Research of a New type of Vehicle Impact Energy-Absorbing Equipment's Energy-Absorbing Performance

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Abstract—This paper introduced the structure and the working mechanism of a new type of vehicle impact energy-absorbing equipment. The Computer Simulation model is set up by MADYMO software to make comparative analysis of the impact performance of the vehicle fitting with or without this equipment during frontal impact and car-pedestrian impact. The results indicate that the vehicle fitting with this equipment has better protective effect for the occupant and the pedestrian. The structure parameter and disposal mode of this equipment is also researched.

Keywords: vehicle collision, energy-absorbing equipment, safety engineering

1 Introduction

With the automobile safety gets more and more people's attention, each developed automobile industry country has put huge manpower, financial and material resources into automobile safety research, and established a lot of standards relates of automobile Safety. Although it has obtained greater development in the initiative security technology today, but as the feasibility condition that the initiative security technology still can't avoid accident to occur completely, the Passive security technology still become the effective guarantee of the occupant to avoid injury and death in the collision accident.

At present, one of the common Passive security technology used in the vehicle is through the bodywork's deformation to absorb energy or collision cushion energy-absorbing equipment to protect the occupant. For this kind of energy absorbing equipment fixed on the vehicle, the collision force may become very great if the deformation of the automobile body to be controlled within a limited length, which is difficult for the supporting structure to bear it. On the other hand, in order to decrease collision fore, the deformation space must be increased, which makes automobile design more difficult. So, the energy-absorbing equipment researched at present is difficult to obtain better energy-absorbing effect. the vehicle body will be badly damaged unavoidably, and the occupant will suffer heavy injury during the accident. This new type of energy-absorbing equipment researched in this paper can put forward the bumper and the energy-absorbing section rapidly to increase deformation and energy-absorbing deformation space when the driver predicts the risk and takes urgently brake, the acceleration and effect force can be reduced effectively during the course of collision, which helps to lighten both the damage of the vehicle and the injury of the occupant.

2. Working Mechanism

The vehicle collision process is a process transforming the automobile kinetic energy into deformation energy and other kinds of energy. According to formula (1), if the kinetic energy is determinant, i.e. the work (W) which acted on the vehicle is determinant, in order to decrease the collision force (F), the deformation length (S) of the collision energy-absorbing must be increased.

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$$W=\int F(t)\times ds \qquad (1)$$

In the ordinary automobile body design, designers must ensure the front part of the vehicle absorb energy as much as possible by biggish deformation to limit the impact load acting on the passengers in a regulated range. This will lead to heavy damage of the vehicle body and other structures of the foreside vehicle, which make it difficult to prevent engine and gear-box invading into occupant's compartment. So, the outside deformation space must be increased in front of the vehicle to decrease collision acceleration and prevent badly damage of vehicle body before the collision happen.

Statistical analysis make it clear that many collision accidents occurred usually not because the driver haven't predict the risk completely [1], but because it's too late to brake or make other measures. So, if the deformation space can be increased in a short time when the driver takes urgent brake, and it reaches a certain condition, the energy-absorbing effect will become much better.

The work mechanism of this equipment is as below---- it adopts a type of square-section thin wall cylinder as its mainly energy-absorbing part, research indicates that this kind of cylinder has better energy-absorbing performance [2]. The front end of the cylinder connects with the bumper. Install two cylinders shells in front of the automobile longeron, which section is similar to the cylinder, and the energy-absorbing cylinders is put into these shells, forming a clearance match allowing them slip relatively. The cylinder shell should have enough intensity so as to ensure it can endure the impact load during the course of cylinder deformation. In normal case the control system detects the acceleration of vehicle real-timly. Before the accident happens, the driver predicts the danger and take urgent brake, when the control system judged the danger exceed a certain condition, it will touch off the impel device, the cylinder and bumper will be pulled out and be limited location rapidly to increase the deformation space. So the impact force acting on the vehicle is decreased through the cylinder absorbing the energy by deformation. In order to increase the protection of the pedestrian during the car-pedestrian impact, the impel device adopts a type of outside-vehicle safety airbag to make the pedestrian get better protection through the airbag's cushioning effect.

