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Review on Whiplash Protection System

Prof.Anup M.Gawande[1] , Mr.Akshay D. Dasarkar[2],

[1] Asst. Prof. Mechanical Engg Dept, STC SERT, Khamgaon, Maharashtra, India

[2]UG Student of Mechanical Engg STC SERT ,Khamgaon, Maharashtra, India

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Abstract- *Neck injuries resulting from rear end car impacts have attracted increasing attention in recent years. Although usually not life-threatening these injuries can have long-term consequences. The exact mechanism of injury has not yet been established. Several probable mechanisms occurring at different phases during the crash sequence have been suggested by researchers. Biomechanical guidelines and test methods are presented, being part of the results of Volvo's Whiplash Protection Study (WHIPS). The biomechanical guidelines are based on an extensive review of accident experience and biomechanical research aimed at reducing the risk of neck injuries in rear end impacts.*

Neck injuries resulting from rear end car impacts have attracted increasing attention in recent years. Although usually not life threatening these injuries can have long-term consequences. The exact mechanism of injury has not yet been established. Several probable mechanisms occurring at different phases during the crash sequence have been suggested by researchers. Biomechanical guidelines and test methods are presented, being part of the results of Volvo's Whiplash Protection Study (WHIPS). The biomechanical guidelines are based on an extensive review of accident experience and biomechanical research aimed at reducing the risk of neck injuries in rear end impacts.

Introduction

Neck injuries, often called whiplash injuries or whiplash associated disorders (WAD, Spitzer et al. 1995) and classified as AIS 1 (AAAM, 1990) are not life threatening, but nevertheless are the most important injury category with regard to long-term consequences (Nygren 1984). Statistics from several countries have reported an increase in the occurrence of neck injuries during the last decades. (Ono et al. 1993, van Kampen 1993, von Koch et al. 1994 and Morris et al. 1996). Due to their long term consequences, these injuries are very costly for society (v Koch et al. 1994). Consequently, there is much to gain in terms of avoidance of human suffering and costs for society by reducing the occurrence of AIS 1 neck injuries. the aim of reducing the risk of neck injuries in rear end impacts .The working name for the study was Whiplash Protection Study, with the experiences from accident research and computer modelling with existing biomechanical knowledge, summarized into three biomechanical guidelines, see Figure 1. In order to be able to evaluate design concepts, the biomechanical guidelines are broken down into engineering requirements and test methods.

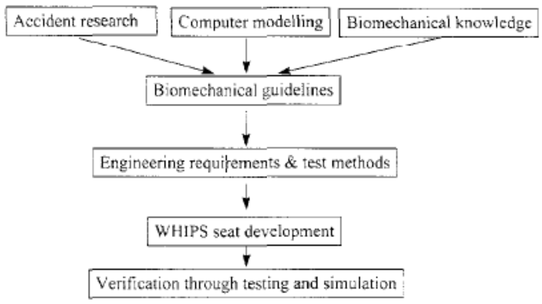

Figure 1. Volvo's Whiplash Protection Study (WHIPS)

The Volvo Whiplash Protection Study has previously been described in detail by Lundell et al. (1998). This paper focuses on the seat design and test performances of the WHIPS seat. As an introduction, the background for the requirements is briefly described comprising mainly accident research and the biomechanical guidelines. The WHIPS seat will come into production in the new S80 Volvo model which is introduced in 1998.

Accident Research

AIS 1 neck injuries (also called whiplash injuries) are I reported in all crash configurations (Morris et al. 1996 and Jakobsson, 1997). However, the risk of sustaining a neck injury is higher in rear end impacts as compared to other crash types (Morris et al. 1996). Volvo accident data indicates a neck injury risk for rear end impacts which is approximately double the rate for frontal or side impacts (Lundell et al. 1998). The frequency of different bodily injuries in rear end impacts is shown in Figure 2. The subset of 605 belted drivers, in Volvo 700 and 900 models between 1985 and 1995 (Volvo Accident Data Base, ref. Lundell et al. 1998).

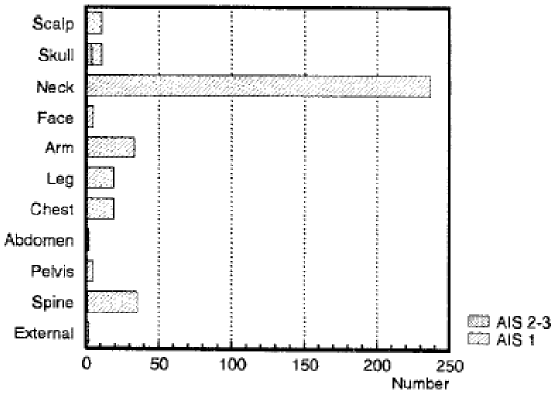

Figure 2. Injury distribution for rear end impacts.

