THE ERGONOMIC RESEARCH AND DESIGN EVALUATION OF CHILD CAR SAFETY SEATING DEVICE

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The purpose of this study is emphasized on searching for the ergonomic child safety seating design to reduce the neck injuries during forward car collision. The new designed prototype of ergonomic safety seat, featuring with two cushions under the seat, buffering device in the back-rest support and lowery placing the child restrain belt through the rear side of the seat, is suitable for the use of those children with weight ranging from 9 to 18 kilograms. The forward car collision experiment was performed in National Vehicle Research Center. Results of the collision experiment show that the new designed ergonomic safety seat can decrease by 30.19 percent, comparing with the national standard value, in the portion of head acceleration and also can decrease by 12.34 percent in the portion of chest acceleration under the conditions of standard impact velocity and maximum simulated car acceleration. The collision experiment also reveals that the new ergonomic designed seat can obviously eliminate the acceleration value in comparison with the conventional standard safety seat in the areas of dummy child's head, neck and chest according to the real dynamic impact detection reports.

INTRODUCTION

The research report of NHTSA (National Highway Traffic Safety Administration) indicated that there were over 600 children died with car accidents in one year and approximately 250 children without using or misusing safety protection devices in U.S.A.（NHTSA,1996） In addition, according to the investigation concerning children's injuries caused by car accidental impact, the most injured portion were head, face and belly and even if using or not using safety protection devices, the injuries in the three portions were still very high ranging from 40~45% and 55~60%, respectively. （Nil,1997） The statistic report in the above survey also indicated that neck injuries using CRS (Child Restrain System) were higher by 15% than without using any protection measures.

Accordance to studies of many scholars, including Kraus（Kraus, 1991）; von Holst et al., 1995 （von Holst , 1995）; Sosin et al.,（Sosin.,1995） . Waxweiler et al.,（Waxweiler.,1995）; Viano et al.,（Viano.,1997） etc., there were at least 40% injuries belonging to neurotrauma injuries caused by car collision accidents. The most serious neurotrauma injuries were produced by neck whips. Kraus, et al.（Kraus,1995） and von Holst et al.,1995 （von Holst,1995）also pointed out that neurotrauma injuries caused the body partially malfunctioned or limb paralyzed. Those injuries took place similarly on children. Children are in the period of rapid growing. Their neck spines are still rather weak. Consequently, in the process of car collision accidents, the neck whip effect will cause children more dangerous and serious injuries than adults. Therefore, how to improve the protection effectiveness of child safety seating devices is remained to be very urgently designing research issues either in domestic or in abroad.

METHODS

This paper attempts to explore better ergonomically preventive designs of child safety seating device in order to reduce the accelerating impact on the neck spine in frontal car crash. Research method employed two standard child safety seats provided by local well-known manufacturer as experimental comparisons with a newly designed ergonomic safety seat. The design characteristics of new child safety seat are depicted as follows:

1. Lowery placing child restrain belt through the rear side of the seat to stabilize the seat while car collision as shown in figure 1.
2. Adding two spring cushions under the frontal side of

the seat to store the impact energy during the crash as shown in figure.2.

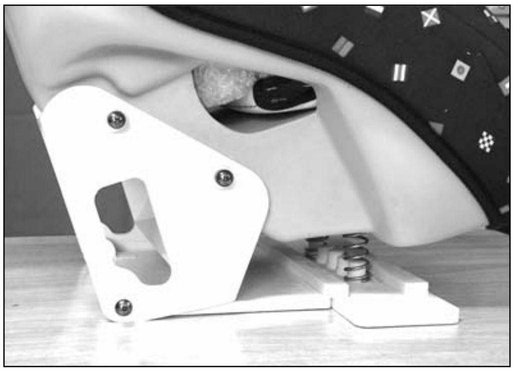

Figure 1. newly designed ergonomic safety seat

3. Adding a buffering device in the back-rest support of the seat to absorb the spring back energy during the process of collision and reduce the velocity of neck whip motion as shown in figure 3.

