Analysis of Vehicle's Frontal Crash Based on Structures' Section Forces

Ying Yang, Guangyao Zhao，Jianwei Di

***Abstract*—In this paper, a new method of structures' section forces is used to analysis the vehicle's front crash. A complete finite element model of a passenger car is presented. According to the basic principle of the dynamic non-linear finite element method, the basic crash describe equation and FE discretized equation are established. The frontal crash of the integrated car system is successfully simulated in LS-DYNA and the results that including the structures' section forces and energy absorption time courses, the effect of the main energy-absorbing parts, the transmitting route of the energy and the forces change are attained. Simulation results show, the structures' section forces can accurately forecast not only crashworthiness of vehicles but also the way transmission of forces in crash process. This method provides an important tool to improve vehicle's structures' performances.**

***Index Terms*—frontal crash, energy absorption, section forces, simulation**

I. INTRODUCTION

Computer simulations of vehicle collisions have improved significantly over the past few years. With advances in computer technology and non-linear finite element (FE) codes, full scale models and simulations of such sophisticated phenomena are becoming ever more possible. Finite element crash simulations have been primarily focused on the vehicle models and their crash characteristics. This allows direct evaluation of occupant risks and injuries using simulation data.

Basing on the mimic crash numeric calculation theory [2], the complete finite element model of a integrated car-occupant restraint system including a dummy is set up. According to the CMVDR 294, the frontal crash is successfully simulated and the results including the vehicle's the transmitting relation of the energy and the structure section forces in the process of crash, achieve comprehensive and credible appraisement with the frontal crash process and crashworthiness. It provides the theoretical reference for the studies of the crash process and the crashworthiness design of vehicles.

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II. ESTABLISHMENT VEHICLE'S CRASH MODE

The establishment of crash finite element model is the key of analysis of crashing. We must consider the specific circumstances of the vehicle analyzed, and consult the criteria and predecessor' experiences [1] [3] in order to make sure the model is reasonable.

In this model, some questions are mainly considered. Element meshing: adopting the reducing integral element with hourglass controlling; making sure of the single direction of parts forming full integral element; controlling element sizes of crashing area between 5mm to 8mm., and element sizes of non-crashing area is about 10mm; the numbers of the triangle element take 9.2% of the total numbers of the element; the numbers of warping element take 10% of total numbers, and avoiding concentration of the warping element; adopting the regular meshing in the area of energy absorption; for parts of stamping, the change of shell element thickness is considered. Contact: taking effective measures aim at the distribution of contact pressure in order to avoid the problems of incipient penetration and side-to-side penetration, in dealing with the contact. Coupling and restriction: all kinds among connecting relation of the bolt, welding and so on, is correctly simulated and avoiding discontinuity of the relational curve about the spring force and its displacement. Material property: sheet metal component adopts the Multi-linear elastic plasticity Isotropic hardening material; Bumper adopts low density, rigid foam element and engine, suspension and braking system adopt stiffness solid element material, and the tire adopts elastic material; We must take the strain rate into consideration when defining material properties, because the distortion and strain rate of the skirts bend are both large in a short-time crash process.

In the preprocessor of the Hype-Mesh in which is the finite element software, the complete finite element model of the integrated car-occupant restraint system is presented, as shown in figure 1.

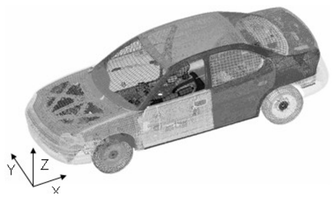


Fig.re 1 Whole Car finite element model

There are 320,000 nodes and 300,000 elements in the whole vehicle finite element model.

III. STRUCTURES' ENERGY ABSORPTION ANALYSIS

According to the CMVDR 294 law, under the MPP 970 edition of the LS-DYNA software, the frontal crash into a rigid wall of the car at about 48.3km/h is simulated.

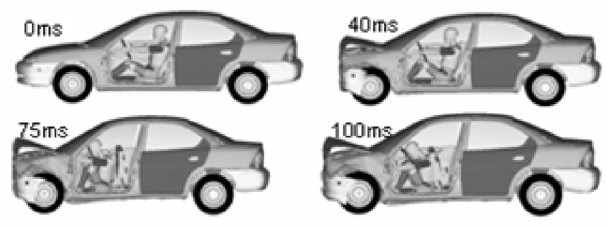


Fig. 2 Vehicle dynamic simulation results

The whole calculation is carried through on the flat of Linux2.4.20 which is part of the workstation DELL PRECISION670, though the process of the crash costs 120ms, the CPU runs 15 hours and 22minutes. The simulation result of the frontal crash is shown as figure 3.

