Global Journal of Researches in Engineering: B
Automotive Engineering
Volume 14 Issue 3 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Drop Damping Seat to Reduce Whiplash Injury in Rear-end Collision

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Abstract- Neck injuries caused by rear end collisions have become a major problem in traffic safety over the last two decades. This situation calls for more research in the field. One area of interest is a damping seat slide to reduce neck injury. To reduce neck injury (Whiplash), based upon new biomechanical research, the motion between head and torso should be reduced. In case of a rear end impact new seat will slide backwards during the impact which allows the motion to damp. Working Model software was used first to simulate and analyse the behaviour of the new system. Also the sled test rig was developed for experimental purposes. The results show occupant protection increases with the new damping seat by up to 75%.

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GJRE-B Classification : FOR Code: 090299

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Drop Damping Seat to Reduce Whiplash Injury in Rear-end Collision

K. Alkhulaifi [α], M. Alardhi [σ], J. Alrajhi [ρ] & A. Abed. [ω]

Abstract- Neck injuries caused by rear end collisions have become a major problem in traffic safety over the last two decades. This situation calls for more research in the field. One area of interest is a damping seat slide to reduce neck injury. To reduce neck injury (Whiplash), based upon new biomechanical research, the motion between head and torso should be reduced. In case of a rear end impact new seat will slide backwards during the impact which allows the motion to damp. Working Model software was used first to simulate and analyse the behaviour of the new system. Also the sled test rig was developed for experimental purposes. The results show occupant protection increases with the new damping seat by up to 75%.

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I. Introduction

Rear-end car collision typically occur in traffic situation with dense traffic and relatively small distances between vehicles in the small lane. Rear-end collisions often result in neck injuries to the occupants of the struck car. During the collision the vehicle is subjected to a forceful forward acceleration and the car occupants are pushed forward by the seat-backs. The head lags behind due to its inertia forcing the neck into a swift extension (rearward binding) motion. This head motion continues until the neck reaches the end of its motion range or, hits a head restraint or some other structure behind the head. From this point on, the head moves forward and stops in a somewhat flexed (forward bent) neck posture. This type of swift injurious extension-flexion motion of the neck (1, 2) and is commonly called "Whiplash motion".

Neck injuries in rear-end collisions mostly occur at very low impact velocities, typically less than 20 Km/h (3,4) and are mostly classified as minor injury (AIS 1) on the abbreviated injury scale (5, 6,7) since the scale classifies injuries according to fatality risk. (8) suggested that the elastic rebound of the seat back could be an aggravating factor for the whiplash extension motion. The rebound of the seat back can push the torso forward relative to the vehicle at an early stage of the whiplash extension motion when the head begins rotating rearward. This in turn increases the relative linear and angular velocity of the head relative to the upper torso at the same time as it delays contact between the head and head-restraint, thus causing a larger maximum extension angle. Subsequent studies support this theory (9,10). If the seat back of the front seat collapse or yields plastically during a rear-end collision, the elastic seat back rebound is likely to be reduced.

To date, the underlying injury mechanism has not yet been established. Several hypotheses have been suggested by various researchers, but are not conclusive. It seams to be generally agreed upon the fact that such injury is related to sudden movement of the head-torso complex (11).

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II. Seat Design for WAD Mitigation

Several seat systems are presented to prevent whiplash injury. Volvo presented the WHIPS seat (12) which is equipped with a recliner that allows controlled backward movement of the backrest during rear-end impact. The motion is performed in two steps: a translational rearwards movement of the backrest is followed by a rotational motion reclining the backrest. Another system, called WipGARD (13), also enables the backrest to perform a translation followed by a rotation. Both the WHIPS and the WipGARD require a critical load to activate the system. The Saab active head restraint (SAHR) system (14), for instance, consists of an active head restraint that automatically moves up and closer to the occupant's head in rear-end impacts. Thus the distance between the head restraint and the head is reduced. The third system is Cervical Spine Distortion injuries (CSD), and the functional principle of the CSD system is based on a defined energy absorption in the backrest. This principle has been employed successfully for a number of years. In standard series seats, the deformation element is located in the recliner. During rear impact, a parallel backwards movement of the seat back begins at a point of critical load, which motion is then transformed into rotation (15). The backwards movement is limited so that the seat back will offer sufficient protection in a high-speed rear impact.

