WRIST AND ELBOW LOADING DURING SIDE AIR BAG DEPLOYMENT

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INTRODUCTION

While automobile side air bags are designed to reduce primarily the risk of thoracic and head trauma in a side impact, their deployment may result in an increase risk upper extremity injury. These injuries may occur in normally positioned occupants whose upper extremity occupies the space needed for the side air bag. Experimental tests with human cadavers and side air bags have illustrated the risk of wrist fractures as the hand may become entrapped in a door mounted hand grip (Jaffredo,1998). Additional testing has elucidated the risk of chondral and osteochondral fractures in the elbow (Duma, 1998). In order to investigate these injury mechanisms and design side air bags that may reduce the risk of wrist and elbow injuries, the kinematics and kinetics of side air bag interaction with the upper extremity must be established. The purpose of this paper is the quantify the loads on the wrist and elbow during side air bag deployment.

METHODOLOGY

Data was collected from side air bag deployments onto a newly designed dummy upper extremity. The tests were conducted in a static environment using an automobile test buck. Computer simulations were used to identify the worst-case position for upper extremity loading (Figure 1). Three seat mounted, thoracic side air bags were used that varied only in their level of inflator output and were labeled A, B, and C with increasing aggressivity respectively. The air bags were prototypes intended for use in a luxury sedan, which contained flexible interior door surfaces with minimal padding.

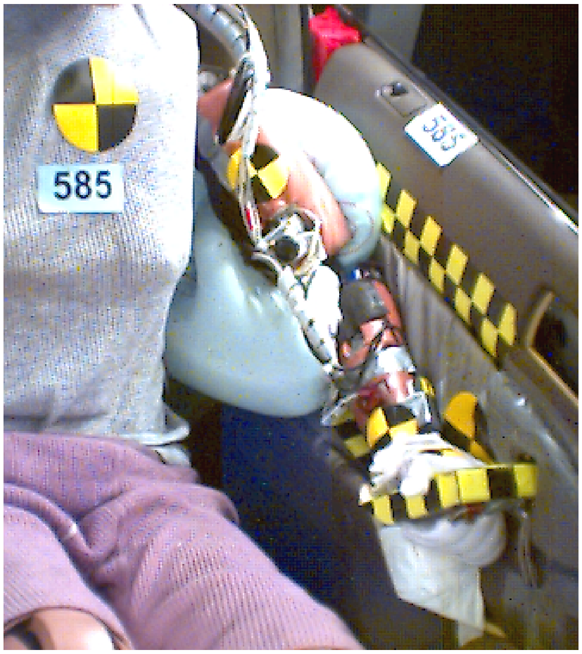

Figure 1. Oblique view of the side air bag loading the upper extremity 15 ms after deployment initiation.

The HIII 5th percentile female dummy was used with the corresponding instrumented 5th percentile upper extremity. Given that previous side air bag simulations illustrated the importance of forearm pronation to accurately model the handgrip interaction, the dummy upper extremity was designed to allow for forearm pronation (Duma, 2000). Instrumentation included a six-axis load cell in the humerus and the forearm. A two-axis load cell was added to the distal forearm to measure wrist bending moments. Internally mounted potentiometers measured forearm flexion and forearm pronation. Accelerometers and magnetohydrodynamic angular rate sensors on the forearm, humerus, and spine were used to track the upper extremity kinematics.

RESULTS

In all tests, the air bag deployed through the seat seam and drove the humerus and forearm forward, thereby forcing the hand into the handgrip. Although the handgrip interaction for each test was slightly different, the overall upper extremity interaction patterns were similar.

In contrast to previous experiments without a handgrip, the experiments with a handgrip resulted in a double peak in the forearm axial load from the inertial loading as well as contact with the handgrip (Figure 2).

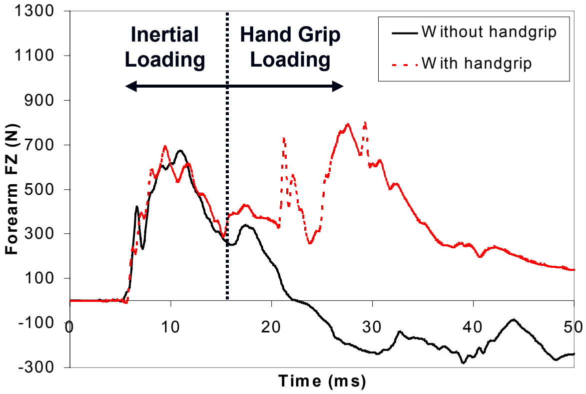

Figure 2. Forearm axial force for tests with and without a door mounted handgrip.

The forces at the wrist and elbow were calculated from the forearm load cell, accelerations, and masses (Table 1). The elbow axial force was the summation of the mid-shaft load cell axial force (FZ) and the forearm axial acceleration (AZ) multiplied by the 0.74 kg, or the approximate mass of the forearm portion between the elbow and center of the forearm load cell. The wrist resultant force was determined by inertially compensating the X, Y and Z axis forearm load cell recordings for the 0.47 kg portion of the forearm between the load cell and the wrist. Unlike the elbow axial load, all three of the inertially compensated wrist loads were included because the interaction of the wrist with the handgrip included significant off-axis loading. The elbow axial and wrist resultant forces are presented with positive polarities indicating an applied compressive load to the elbow or wrist respectively.

Table 1. Upper extremity loading summary.

Test	Air Bag	Humerus Resultant Bending Moment (Nm)	Elbow Axial Force (N)	Wrist Resultant Force (N)
1	A	38	925	1019
2	B	74	1660	1021
3	C	94	2439	1415

DISCUSSION

As expected, the upper extremity loads increased with the increasing air bag aggressivity. For all tests, the humerus resultant bending moments were well below the established dynamic injury tolerance of 128 Nm and did not indicate a risk of humerus fracture (Duma, 1999). For air bag C the peak elbow load was 2439 N and peak resultant wrist load was 1415 N. While the dynamic injury tolerances for these joints are not well defined, it is anticipated that these loads are sufficient to result in the elbow in wrist injuries observed in similar cadaveric testing. This test data will allow the designer to minimize the risk of upper extremity injury while keeping the beneficial aspects of the side air bag.

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