3. Simulation of the equipment's energy-absorbing performance

3.1 Frontal impact Simulation

In order to analyze this equipment's protective performance in the frontal impact, the frontal impact simulation model of a certain type vehicle is established by MADYMO software, (as fig.1 shows). Because in the frontal impact, the automobile's frontal part is the main distortion part, however,

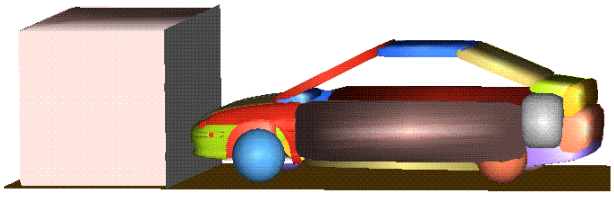


Fig.1 The frontal impact simulation model

the deflection of the rear part and occupant room is relatively very small, so, the rear part and occupant room of this vehicle simulation model is established by Ellipsoid Models, and the frontal part by Facet Models to really respond the vehicle's outside dimension and spot enduring the impact force. Through adjusting the stiffness of the bumper and the engine hood to make the frontal impact simulation acceleration curve be consistent with the test curve, (as fig.2 shows), the peak valve of the curve is 414.43（m/(s^2)）. [3]

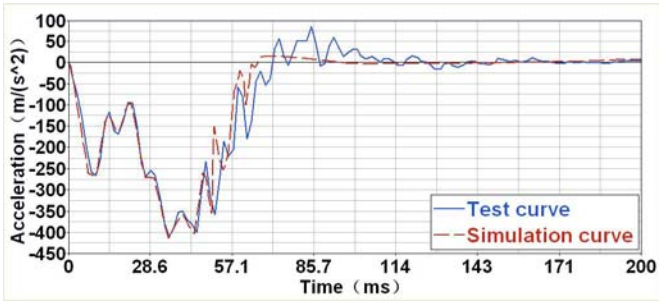


Fig.2 The compare of test curve and simulation curve

This energy-absorbing equipment is mainly by its energy-absorbing part---metal thin-wall cylinder producing folding distortion to absorb the vehicle's collision kinetic energy.

In order to be easy to fix it with the vehicle longeron to control the force transmission way the distance of the two cylinders choose 1.05m, which is nearly equal to the distance of the two cylinders of the simulation car model, the frontal end of the cylinder connecting with the bumper. Considering the coordination with the vehicle structure and for the disposal convenience, the length of the rectangular cylinder choose 350mm, and the section size choose 80×50mm. the equipment's finite element model is established by MADYMO software, as fig.3 shows. Coupling the degrees of freedom of the nodes of the cylinder's end

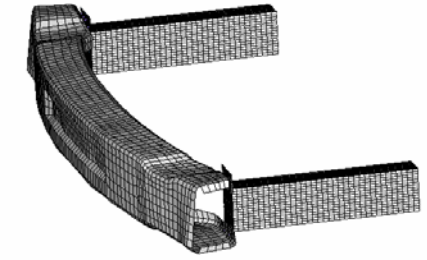


Fig.3 The FE model of the equipment

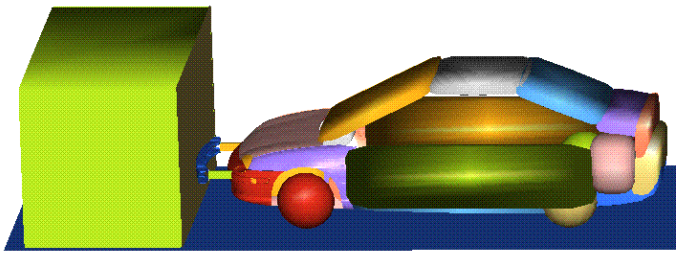


Fig.4 The frontal impact simulation model fitting with the equipment

surface with the vehicle model by 'support', as shown in fig.4. In order to obtain the reasonable thickness parameter of the cylinder suiting for the simulation vehicle, choose different thickness of the cylinder, and make Simulation computation of the vehicle frontal test separately by given a same initial velocity (13.33m/S), fig.5 shows a compare of each corresponding simulated acceleration curve and that of vehicle without this equipment. Table 1 listed the peak valve of the curve corresponding with each kind of thickness and their comparison situation. The simulation computation results indicate that as fitting with this equipment the acceleration curve become flatter and the acceleration peak value decreased obviously by the columns to absorb energy. It can be seen from the fig.5 that the curve corresponding with the thickness of 1.8mm is relatively ideal, the acceleration peak fall from

414.43（m/s^2）to 315.40（ m/s^2）, Reduced 23.90%, which is beneficial to decrease the injury of the occupant. The deflection of the energy-absorbing equipment reaches about 300mm, causing the cushioning time of the vehicle distortion increased about 20ms. The result after occurred fold distortion is shown as fig.6.