III. Drop Damping Seat

The Drop Damping Seat (DDS) proposal was to develop a mechanism which can be attached to production car seats to reduce the relative motion between the head and lower end of the neck. As stated in the literature [17,18,19] this will reduce the risk of whiplash injury. The DDS was developed to overcome this problem by limiting rearward movement but permitting vertical movement to increase the efficiency of whiplash reduction system. The DDS contains four linkages attached to the seat base and the trolley (car floor). During a change in motion of a vehicle, they provide for a change in position of the seat in the form of rotational dropping movement in a generally backward direction opposite the direction of move of the car (Figure 1). As the seat and the occupant of the seat move rearward relative to the car, the head of the occupant accelerates over a longer time. The design was found to work in a satisfactory manner, without the risk of the seat pivoting rearward as in a standard motor vehicle seat.

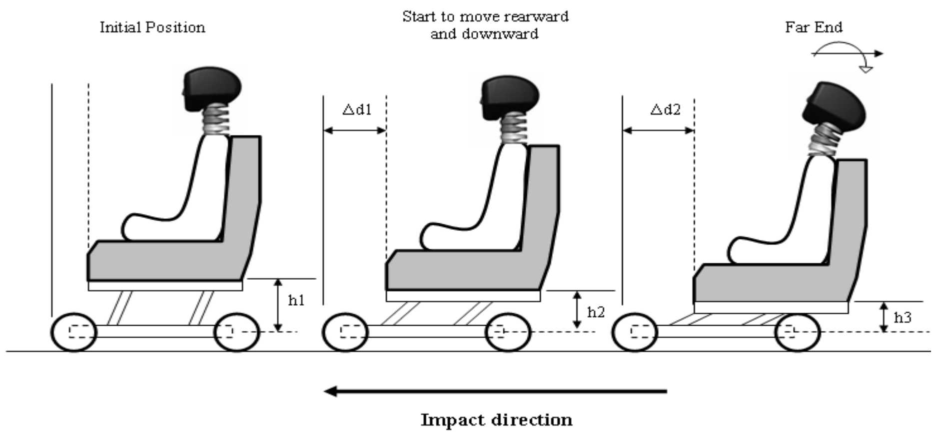

Figure 1 : Drop damping seat during rear-end impact

Different vehicle protection systems have been proposed including those dependent on inertia and those with power drive. Inertia type devices are reactive to inertial forces. Power-derived safety devices have many disadvantages. They require that a sensor react to an event and start an action. Such requirements need exact timing and can fail to perform within the time period available, or at least can fail to perform soon enough for the device to do its job within that period of time. Also, power-operated safety devices are very costly and have a number of mechanisms that can fail. By contrast, on vehicle impact, the DDS reacts completely to the inertia of the vehicle seat to begin its action, the device functions instantly in reaction to the shock force of a rear-end impact. The present device is not expensive and has only a few parts and as well it is maintenance free (Figures 2 and 3).

The DDS generates a movement of the seat that dissolves the backward energy of the occupant by moving the occupant downward as well as rearward. This movement increases both the distance and time of travel of the occupant and reduce the head acceleration, and there is minimum head snap or whiplash injury. The seat motion is controlled by four identical linkages with pivotal connections between the trolley (vehicle floor) and seat base frame. The initial linkage angles should be less than 90°to insure the rearward and downward motion (not rearward and upward as would occurs if the angle is more than 90 degree) Figure 2. One target is that the DDS start motion of the seat at the instant acceleration of the rear-end impact begins. An additional objective is that the DDS maintains the controlled seat motion for the length of acceleration of the occupant.

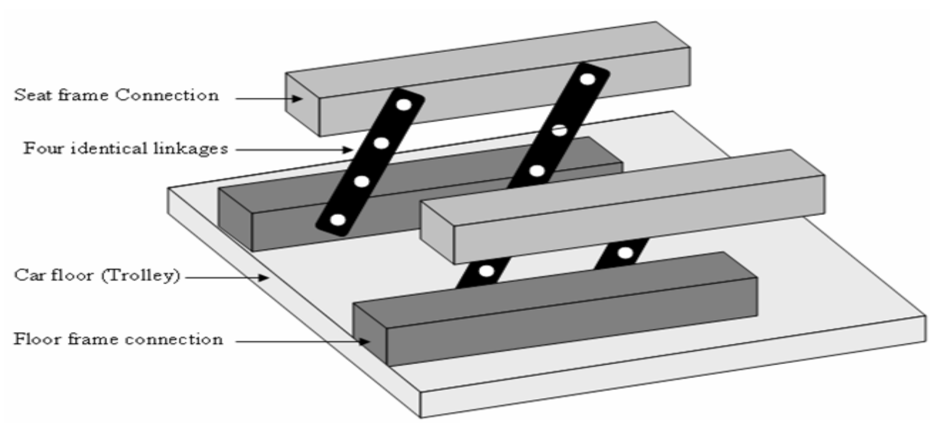

Figure 2 : Schematic drawing of the linkage arrangement

Figure 3 : Drop damping seat, (a) showing the linkages (b) the motion of the system during rear-end impact

IV. Method

The Working Model dynamic simulation program was used to study the effect of stander seatback compared with Drop Damping seat during the rear-end impact.