As can be seen in Figure 2, AI'S 1 neck injuries are by far the most common injury type in rear end impacts .Negron (1984) has reported similar findings. Neck injuries are reported at all impact speeds (Jacobson 1997 and Otte et al. 1997). From accident

Research as well as tests with volunteers, it is shown that people sustain neck injuries frequently even in impacts with very low severity (Olsson et al. 1990, Morris et al. 1996, Sigmund et al. 1997). An example of this was

Presented in Blundell et al. (1998), as show-n in Figure 3. The graph is based on a subset of 1467 belted drivers in Volvo cars involved in a rear end impact. In Figure 3, the injury risk is shown to be almost constant irrespective of the degree of vehicle deformation. Severity measures based on deformation depth are obviously not good predictors of neck injury risks. Other factors, such as whether stiff vehicle structures have been involved or not, have shown to be more related to neck injuries in some studies (Olsson etal. 1990). Figure 3 also tells that in order to significantly help reduce the number of AIS 1 neck injuries in rear end impacts, minor and moderate crash severity must be the main focus since they account for the majority of the Knowledge of the individual differences are important when analysing accident data as well as designing protection systems. Women are more likely to sustain a neck injury in the event of a rear end impact (LSvsund et al. 1988, Spitzer et al. 1995, Kraft et al. 1996, Morris et al. 1996, Minton et al. 1997, Otte et al. 1997, Lundell et al. 1998). There is also an increase of neck injury risk for taller occupants (Lundell et al. 1998). However, this becomes only clear when considering the occupants by gender, since the height distribution for men versus women differs and these two factors interfere. Volvo accident data shows that medium height women are at the same level of risk as tall men (Lundell et al. 1998).

This indicates that the height of the head restraint is not the only issue related to the reduction of neck injuries. Although head restraints are important, the height of the head restraint is, however, not a guarantee that the occupant will not be injured. This is also supported by volunteer tests (Brault et al. 1998) another factor influencing the risk of neck injury in rear end impacts is seating position in the car. Volvo accident statistics report a significantly higher risk of the driver sustaining a neck injury than the passengers (Lundell et al. 1998). Lundell et al. hypothesized that the differences between the driver and front seat passenger could be mainly due to different seating postures. Drivers are probably more prone to bend forward and away from the seat backrest and head restraint than passengers, who are more relaxed and probably more likely to rest their head against the head restraint. The head restraint and risk of neck injury has been shown, both in accident studies (Olsson et al. 1990, Jakobsson et al. 1994) as well as in studies based on tests with volunteers (Deutscher 1996).

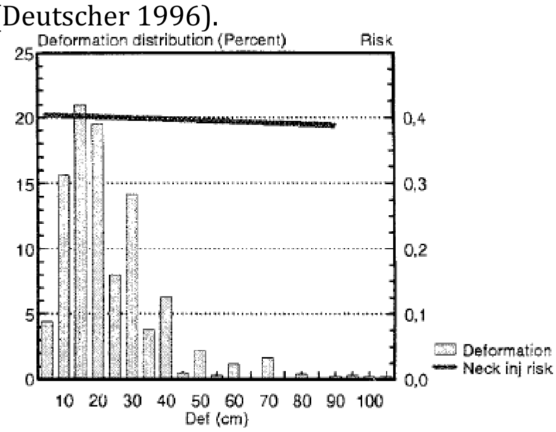

Figure 3. Vehicle Deformation Distribution and Neck Injury Risk vs. Vehicle Deformation.

Also, several studies indicate that the front seat occupants are at a higher risk than rear sea occupants (States et al. 1972, Carlsson et al. 1985, Lovsund et al. 1988). One reason for this could be a more rigid, uniform and less elastic design of the rear seats than the front seats.

Accident studies have found that lumbar spine injuries occur together with cervical spine injuries (Minton et al. 1997). The exact relationship is not stated, but it stresses the importance of regarding the whiplash problem as an issue concerning the whole spine, and thus neck injury protection systems must include the support of the whole spine.

