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EFFECT OF HEAD RESTRAINT POSITION AND NECK INJURY CRITERIA IN REAR IMPACT

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ABSTRACT

The objective of this study was to determine the forces and bending moments at the top of the Hybrid III dummy neck secondary to rear impact acceleration and evaluate the various proposed injury criteria. Rear impact sled tests were conducted by applying the Federal Motor Vehicle Safety Standards FMVSS 202 acceleration pulse. Differing positions of the head restraint in terms of height (750 and 800 mm) and backset (zero, 50, and 100 mm) were used to determine the axial and shear forces, bending moments, and injury criteria (NIC, N_{ij}, and N_{km}). The time sequence of attainment of these parameters was determined along with peak values.

INTRODUCTION

Anthropomorphic test devices, i.e., dummies, are often used to assess injury-mitigating characteristics in a vehicular environment. Mechanical responses such as forces and bending moments are recorded using dummies in simulated impacts such as sled tests. Rear impact simulations using dummies involve a measurement of these variables at the top and bottom of the dummy neck along with the documentation of dummy kinematics using high-speed cameras. Injury criteria are derived using these responses as a basis. The objective of this study is to determine the forces and bending moments at the top of the dummy neck secondary to rear impact acceleration and evaluate the various proposed injury criteria.

METHODS

The federally approved Hybrid III anthropomorphic test device was used in the study [1]. Tests were conducted using a deceleration sled, and the dummies were placed on a standard automotive seat with head restraint. The seatback was reinforced to increase reproducibility of the results. The dummies were positioned such that the head restraint and the back of the dummy head (termed backset) were at an initial distance of zero, 50, and 100 mm. In addition, the head restraint height was adjusted to 750 or 800 mm. A total of six sled tests were performed at a change in velocity of 21 km/h. Instrumentation consisted of a six-axis load cell placed at the head-neck junction of the dummy to record forces and bending moments, tri-axial accelerometer at the center of gravity of the head of the dummy to record the linear accelerations along the three Cartesian coordinates, a tri-axial accelerometer in the dummy thorax to record T1 accelerations, and a sled accelerometer to record the input rear impact acceleration pulse. In addition, tests were photographed using a high-speed digital camera operating at 1000 frames per second. All sensor data were gathered according to the Society of Automotive Engineers Specifications (SAE J211) at a sampling frequency of 12,500 Hz. Accelerations and forces were filtered at SAE Class 1000 HZ, and moments were filtered at SAE Class 600. Peak axial and shear forces and bending moments in the sagittal plane were extracted from the processed signals. In addition, the time of attainment of these peaks were obtained. A comparative evaluation of the peak forces and moments and their times of occurrence was made as a function of head restraint height and initial backset. Additional processing included the computation of the neck injury criteria (NIC) according to equations (1a and 1b), N_{km} injury criteria according to equation (2), and the N_{ij} criteria according to equation (3).

$$NIC = 0.2 \times a_{rel}(t) + v_{rel}(t)^2 \qquad (1a)$$

$$v_{rel}(t) = \int a_{rel}(t)dt \qquad (1b)$$

where a_{rel} is the difference in x-acceleration between T1 and the center of gravity of the head, and v_{rel} is the relative velocity between T1 and the head.

$$N_{km}(t) = \frac{F_x(t)}{F_{\text{int}}} + \frac{M_Y(t)}{M_{\text{int}}} \quad (2)$$

where shear force (F_x) and bending moment (M_y) are measured at the upper neck load cell, and F_{int} and M_{int} are intercept values for the specific dummy size.

$$N_{ij}(t) = \frac{F_z(t)}{F_{\text{int}}} + \frac{M_y(t)}{M_{\text{int}}} \quad (3)$$

where axial force (F_z) and bending moment are measured at the upper neck load cell.

RESULTS

The magnitudes of peak variables were similar in tests with 50- and 100-mm backset. The time sequence was such that the compressive force (45 to 90 N) reached its peak first. This was followed by peak torso accelerations (44 to 46 g). The NIC (43 to 55 m^2/s^2) was maximized at the time of peak torso acceleration (44 to 45 ms). Peak shear forces (12 to 347 N) and peak flexion bending moments (5 to 32 Nm) occurred 5 to 10 ms subsequent to NIC and torso accelerations. Peak extension bending moments (11 to 34 Nm), tension forces (470 to 1407 N), and N_{ij} (0.21 to 0.44) occurred at approximately the same time. The N_{km} injury criterion (0.27 to 0.65) also reached its peak at this time.

There was no initial flexion bending moment, compressive force, or positive shear for zero backset tests with shorter head restraint height. Head contact with the head restraint resulted in peak extension moment, anteroposterior shear, and axial tension at 33ms, 33ms, and 35ms, respectively. The max NIC (again) occurred when the torso acceleration peaked 14 ms after head motion. The taller head restraint with a zero backset test resulted in a flexion bending moment peak of the similar magnitude compared to tests with 50- and 100-mm backset. The N_{ij} and N_{km} values ranged from 0.14 to 0.17 and 0.22 to 0.24, respectively.

DISCUSSION

The objective of the study was to conduct tests with FMVSS 202 acceleration pulses using the Hybrid III dummy, determine the forces and bending moments at the head-neck junction, and compute various injury criteria [2]. In general, increasing initial backset resulted in higher magnitudes of injury metrics (e.g., forces). The patterns of responses (e.g., moment history) were similar between the two nonzero backsets and head restraint height tests. However, in all tests NIC and T1 accelerations attained their peaks at approximately the same time. Other variables (shear forces, axial forces and bending moments) reached their peaks later in tests with nonzero backset. This implies that NIC is more dependent on torso motion than head-neck force and moment. Because NIC attained its maximum independent of head restraint position with respect to the dummy head-neck (backset and head restraint height), NIC appears to be a less efficacious criterion in accessing the injury-mitigating characteristics or design of head restraints. In contrast, N_{ij} reached its peak after the head fully loaded the head restraint. Consequently, N_{ij} appears to be better suited to assess rear impacts and head restraints. The N_{km} injury criterion, by definition, applies to the rebound phase of rear impact. For nonzero backset tests in the present study, N_{ij} and N_{km} criteria reached their maxima at approximately the same time, and this coincided with the time of peak occurrence of the extension bending moment. In contrast, for the zero backset tests, the N_{km} criteria reached its peak later because of the delay in the development of the shear force. These results suggest a lack of consistency among the different injury criteria for rear impact. The present study needs to be extended to study the responses from other dummies developed in Europe and other anthropometric sizes to reinforce the findings from this investigation.

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