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Passenger head in impact with frontal airbag in OOP postures

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Abstract. Road accidents represent an aspect of road traffic that may lead negative consequences. In order to solve the problems associated with such events, interdisciplinary knowledge is called for, complex teams of engineers, doctors, lawyers, experts working together in order to reduce the severity of such events. Road safety is a continuous concern for both experts and various government organizations with the aim of protecting the lives of the participants in traffic. It has been estimated that the costs of traffic accidents account for 1-3% of a country GDP, depending on the level of country development [26]. In this paper we analyze a particular class of cases of injuries caused by the inflation of the frontal airbag when they are with the passenger out of position. Head kinematics, accelerations, as well as the severity of injuries expressed by HIC, as related to the AIS scale have been analysed.

1. Introduction

Most of the participants in road traffic, occupants of a vehicle, use the seat belt and have a correct sitting posture in the chair. Nonetheless, there are situations when occupants do not wear a seatbelt or when their attention is diverted for various reasons and they are not correctly sat positioned in the chair. An imminent accident occurred at such a time usually has serious consequences upon the state of injury of vehicle occupants.

Occupants' posture called Out Of Position (OOP) increased risk of severe and lethal injury. In vehicle crash testing this term indicates a passenger position which is not the normal upright and forward-facing position, [9]. For example, a common case observed in crashes is the position of an occupant when reaching for the car radio, [16], or panic braking in unbelted passengers [25].

The concept is of interest because small changes in a passenger's position can have profound effects on the actual kinematic response, especially in rear impacts, as shown both by practical testing and theoretical models, [9].

According to Huelke, women and shorter drivers are more likely to receive facial injuries from an inflating airbag. Nearly 42 % of the female drivers in the sample suffered facial injuries from a deploying airbag, as compared with about 24 % of the male drivers. Likewise, half of the drivers under the height of 5'5" received facial injuries, while only about 18 percent of drivers under 5'11" or taller suffered facial injuries. [10].



There have been multiple reports of head and neck injuries related to airbags. The injuries in the head-neck area include facial trauma, [15], cervical spine fractures [12], [2], mandibular joint injury, [13] and even decapitation [11]. In addition, soft tissue injuries are also seen, including damage to the blood vessels, [7], [8], [17]. The eye seems to be particularly vulnerable to injury, especially if spectacles are worn [5]. Injuries include orbital fractures, [3], retinal detachment, [18] and lens rupture, [21]. The chemicals involved in inflating the bag have been implicated in eye injury [19], as have the cover components [6].

Similarly, there have been numerous reports of injuries directly attributable to airbags, with some calls for them to be removed or deactivated. While accepting that these injuries occur, most (up to 96%) are comparatively minor. Most occur with the larger system used in the US, although UK airbags have been associated with a wide range of injuries [22]. In this paper we analyzed the effects of airbag inflation through the injuries caused to the occupant's head, considering two seating postures of the passenger in a vehicle.

2. Method

About 85 % of vehicles involving in accidents are passenger cars, [20]. The first case refers to overweight people who tend to position the car seat as back as possible in order to have a relaxed posture during traveling. The second case shows the car seat positioned forwards toward the dashboard, providing a more cramped seating posture. In both cases we considered fixed seating positions, with the passenger not leaning back in his/her seat back but bent towards the dashboard at various distances from it, according to the scenarios reported in [16] and [25]. In both cases analyzed the occupant sizes were the same. Seven experimental tests have been carried out.

The seating posture of the passenger dummy was selected to represent a position which is not default but also not less realistic. Such a posture for example can occur when the passenger is looking for something in the glove box. Other, in some cases more extreme seating positions were proposed by the automotive industry for evaluating out-of-position vehicle occupant's interactions with inflating air bags.

The risk of injuries induced by the air bag increases in cases of extreme out-of-position situations [1]. Considering the vehicle stationary, the upper torso of the passenger is bent forwards at various distances from the dashboard, the airbag is triggered, inflating and hitting the face of the passenger who is in a out-of-position posture.

The dimensions and kinematics of the test device are meant to replicate unbelted adult passenger who is to an OOP posture.

In all cases studied it is noticed that in the first stages of airbag deployment, the airbag is projected like a lash towards the occupant's face. Although high levels of accelerations are not recorded (at this moment), this hit may cause injuries to the eyes and the soft tissues of the face, like in [5], [3], [18], [21].