To analyze whether the new drop damping seat offers the possibility of preventing neck injuries, sled test were performed. The sled test rig was designed and developed to validate the simulation model and to be flexible for different verity of rear-end impact test such as head restraint position or seatback stiffness.

V. Experimental Results

The experiment results show a comparison between DDS results with RS and LDS. The sled test accelerations of the head have been plotted against time. The Hybrid III head-neck complex was used with and without the car seat on the sled test rig. The results from the DDS compared to the RS and LDS are shown in Figures 4, 5 and 6.

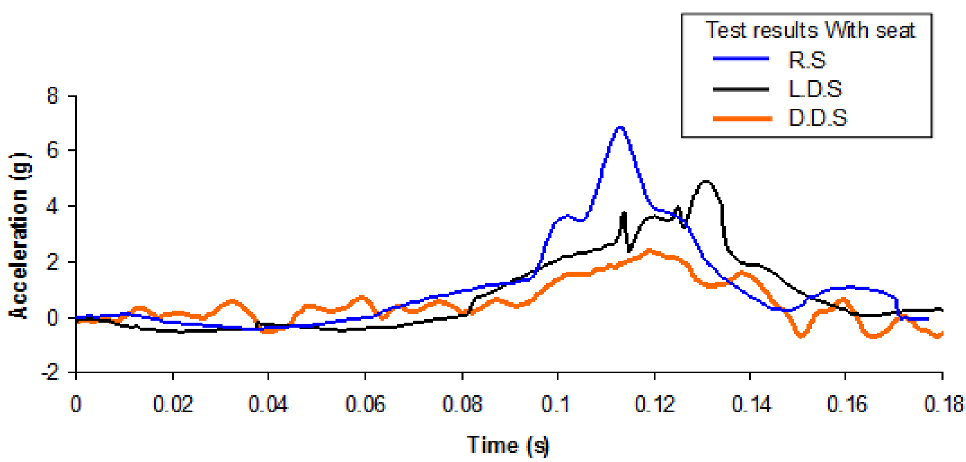

Figure 4 : Test results comparison between RS, LDS and DDS with seat at 14km/h-4 g

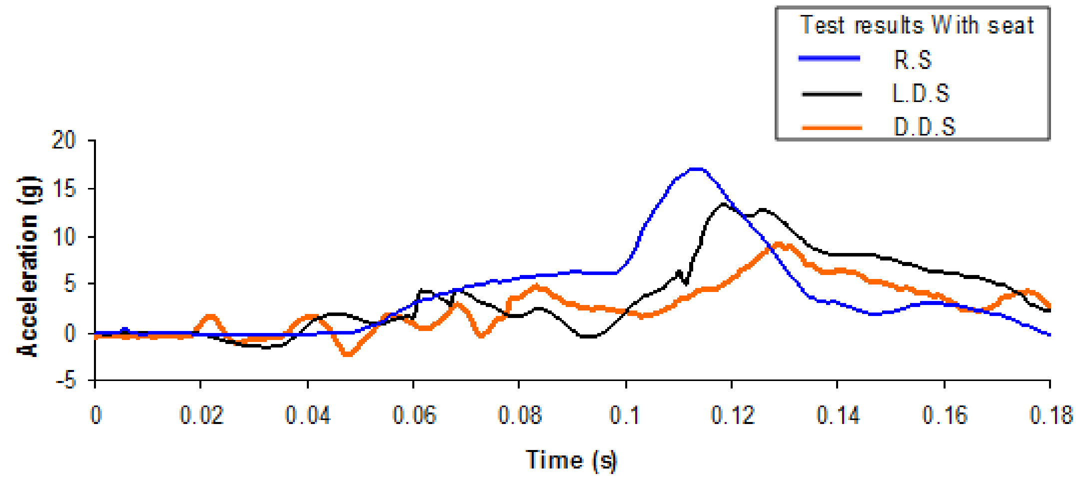

Figure 5 : Test results comparison between RS, LDS and DDS with seat at 18km/h-4 g