The process of collision experiment applied to the child safety seat in the current study complies with the regulations of China National Standards.（CNS11497） Dynamic testing process is depicted as follows: （Central Standard Bureau,1998, Lai,1999）

Firstly, several newly designed prototypes of ergonomic safety seat were constructed before the collision experiment, then through the design evaluation, an optimal prototype was chosen for dynamic collision testing.

Secondly, the optimal prototype was proceeded more accurate measurements in order to verify if the ergonomic safety preventive design could reduce neck injures.

Finally, the acceleration values of head and chest can be detected through connecting sensors and then are used to estimate the effectiveness of new cushion design of the seat.

Three collision tests were performed in the experiment. The experiment was divided into two large parts, experiment part and contrast part, to proceed forward collision testing. The experiment part utilized safety seat with new cushion designs. The first contrast part utilized the same safety seat but without new cushion designs. The second contrast part utilized the original designed safety seat by the manufacturer. The motion pictures of collisions were recorded by using high-speed photographic camera. The reason of adding the manufacturer's original designed safety seat was that the first contrast might be failed due to the personal revision factors of new design. Facilities used in the experiments include simulated car cabinet, impact-producing devices, testing chairs, dummy child and sensor-detecting devices. Except for the testing safety seats, other equipment, measuring devices and system setups were provided and implemented by the technicians in National Vehicle Research Center. The dummy used in these tests were Hybrid III Dummy for 3-year-old child suited for the children weighting from 9 to 18 kilograms and all tests adopted forward-facing three point safety seats meeting with international specifications.

RESULTS

According to the experimental data of experiment section, as shown in figure 4-6 and figure 13-15, we can point out the effect of cushion design for reducing the acceleration on the portion of head and chest. The peak value, about 52 G, produced at about 80 to 90 milliseconds after the collision., which is lower some 23 G than the standard value of CNS11497. Also the peak value of chest is about 37 G, which is lower some 23 G than the standard value. The acceleration data of contrast section are in failure due to some unidentified reasons, but we still can analyze motions from the pictures taking by the high-speed photographic camera. The possible causes of destroying produced by the experimental failure can also be studied. Judging from the accelerating curves of experiment section in the portion of head and chest, the first accelerating wave happened at about 37.5ms after the impact actuation. The first accelerating peak value, 36 G, produced at about 58ms. At the same time, the first accelerating peak value, 52.16 G, produced due to the head forward. As for the head part, A wave of about 21 G produced at 337ms after the impact. The explanation from the Research Center is that the wave shape was generated by the ergonomic damping device set up in the back of safety seat. In general, in view of the wave chart, the cushion design can spread the impact energy and the damping consumes partial energy resulting in the decreasing of head and chest accelerations. In other words, it reduced the amount of impact.

From the moving pictures taking by high-speed camera, we can find that the safety seats of the first and the second contrast parts are all destroyed in the impact experiments, as shown in figure 7-12 and figure 16-17. The child dummy is slipped out and the safety belt is unlocked due to the bad design of weak strength seats during the collision process. The possible reason is that the stress of structural conjunctions is too concentrated and eventually resulting the compound torque not be able to undertake the destroying load in the process of collision.（due to limited pages, figures are omitted.）

DISCUSSION

The experimental results indicated that the child dummy, safety seat, safety belt and car seat are all motion-related during the collision process. According to the experimental results, focusing on the ergonomic safety preventive design for safety seats, further discussions are as follows:

1. We all believe that fastening the child stably on the safety seat is a safer method. Actually, this kind of method can ensure the child not to fly away from the seat during the collision, but the impact energy will be concentrated and transfer to the unfastened body parts such as hands, feet, head and neck and consequently, all these joints will immediately produce high-speed accelerating displacements. The weakest part of head and neck is just located on the position which undertakes largest toque moments during impact. This is the reason why the other parts of body injured less while the parts of head and neck injured more.

2. In fact, the safety belt cannot also fasten the safety seat on the car seat stably. Owing to the locking function of safety belt actuated by the initials, the initial speed caused by the impact will affect the locking time of safety belt. Restricted by the responding delay of this kind of mechanical action, the safety belt cannot pull back the safety seat immediately while encountering impact. Consequently, the safety belt will be pulled out a little distance and the safety seat will forwardly escape from the car seat. Therefore, the child and safety seat are totally locked, but the action of impact caused the child and seat to move forward quickly till the safety belt produced the function of lock promptly. At the same time, the safety seat is restrictedly pulled immediately while the head and neck are still moved ahead by the initial force. At that time, the safety seat has been escaped from the car seat. Therefore, the relative rotation directions between the head and neck portion and the truck portion are unstable. The injuries caused by the displacement movement of acceleration are hard to be predicted.