The sudden changes in acceleration, as noticed on all three axes of measurement, ranging from negative to positive values, indicate a strong effort which can cause serious damage to the brain by shaking and extruding it out of the skull. Similarly, these accelerations are transmitted towards the cervical vertebrae that they can damage along with the spine.

For the calculation of HIC, in accordance with regulations from [4] we may use as a domain the entire duration of impact, lasting for 36 milliseconds, that is a HIC36 and an impact duration of 15 milliseconds, that is HIC15.

$$HIC = \max_{t_1, t_2} \left\{ (t_2 - t_1) \cdot \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t) dt \right]^{2.5} \right\} \quad (1)$$

where

$$a = \sqrt{a_x^2 + a_y^2 + a_z^2} \quad (2)$$

is the resultant acceleration of the center of gravity of the head, measured in (g) units and t1, t2 is the time limits of crash, in second, for which the HIC is maximum.

According to European Regulation ECE/96/79 $HIC_{36} \leq 1000$ and the resultant acceleration ≤ 80 (g) for an impact duration of 3 milliseconds.

3. Results

3.1. Cramped sitting posture

The acceleration chart reveals that the time zero was the trigger marking the hit given by the deploying airbag as felt by the head (lash). Thus, a correlation with the value of the maximum impact is noticed, depending on the distance between the head and the dashboard (passenger airbag). Therefore, for a distance = 240 mm the maximum impact occurs in the range 0-20 ms, for a distance = 280 mm the impact has maximum intensity and it occurs in the range 20-40 ms. For a distance = 310 mm maximum impact is felt in the range 60-80 ms. For a distance = 340 mm it is noticed that the hit was of minimum intensity.

For the cramped sitting posture the maximum head acceleration is obtained at a distance of 280 mm from the dashboard (airbag). The value of the HIC criterion was calculated and summarized in Table 1.

The maximum duration of impact between the deploying airbag and the occupant's head is of about 20-25 ms for this posture, depending on the distance between the head and dashboard, figure 1.

Table 1 Cramped sitting posture

Pos.	F=240 mm	F=280 mm	F=310 mm	F=340 mm
Values	axmax(g) =49.8	axmax(g) =111.4	axmax(g) =86	axmax(g) =19.4
	aymax(g) =18	aymax(g) =228.3	aymax(g)=108.8	aymax(g) =4
	azmax(g) =33.4	azmax(g) =86.5	azmax(g) =40	azmax(g) =5
	axmin(g)=-117.2	axmin(g) =-133	axmin(g) =-75.4	axmin(g) =-16.8
	aymin(g) =-74.9	aymin(g) =-96.3	aymin(g) =-66	aymin(g) =-12
	azmin(g) =-61.4	azmin(g)=-293.4	azmin(g) =-33.4	azmin(g) =-25.4
	amax(g)=132	amax(g)=348	amax(g)=132.6	amax(g)=28
	HIC =198	HIC =1360	HIC =290	HIC =12
	40 ms	40 ms	40 ms	40 ms
	HIC36 =200	HIC36 =1520	HIC36 =315	HIC36 =14
HIC15 =248	HIC15 =3240	HIC15 =470	HIC15 =8.5	

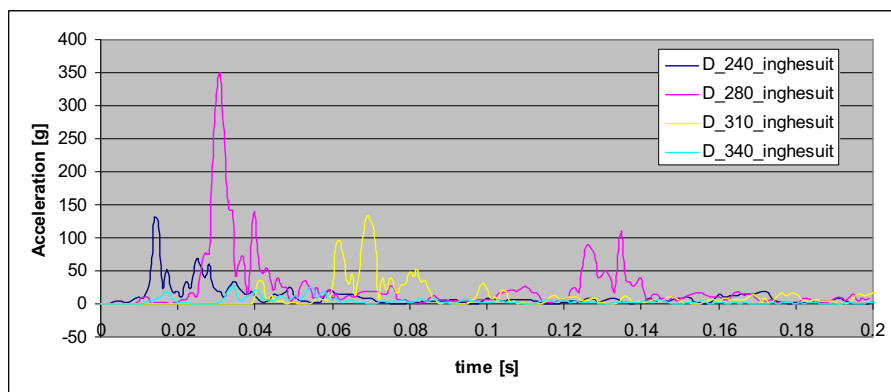


Figure 1. Resultant head acceleration for cramped sitting posture

At a distance of 340 mm the level of accelerations is minimized, in this case the occupant's head being only easily touched by the airbag, as there is not a strong flexion/extension of the neck like in other cases.