The figure 2 shows of the whole vehicle structure deformation at the time 0ms, 40ms, 60ms, 75ms and 100ms. It can be seen clearly that the bumper, engine cover and the front of carline have generated large plastic deformation, extruding the front component of above them. And the front of carline which have shown large folding deformation takes effects in absorbing the energy. At the same time, the cockpit and the rear of the vehicle body haven't shown deformation basically. The reason of the phenomenon is with the occur of collision, the front of the vehicle have taken great impact, so the impact energy is tremendous, and the momentum changes rapidly in a very short time, it forms impact force in a moment, and the number is very large. Greater plastic deformation is taken place because the stress surpasses the material yield stresses greatly when the front body of the vehicle suffered a great impact force. At the same time, it can absorb the impact force mostly, so the kinetic energy of the vehicle decreased and the number attenuates obviously, and the stress which effects on the occupant-cabin and the rear of the vehicle body also comes down, haven't resulted in obvious deformation. From the time of deformation, the phase that the vehicle body deforms at more rapidly is after 40ms, and after 75ms the structure deformation is just little.

The figure2 can reflect the change of the energy during the process of the crash. From figure3 we can see the maximal kinetic energy of the system is 117KJ.It descends sharply with the process of the crash. At the same time, due to the distortion of the components, which can absorb the energy, the internal energy ascends sharply. Up to the end of the crash, 90% kinetic energy has been transformed to the internal energy of distorted components. Because of the rebound of the vehicle at the end of crash, the kinetic energy has not descended to zero; it still remains 2KJ or so. We can see from figure4, the maximal of hourglass energy is 8KJ, which is about 6.8% of the total energy. It is within 10%[6]. Sliding interface energy is 3.25KJ. After all, it is a positive number, so we can conclude that this simulation calculation is successful.

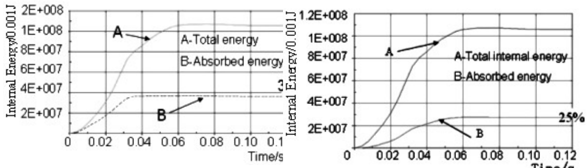


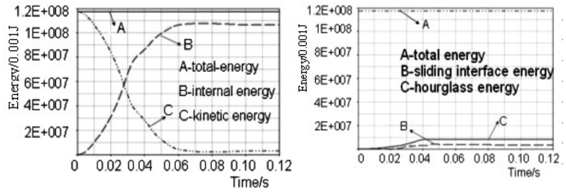
Fig. 3 The curve of energy

In the process of crash, the front of energy-absorbing components absorb the main internal energy and try to stop passing or only permit a little energy to the occupant-cabin, for keeping the space of the occupant unchanged. The energy-absorbing components vary with the time changing.

During the process of 0ms-35ms the vehicle contacts the rigid wall. Firstly, the bumper including the defending foam undergoes the fierce impact which can make a big distortion and absorb a great deal of the internal energy. The front longitude member which is connected with the bumper is also the main energy-absorbing component.

The figure4 shows the energy absorption curve in 0ms-35 ms, from the figure, it can be seen clearly that those components can absorb 35% of the total energy.

Between 35ms and 50ms, main parts of the energy absorption are inner reinforcement front subsidiary frame, inner and outer board of engine cover, front wing, side panel, cross member beneath bumper beam and so on. The internal energy which these parts absorb is about 25% of the total energy.



(0-35ms) (35-50 ms)

Fig. 4 The energy absorption curve

Between 50ms and 60 ms, main energy-absorbing components are the extension of carline firewall, side panel of the vehicle, the floor and so on. Figure5 shows the internal energy which these parts absorb is about 9.9% of the total energy.

The energy-absorbing components analyzed above absorb about 70% of the total internal energy. The other front components of the vehicle such as engine can also absorb part of internal energy. So the front components of the vehicle absorb most of the internal energy.

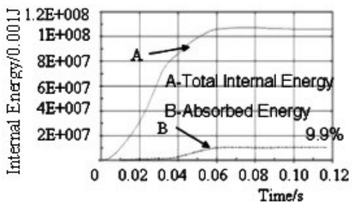


Fig. 5 The energy absorption curve in 50ms-60ms

Figure6 shows the condition of the main energy-absorbing components in the process of crash, from the figure we can see the front bumper absorbs 20KJ internal energy which occupies about 20% of the total energy. The effect of energy absorption is good .the carline absorbs 14.5KJ internal energy and the effect is not better than the bumper. We can consider changing the energy absorption mode of the front carline by adding buffer components between the front bumper and the front of carline. As one part of the front of carline assembly well-designing the crash intension of the buffer can make the new front of carline produce folded failure mode in phase and then cause the succeeding failure of the behind of carline structure. So it can improve energy absorption of the front of carline assembly structure in the process of crash.