3. The prompt initial actions added on both the safety belt and the safety seat as the safety belt locked will result in some structural relative movements among the child, safety seat, car seat and safety belt. From the viewpoint of physical dynamics, it is not a bad thing because these movements and destroying will also absorb impact energy. The problem is that the extremely short time of action will explode massive energy. At that time, even if only the difference of impact directions or the uneven friction forces on surfaces of car seats, the movement types and directions will not be easily predicted and controlled. Consequently, in the process of impact the safety seat will cause unexpected destroying, escaping and overturning, and result in child’s serious injuries.

In accordance with the above observations and analyses, no matter because of structural destroying which caused escaping or the impact on head and neck, the reason is that the impact energy is concentrated on the weakest parts, perhaps the fasten joints on safety belt or safety seat without strong structure, in extremely short time. Thus the blame that using safety seat, but still leads to serious accidents, entirely attributes to the user’s unfastening safety belt or the safety seat without strong structure is not totally true.

Judging from the acceleration curve diagrams of head and chest in the experiment part, the ergonomic safety design made the child dummy reduce the amount of impact. Partial energy had been absorbed and stored due to the ergonomic cushion design. Thus the value of acceleration was significantly lower and the change curve was much smoother. The successive peaks of two group waves should be produced by the restriction of the safety belt that generated a reverse direction of acceleration.

While comparing the first contrast part with the second one, both actions were almost the same before 0.030 seconds. The reason of producing destroying curve is the height of safety seat, which is set on upper part. In other words, the higher seating height will produce the larger compound moment. While comparing the experiment part with the second contrast part, the gravity center of seating in experiment part was higher, which may produce larger compound moment, but the compound moment was effectively absorbed by the ergonomic cushion design. Consequently, no destroying phenomenon arose, and the effective function of new ergonomic design was obviously proved.

CONCLUSIONS

In the current study, the acceleration reduction on the head and neck by using ergonomic safety design is well proved. The followings are several important suggested design principles by using this creative ergonomic seating device:

1. The impact is much smoother by using ergonomic safety design, but the destroying caused by the impact in extremely short time still demands to be noticed. The safety belt, safety seat and other buckles should also have enough

strength in design.

2. A series of locking structure which fastens child to the safety seat must be completely rigid. If the child escaped and flied away from the seat, the design of ergonomic cushion device would be no meaning. To prevent child from escaping is absolutely an essential design.

3. The main function of new ergonomic cushion design is to store, absorb or spread the over concentrated energy during the accidental impact. Because the child and safety seat are in fixed states, we can nearly consider them as a whole. Thus the cushion effect of child's chest and the safety seat is similar. This result means that only if the cushion device can reduce the directions of moment and forward velocity effectively, the position of ergonomic cushion design is not necessary to be in the front of chest.

4. The design of ergonomic cushion device have to notice that the maximum distance allowing for the cushion displacement cannot make the child collide the objects in the front.

5. the magnitude of relative cushion force needed for slowing the impact is not a constant. It is changed by the speed of impact, the total weight of child and safety seat and the distance between the gravity center and the fastening point of safety belt, which is the center of moments. The optimal magnitude is the maximal distance allowing for cushion displacement, which is equal to the maximal displacement produced in the impact. In this way, it allows the energy to be spread in the longest period of time.

6. When the child seats in the safety seat, the weight of child will make a displacement to the ergonomic cushion device and reduce the total cushion distance for absorbing impact force. Thus the design of ergonomic device should also consider the child's weight together to have adjustable mechanism for reaching optimal cushion effects.

7. The technique of structure design accompanying with the new ergonomic cushion design can assist the safety seat to overcome the stability of moving in the same direction while the safety seat produces the phenomenon of displacement. Therefore the destroying to the safety seat caused by uneven forces and injuries to the child can be avoided to a minimum.

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