3.2. Relaxed sitting posture

In this case the inclination angle of the mobile arm of the test bench is greater, as related to the normal sitting position (with the back leaning against the seat back), figure 2.



Figure 2. Inclination of mobile arm in the two cases

Similar to the previous case, the time zero was the trigger marking the hit given by the deploying airbag as felt by the head (lash). Thus, a correlation with the value of the maximum impact is noticed, depending on the distance between the head and the dashboard (passenger airbag). Therefore, for a distance = 240 mm the maximum impact occurs in the range 20-55 ms, for a distance= 280 mm the impact has maximum intensity and it occurs in the range 25-70 ms. For a distance = 340 mm it is noticed that the hit was of minimum intensity.

For the relaxed sitting posture the maximum head acceleration was also obtained at a distance of 280 mm from the dashboard (airbag). The value of the HIC criterion and of both maximum and minimum acceleration was summarized in Table 2.

Table 2 Relaxed sitting posture

Pos.	F=240 mm	F=280 mm	F=310 mm	F=340 mm
Valuess	axmax(g) =38.3	axmax(g) =50.7	axmax(g) =n/a	axmax(g) =30.7
	aymax(g) =90	aymax(g) =49.3	aymax(g) = n/a	aymax(g) =17.9
	azmax(g) =92.3	azmax(g) =98	azmax(g) = n/a	azmax(g) =50.7
	axmin(g) =-95.5	axmin(g) =-62.4	axmin(g) = n/a	axmin(g) =-15.8
	aymin(g) =-29.8	aymin(g) =-70.8	aymin(g) =n/a	aymin(g) =-30.4
	azmin(g) =-58.4	azmin(g)=-122.3	azmin(g) =n/a	azmin(g) =-42
	amax(g)=121	amax(g)=133.6		amax(g)=51.8
	HIC =605	HIC =450		HIC =84
	50 ms	50 ms		50 ms
	HIC36 =550	HIC36 =545		HIC36 =70
	HIC15 =390	HIC15 =338		HIC15 =47

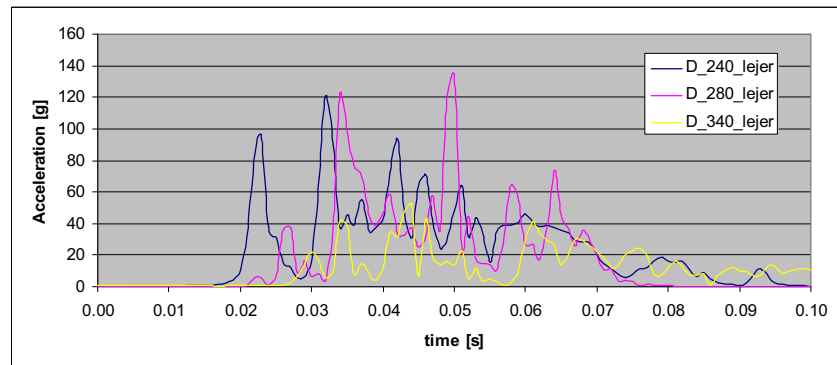


Figure 3. Resultant head acceleration for relaxed sitting posture

The maximum impact duration between the deploying airbag and the occupant's head is of about 40-45 ms for the relaxed sitting posture of the occupant in the car seat, figure 3.

4. Conclusions

The analysis of the two OOP sitting postures shows that the cramped posture causes greater injury to the occupant when the distance between the occupant's head and the dashboard is 280 mm.

For extreme postures at 240 mm and 340 mm from the dashboard, the cramped posture causes HIC values that are slightly lower than in case of the relaxed posture at same distances to the dashboard.

Impact duration between airbag deployment and dummy's head is shorter in the cramped sitting posture, which is reflected by the higher level of head acceleration.

In order to reduce the accidents injuries to vehicle occupants, found in OOP, an important role is held by the road traffic education, not only for drivers but also for passengers. Thus, education campaigns should be organized in this respect from an early age, educating young people in schools and not only.

Future advances in airbag technology will help to reduce injuries caused by these devices, but will need to be implemented in conjunction with advances in other restraint and sensing systems to be most effective, (Wallis and Greaves, 2002) [22].

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