There are some studies indicating that the seat belt system increases the risk of neck injury (Spitzer et al. 1995, Morris et al. 1996, v. Koch et al. 1995, Kraft et al. 1996). This may be so, in some cases, but rather than discussing what to do about the seat belt system in a rear end impact, the objective should be to design a system that will help reduce the occupant's rebound into the seatbelt. The WHIPS study is based mainly on experience from accident research. More than ten years of on cent rated effort by Volvo, on the study of whiplash, has shown that it is important to consider the whole spine of the occupant and. accordingly, the whole seat when addressing whiplash injury resulting from rear end impact. Minor and moderate severity crashes should also be focused on in order to achieve a true injury reduction in real world accidents. The individual differences between occupants (gender, height and other), the seating position and the variety of seating postures must also be considered in order to get a true injury reduction in real world accidents. All these areas were considered when defining the design guidelines, as presented below, and when the guidelines were broken down into requirements .

The Whips Seat System

In the Whiplash Protection Study, the above requirements were used to develop a new seat concept. The new concept is based on a production Volvo seat. The WHIPS system in the seat consists of two new recliners, together with a modified backrest and head

Restraint. These are further described below. The WHIPS recliner is designed to give a controlled rearward motion of the backrest in a rear end impact. For this purpose, the production recliner was modified by adding the WHIPS mechanism. In a rear end impact of sufficient severity the WHIPS mechanism is activated and then controls the motion of the backrest in relation to the seat base. This motion may be divided in two phases, as shown schematically in Figure 4.

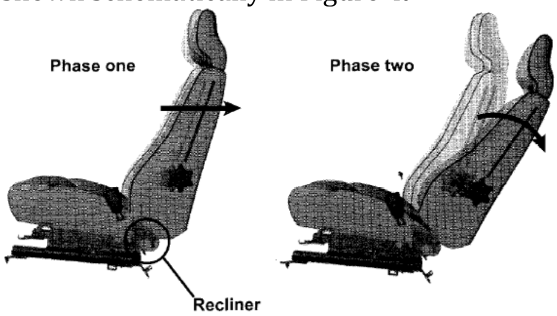

Figure 4. The WHIPS seat motion.

The two phases are actually, in most cases, overlapping to some extent. The degree of overlap depends upon several parameters such as occupant weight and posture, and also impact severity. A more detailed description of the two phases follows below.

In a rear end impact, the seat is accelerated forward with the car. Due to the inertia of the occupant, the back of the occupant is then pressed into the seat. When the forces from the occupant acting upon the seat backrest exceed a certain level, the WHIPS system will be activated. Hence no external sensor system is needed to activate the WHIPS system. The purpose of the first phase is: 1) to let the occupant sink into the seat, thereby reducing the distance between the head and the head restraint, 2) to create an initial rearward motion of the backrest which does not move the head restraint away from the head, and 3) to keep occupant acceleration levels low, by letting the backrest move rearwards in a controlled way. This is accomplished by the first phase being a rearward motion of the seat backrest, the nature of this motion being essentially translational, i.e. without rotation. However, depending upon the pre-impact posture of the occupant, the motion characteristics of the backrest are to some extent adaptable and adjust to the occupant's position relative to the backrest. For example, if the occupant is leaning forward before impact, this may give an initial tilt-forward motion of the backrest. The purpose of the second phase is to limit occupant acceleration to a low level.

Testing

During the development of the WHIPS seat, both sub-system testing and sled testing was used. Mathematical simulation was also used as an important tool. In the sled tests, presented below, the 50th percentile Hybrid III dummy was used. One reason for using the 50th percentile dummy was that, apart from it representing a mid-size male it may also, to some extent, be assumed to represent a tall female. Tall females were shown in the accident studies to be at higher risk. Tests were also run with the 5th percentile female and the 95th percentile male dummies.

Other Aspects of the WHIPS Seat

In addition to what has been described above, the seat has the same strong structure as Volvo production seats. These seats are several times stronger than required by the existing legal requirements for seat backrest strength. This is accomplished partly by having recliners at both seat sides. The new recliner matches the strength of the existing backrest, meaning that the high speed crash performance has not been compromised by the new design. Thus, there is no increased risk in rear impacts, neither for the occupant of a front seat nor for adult or child occupants of a rear seat. This also applies to frontal impacts, when the seat backrest may be loaded from the rear, e.g. by luggage on the rear seat. The modified seat backrest is also equipped with the same side impact protection system (SIPS) as the standard seat.