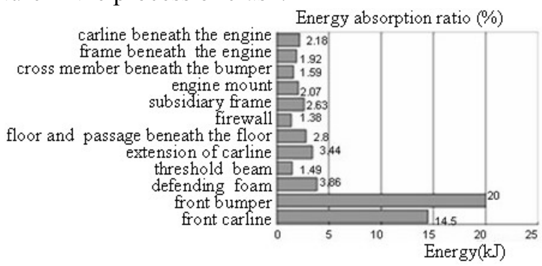


Fig. 6 main parts adsorbed energy in crash

IV. Structures' section forces analysis

During the process of collision, the front frame suffered a very big wallop, and then the wallop will transmit to the other parts of the car along some routes. In order to analyze the transmitting route of the force, a section such as figure.7 has been defined before analyzing. Then the section-force's changing along with the time in the main energy-absorbing parts can be worked out by the simulation analysis, and so does the changing curve of the section force. These have been shown in figure 7 to figure9.

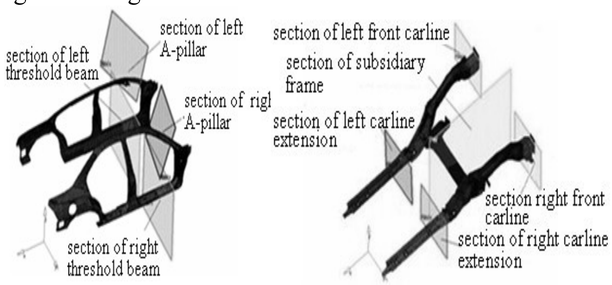


Fig. 7 The section force plane of car model

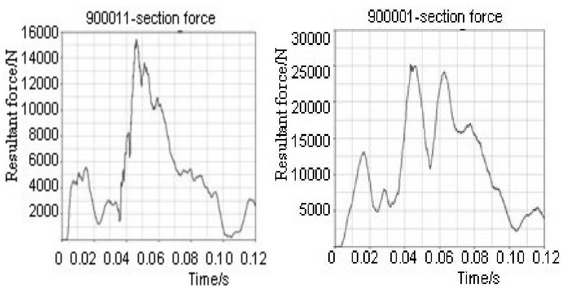


Fig. 8 The section of right carline extended

The bumper suffers the very big wallop when the car strike against the rigid wall fiercely, then transferred the force to the front of carline which connected with it. Along the crash process, the force is transmitted to the back end of the front carline, where it is connected with the assistant suspension and the extension of the carline. The wallop suffered by the front of carline is divided into two parts, one is transmitted to subsidiary frame and another is transmitted to the extension of the carline.

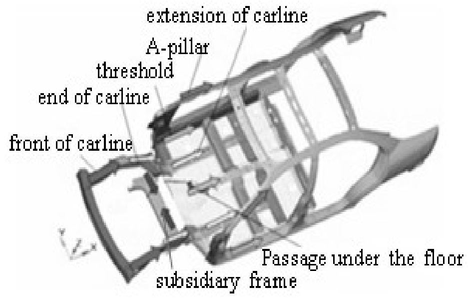


Fig. 9 The transmitting route of the force

The subsidiary frame and the extension of the carline suffer very little force before 30ms, and the force reaches peak value at 40ms and then decreases. (The assistant suspension suffers a peak force at 60ms and 75ms because of the backward strike of the engine).The force transmitted to the extension of the carline can also spread to the front floor, the front passage, side panel and threshold beam. From the figure.8 we can see that the left and right A-pillar and threshold beam reaches peak value about 50ms.

The transmitting route of the force during the collision is: bumper → the front of carline → the end of carline and subsidiary frame → the extension of the carline, passage of floor below, threshold beam and A-pillar.

V. Conclusions

All the guidelines of crash estimation of the vehicle, which has good passive safety, are quite enough to meet the requirement of crash regulation. Further more, the occupant restraint space distortion is small so that the occupant can get enough living space.

The hourglass energy of the model is only 6.8 percent of the total energy, which shows that the simulate calculation is reasonable. The energy-absorbing parts at the front of the car, which have a good effect to absorb the energy, absorb most of the internal energy. The design of the front of carline should be improved because it has less effect for absorbing the energy.

It is a beneficial study in the transmitting route of the force and the relations of the absorb-energy sequence by analyzing the structures' section forces defined in the crash model. All these achievements are very valuable to go on the research of the crashworthiness design of the body. The simulated testing results indicate that the safety of the vehicle is good when taking place the frontal crash.

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