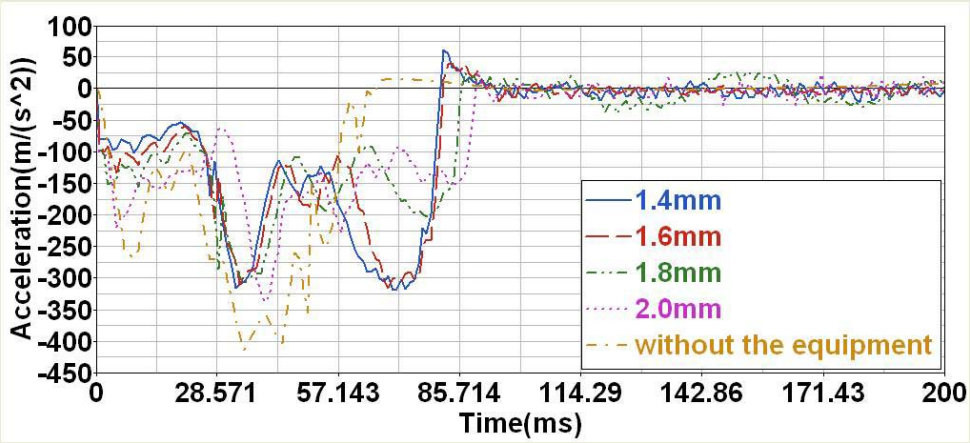


Fig.5 Compare of the simulated acceleration curves

Table1 Compare situation of the peak valve of each curve

Thichnes s	1.4mm	1.6mm	1.8mm	2.0mm
Peak value （m/(s^2)）	319.22	315.51	315.40	338.99
Decreased (%)	22.97	23.87	23.90	18.20

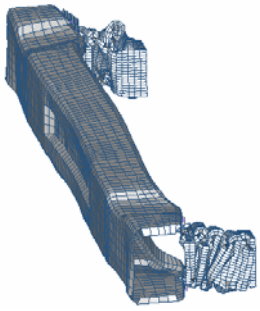


Fig.6 The equipment after distortion

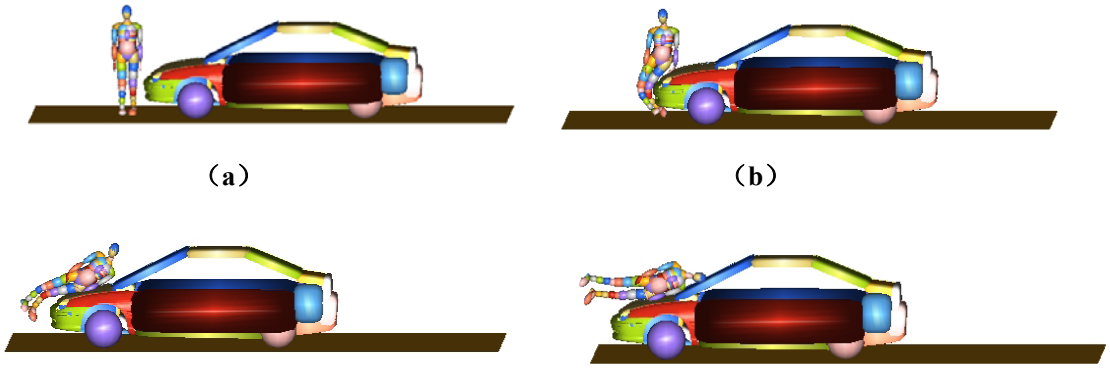
3.2 car-pedestrian impact Simulation

In car-pedestrian collision accident, because the pedestrian is the weak one of the collision, so it is mainly to be injured. If coordinated with the outside-vehicle airbag, this equipment can make better protective effect for pedestrian, the cushioning effect of airbag for pedestrian's thigh, buttocks and waist causes the load acting on the human body's parts which is mainly to be injured reduced obviously. Thus, it reached the goal of reduce the pedestrian injury. Moreover, during the impact accident of Miniature passenger vehicle with pedestrian, this equipment can also prevent the high pedestrian's head hit to the frontal cross-member of vehicle ceiling which is relatively very rigid.

In order to make comparative analysis of the different injury degrees of the conditions that fitting with or without this equipment, The simulation models of the two situations are established by MADYMO software. Because the deflection of the equipment is very small during the actual car-pedestrian impact accident, the equipment model is established by Facet

Models to enhance computational efficiency.