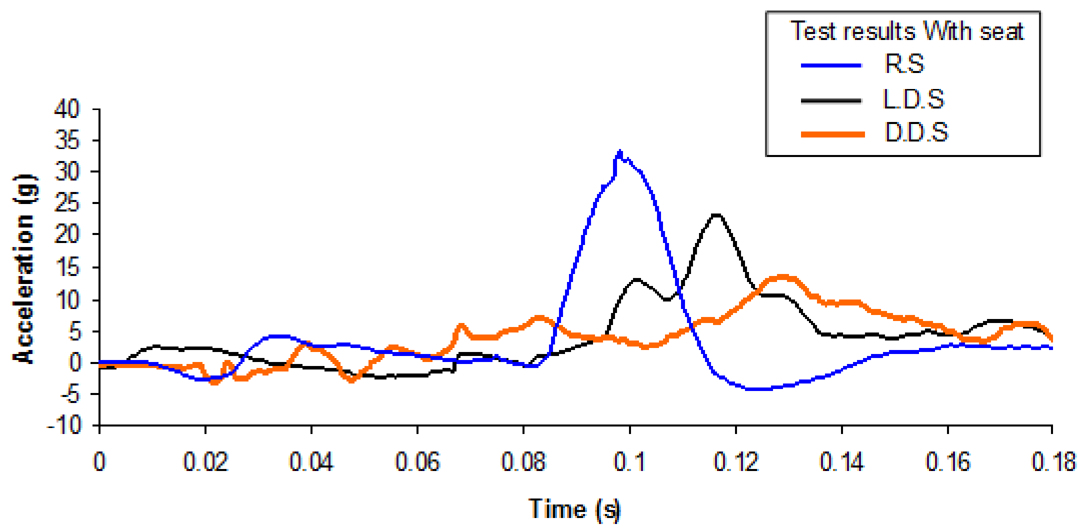

Figure 6 : Test results comparison between RS, LDS and DDS with seat at 18km/h-7 g

During rear-end impact, the both rearward and downward movements of the DDS were occurred. The results for the head acceleration peak values are 2.5 g at 120 ms, 9 g at 131 ms and 14 g at 129 ms as shown in Figures 5-34, 5-35 and 5-36. These figures also compare the DDS with the RS and LDS results. The results indicate major head acceleration reductions by using the DDS for the same sled conditions with respect to RS and LDS. Figure 5-37 summaries the head acceleration results for RS, LDS and DDS, and shows that the amount of head acceleration ranges from 47 % up to 64 % with respect to RS. This significant reduction was due to the energy absorbed by the DDS system.

In general the DDS results show a significant reduction in the head acceleration peaks for all sled test results. Also the gradual rise of the head acceleration as shown (Figures 4, 5 and 6) are due to the kinematic motion of the DDS.

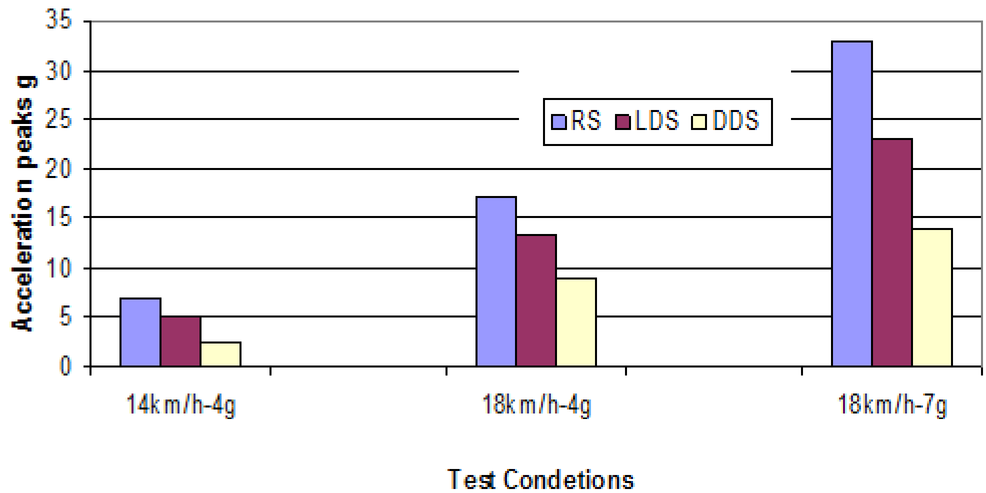

Figure 7 : Sled test head acceleration peaks results comparison between LDS, DDS, and RS (with seat)

VI. Conclusions

The new Drop Damping Seat design for reduction in whiplash injuries, allows less motion between head and torso as shown in the experimental results (trail sled tests), linear damper shows lessen the movement of the neck (spring) extension. A comparison between three cases is created to show the effect of DDS on reducing the neck acceleration during impact.

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