Manufacture

The WHIPS recliner is assembled by the system supplier (Autoliv Sverige AB). The recliners are welded to the backrest by the backrest manufacturer (Autoliv Mekan AB), and the complete backrest is assembled to the seat by the seat manufacturer. Each recliner is given its own individual number for the tracking system. The parts of the recliner are linked batch by batch to the individual number.

Sleb Test Results

Several parameters were studied in the tests. As explained above, low acceleration was chosen as a major criterion. The lower neck horizontal acceleration was chosen to be displayed here.

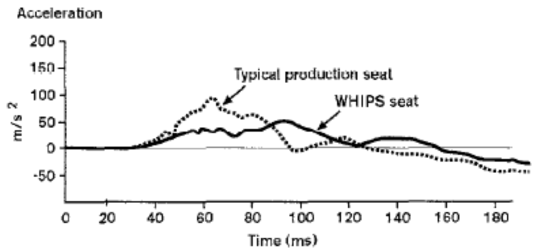

Figure 8. Sled test results, lower neck horizontal acceleration; Δv 10 km/h.

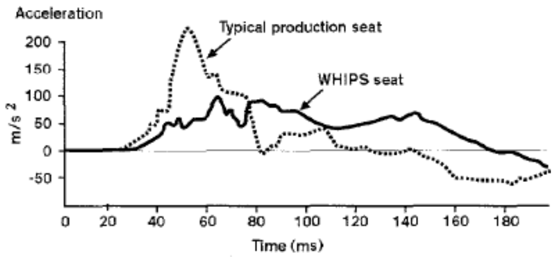

Figure 9. Sled test results, lower neck horizontal acceleration; Δv 20 km/h.

Sled test results are shown for a Av of 10 km/h in Figure 8, and for a Av of 20 km/h in Figure 9. The results show that the acceleration peak value decreases by approximately 40% - 60% as compared to a typical production seat, under the same test conditions. The sled testing also confirmed that forward rebound towards the end of the impact is reduced.

Discussion

the procedure for the Whiplash Protection Study follow the whole chain; from the accident research and biomechanical knowledge; the interpretation of this knowledge condensed into guidelines and requirements; and finally seat development, validated by testing. We consider that this method represents a unique and holistic approach, which gives a considerable strength to this study. The study has focused on the whole seat, and not only the head restraint. This is important, since the Motion of the whole spine affects the neck. and also for the reason that the exact injury mechanism is not known. When developing the WHIPS seat, a very important rule has been to address all aspects of the biomechanical guidelines. Increased responses of any kind should b avoided, since reductions in other responses may be

Countered and no real positive effect achieved.

The sled test results presented should be regarded as an indication of how- much reduction may be achieved. Thresholds cannot be determined due to the nature of the requirements. There are only a few test results presented in this study. More measurements, different dummy sizes and seating postures were included in the holistic approach, combined with engineering evaluation, sub system testing, mathematical modelling and geometrical requirements, in order to know that injury reduction could be achieved. The results are consistent in giving reductions in line with the guideline parameters, thus leading to a reduced risk of injury.

Conclusions

In this study the WHIPS seat for improved whiplash protection was developed. The new seat is based on a production seat, and comprises two new recliners, together with a modified backrest and head restraint. The development of the new seat was part of Volvo's Whiplash Protection Study (WHIPS). The seat backrest was locally modified to give a more even force distribution along the spine of the occupant.

The head restraint was modified to be positioned somewhat closer to the head and also somewhat higher. The new seat recliner was designed to be activated in

Case of a rear end impact, and to operate primarily in low to moderate impact speeds, w-here many whiplash injuries occur. The WHIPS recliner is activated by the forces from the occupant, without any external sensor system. The seat backrest will move, together with the occupant. in two phases.

Phase one is essentially translational motion, improving the closeness and support of the occupant's back and head. The second phase gives a rearward reclining of the backrest, mainly to reduce acceleration and forward rebound by plastic deformation of a metal element in the recliner. Test results presented in this paper show that the WHIPS seat reduces peak lower neck horizontal accelerations approximately by half Further, the WHIPS seat reduces forward rebound. The WHIPS seat also gives improved closeness as well as improved distributed load support of the back and head. All results, including sub system testing, mathematical modelling, and sled testing as well as geometrical parameters show that the WHIPS seat will

have a considerable potential for offering increased protection against neck injuries in rear end impacts.

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