, the centerline of the mobile deformable barrier is perpendicular to the centerline of the test vehicle passing through the R point of the seat.

Seat: Adopt twelve ellipsoids to simulate the shape of the seat of the actual vehicle, and fix the seat to the vehicle body structure.

Dummy: Select EUROSID-1 according to requirement of ECE R95, constituted by 83 bodies, expressed by 129 ellipsoids and sitting for standard. This dummy has high Bio-fidelity and can describe the behavior of kinematics and dynamics of the passenger exactly in actual collision.

Adjust included angles of all correlative arthrosis of the dummy before pre-simulation, then carry through this pre-simulation to the dummy in the action of gravity field, make body of the dummy joint the seat, and the H point of the dummy coincide with the R point of the seat, satisfy equilibrium relationship of statics.

Contact: Defined all contingent contact during first impact: wheels-ground, door-MDB, sill-MDB, B pillar-MDB, floor-left and right feet, seat back-thorax and pelvis of the dummy, seat cushion-pelvis and femur of the dummy. The program would search contact in the likelihood, then would account the contact force if the contact is discovered, and output the dummy injury defined by the program.

Side Rigidity: stiffness coefficient is one of important parameters to describe collision characteristic of the car, it's usually to be expressed by a relation of force and deflection. The main basis of confirming stiffness coefficient is the destruction status of the car, one of the ways to obtain collision stiffness coefficient of the car is by impact test of the actual vehicle. The Website of The Accident Reporting Company has recorded impact test data of the actual vehicle of NHTSA, established data-base of stiffness coefficient, but some related data of side impact of some vehicles have never been recorded yet. However, research of the collision stiffness coefficient is still blank in China[3].

Good safety airbag should detonate after first impact and before second impact to protect passenger. It has been calculated that normal airbag is that microprocessor must set to work in 10ms, and portfire must start in 20ms, so it can be deduced that preceding 20 ms is the acting time of first impact when collision case of the car occurred. Define a function curve reflecting side rigidity of the car in this paper, regard it as contact characteristic of the model, and then output the curve (Simulation-two) of change of deceleration of MDB in 20ms through simulation, as shown in fig. 2. Literature[4] narrated a research on test and simulation of a full-scale side impact in China, the paper has compared the curve of output with the curves (Test and Simulation) of change of deceleration of MDB in the literature [4]. It can be observed that the group of curves has good consistency in the preceding 20 ms, thereby it can validate that the above function curve of side rigidity has definite representative. Of course the succeeding trend of this curve is not consistent completely, because that the research content of this paper is only about first impact, and only defines all contingent contact during first impact, not defines all contingent contact during second impact, for example contact between dummy and component inside the car, between the seat and MDB whisked into the impacted car, all these affect the succeeding deceleration of MDB.

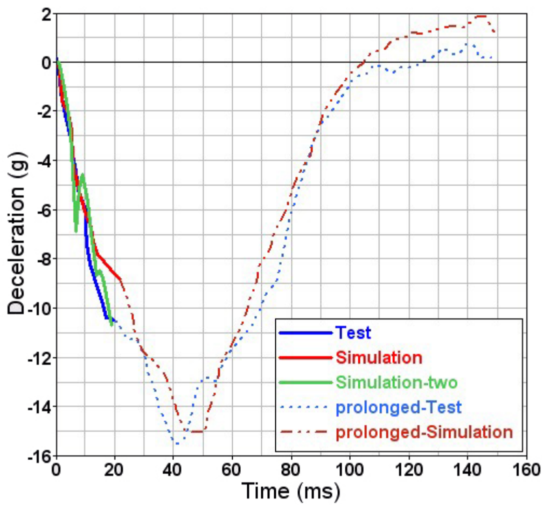

Fig 2 Change of Deceleration of MDB

Based on this rigidity curve, research the relationship between side rigidity of the car and passenger injury in side impact by changing the rigidity with sliding scale.

3 Results and Analyses of Analog Simulation

Carry through the simulation according to requirement of ECE R95, the vehicle to be tested is stationary, the trajectory of the mobile deformable barrier longitudinal median vertical plane is perpendicular to the longitudinal median vertical plane of the impacted vehicle, the MDB speed at the moment of impact is 50km/h[5]. The simulation result would output a series of response of the dummy arose by effect of inertia during first impact.

The test of European side impact treats extrusion displacement and load endured of impacted part as evaluating indicator, they think the best serious passenger injury is the injury of parts of head, thorax, abdomen and pelvis, so the performance criteria of ECE R95 shall meet the following conditions: Head Injury Criterion (HIC) shall be less than or equal to 1,000, Rib Deflection Criterion (RDC) less than or equal to 42 mm, Viscous Criterion (V*C) less than or equal to 1.0 m/sec, Abdomen Peak Force (APF) less than or equal to 2.5kN internal force (equivalent to external force of 4.5kN), Pubic Symphysis Peak Force (PSPF) less than or equal to 6kN[6].