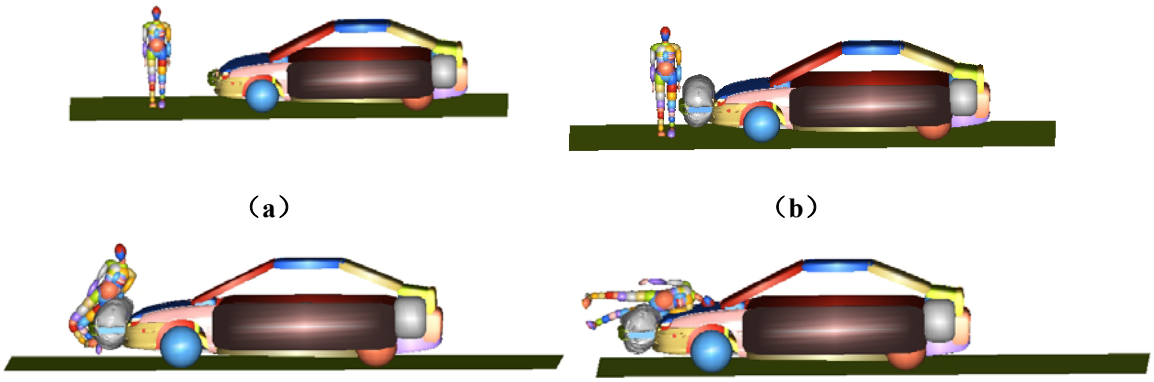
According to a investigation report of NHTSA that the collision speed of 76.2% car-pedestrian impact accident occurred below 45km/h[4], so, both of these two kinds of simulation situation choose the same impact velocity of 36km/h, their movement response processes are shown as fig.7 and fig.8 respectively. It can be seen from fig.7 that the pedestrian's head hits onto the windscreen.Fig.8 (a) is the situation before the equipment been triggered. Fig.8 (b) is the situation that the energy-absorbing part been pulled out by the airbag. During the course of impact with the pedestrian, firstly the bumper connected with the cylinder contact with the pedestrian's leg, then the pedestrian's thigh, buttocks, waist and arm contact with the airbag, after the human body been cushioned, the head contact with the engine hood at a relative lower speed.



（a） （b）

（c） （d）

Fig.7 The movement response process without the equipment



（a） （b）

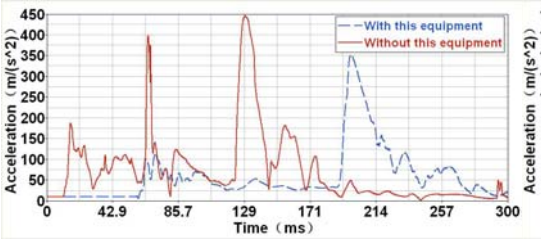
（c） （d）

Fig.8 The movement response process with the equipment

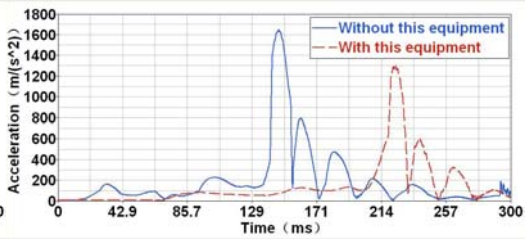
Fig.9 compared the impacting acceleration curve of each pedestrian's part that is mainly to be injured under the conditions fitting with or without this equipment, and table2 show the compare of their peak values. It can be seen from it that the peak acceleration value of the pedestrian's head, chest, pelvis and thigh are all reduced obviously, so, this equipment has a very well protective effect for the pedestrian.

Theoretical analysis and test shows that the whole time that from control system produce action till the column to be pulled out completely is less than 0.1s, which is perfect within the range the driver can predict the risk advancing. The columns absorb the collision energy by

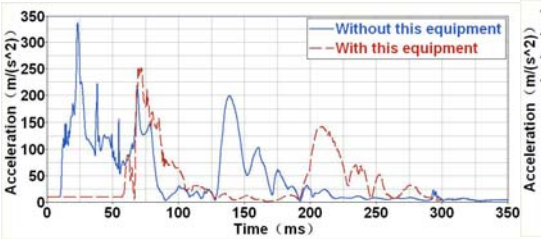
deformation during the course of collision, as a result, the acting force and acceleration during the collision course can be controlled effectively, and the protection both of vehicle and passenger is realized.



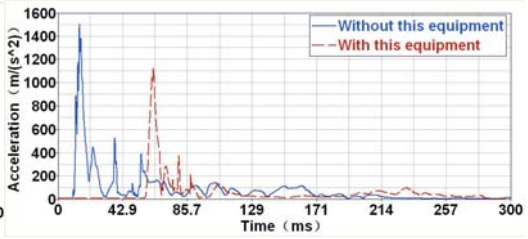
（a）Compare of the head acceleration



（b）Compare of the chest acceleration



（c）Compare of the pelvis acceleration



（d）Compare of the left thigh acceleration

Table 2 Compare of the peak values of the pedestrian's mainly injured parts

Peak value / different situation	Head acceleration （m/(s^2)）	Chest acceleration （m/(s^2)）	pelvis acceleration （m/(s^2)）	Left thigh acceleration （m/(s^2)）
Without this equipment	1648.25	445.452	337.17	1503.14
With this equipment	1312.92	351.54	252.34	1129.77

4. Conclusion

This type of active energy-absorbing of vehicle impact cushioning equipment presented in this paper can reach very well energy-absorbing effect by energy-absorbing columns of low cost. It can decrease the impact force and acceleration trough increasing the deformation space actively, and thereby avoid or decrease vehicle damage and passenger injury.

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