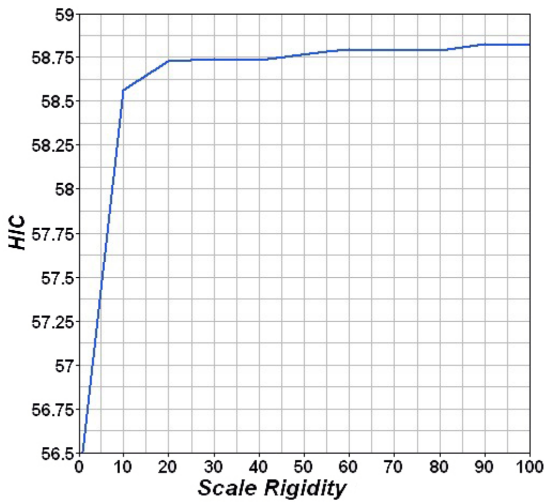

Fig 3 the Values of HIC under Different Rigidity

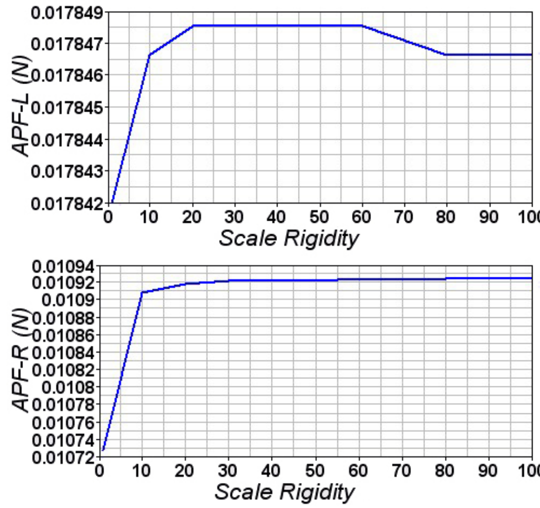

Fig 4 the Values of APF under Different Rigidity

From each parameter figure of passenger injury we can see:

1）Values of HIC of head as shown in figure 3 are all on the small side and not exceeding 1000, because it has no time to contact or doesn't yet happen to impact intensively between head and inner decoration of the impacted vehicle during first impact.

2) The abdomen of EUROSIDE-1 is constituted by many ellipsoids, so the output curves split into left and right part. Because the abdomen doesn't suffer direct impact, the APF is very small and not exceeding the permitted level of the regulation; Some impact energy is absorbed by the deformation of the hip, the lumbar vertebrae brings along movement of the upper limbs and the femur brings along movement of the lower limbs; the kinetic energy of the abdomen increases due to being brought along by the lumbar vertebrae. So the curves assume an upward trend on the whole, as shown in figure 4.

3) Impact energy is transferred to the seat by the vehicle, then to the dummy by the seat. As the direct contact part with the seat, the PSPF of the pelvis as shown in figure 5 is biggish, approaching tolerance range of 6kN. It is observed that from figure 5 when increased side rigidity from 55 times to 60 times based on origination, the PSPF increased from 5.7841kN to 5.7845kN, only increasing 0.0004kN, and when increased side rigidity to 80 times, the PSPF is 5.7858kN, only increasing 0.0013kN. Increasing side rigidity with germination, the PSPF has only been increased by several in a thousand or ten thousand, not exceeding the permitted level of 6kN. This shows that at the time increasing side rigidity is not so influencing on the PSPF.

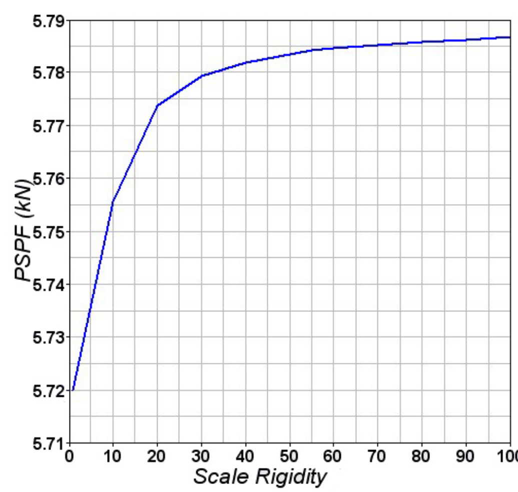

Fig 5 the Values of PSPF under Different Rigidity

4) The thorax of EUROSIDE-1 are constituted by one rigid acantha antrum and three alike ribs for satisfying Bio-fidelity, therefore the curves split into upper, middle and lower, as shown in figure 6 and 7.

Array the numerical values of RDC and VC in turn for lower part, middle part and upper part from high to low, among these, the numerical values of lower part is on the high side clearly, especially the RDC of lower part is very close to the permitted level of 42 mm. It can show that further impact energy is transferred to lower thorax due to being brought along by the lumbar vertebrae.

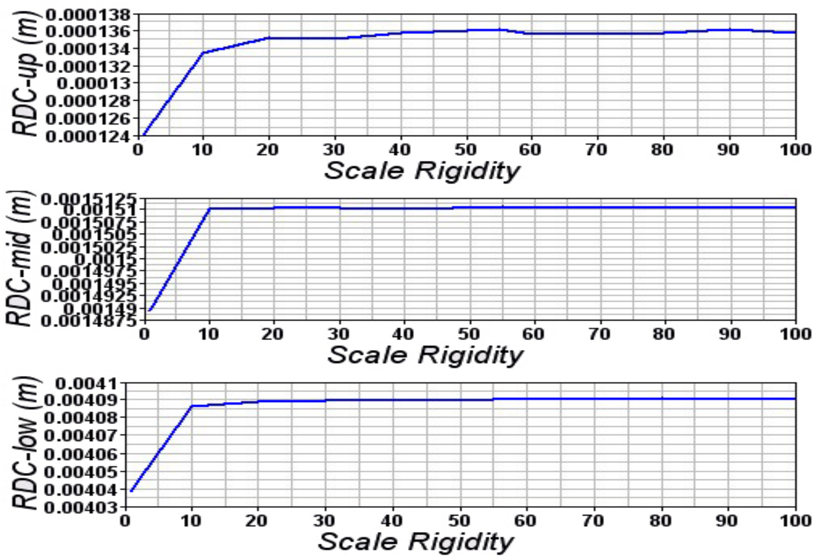

Fig6 the Values of RDC of Upper, Middle and Lower Thorax under Different Rigidity

4 Conclusion

Based on ECE R95, a side impact simulation model has been established. Using MADYMO6.2.1 software, a series of simulation has been done to research the relationship between side rigidity of the car and passenger injury in side impact during first impact, then comes to the conclusion that:

(1) When side impact accident occurred, the most serious part of passenger injury is pelvis and lower thorax during first impact;

(2) From the above passenger injury parameter figures, it's observed that the values of passenger injury is all not exceeding the permitted level, when increasing side rigidity, the increase range of passenger injury is not quite, especially when increasing side rigidity exceeding 10 times, the passenger injury has few increase, that is to say at the time the rigidity has little effect on passenger injury. This shows that during first impact the bigger side rigidity is, the more advantaged protection for the car and passenger in a definite range; after this in order to improve safety of side impact of the car better, it must consider synthetically the case of second impact, and take corresponding research for specific effect on passenger injury.

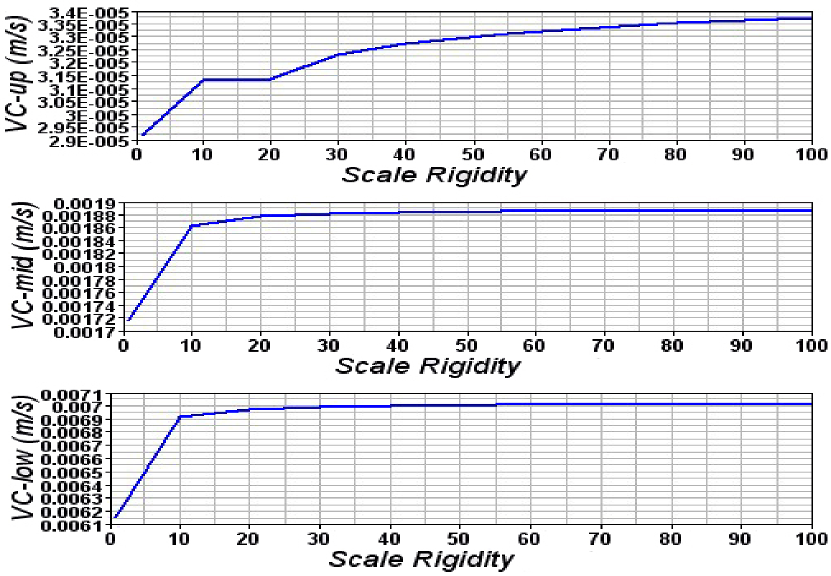

Fig7 the Values of VC of Upper, Middle and Lower Rib under Different Rigidity

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