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An Improved Dummy Neck Assembly for Dynamic Rollover Testing

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ABSTRACT

In the U.S., more than 27,000 catastrophic and fatal injuries occur annually in rollover crashes. Due to the incidence and severity of injuries in rollover crashes, a strategy for injury mitigation is dynamic compliance testing with dummy-occupied vehicles and occupant protection requirements, similar to that required for frontal and side impacts. Presently, there are dynamic vehicle rollover test devices like the Controlled Rollover Impact System and the Jordan Rollover System that realistically recreate real-world rollover crash scenarios. However, the Hybrid III dummy, which is considered to be the best available human surrogate for dynamic rollover tests, has a very stiff neck with limited biofidelity in rollover crashes; the Hybrid III neck is much stiffer than the human neck. Catastrophic human head or neck injuries resulting from roof interaction and partial ejection in real-world rollover crashes are poorly replicated by dynamic rollover tests with the non-biofidelic Hybrid III dummy neck. Only with a more biofidelic dummy can effective testing result in injury mitigation in rollover crashes.

This study is part of an ongoing research project aimed at mitigating catastrophic human neck injuries in real-world rollover crashes. The goal was to develop a biofidelic neck assembly for the Hybrid III dummy in rollover crash environments. The design goals of this prototype neck included decreased stiffness and a mechanism that represents the unknowable human muscle tension in rollover crash environments.

This paper and its companion paper in this conference introduce the new neck design, present results of matched-pair tests that compare the responses of the new neck with the production Hybrid III neck, and propose preliminary rollover injury criteria for this neck. The neck demonstrates repeatability, improved biofidelity, which results in more realistic occupant kinematics, dynamics, injury prediction, and evaluation of various countermeasures.

INTRODUCTION

This study is part of an ongoing research project aimed at mitigating catastrophic human neck injuries in rollovers. Catastrophic neck injury in rollover crashes is predominantly due to excessive neck bending; such bending is clearly visible in high-speed videos of dynamic rollover tests. At present, the Hybrid III dummy is considered to be the best available human surrogate for dynamic rollover tests. The objective of this paper was to design and test a more biofidelic neck for the Hybrid III dummy to be used in rollover testing.

METHODS

Prototype Neck Design: The prototype neck was manufactured by Denton ATD using the production Part 572E Hybrid III neck mold. The stiff 67-durometer butyl rubber used in a production Hybrid III neck was replaced by softer 35-durometer butyl rubber discs and nodding blocks for improved biofidelity.

Test Description: Pendulum tests were conducted at CfIR using the test setup illustrated in Figure 1. The production Part 572E Hybrid III dummy neck tests were presented in 2008. Using the same protocol, tests were conducted on the Part 572E Hybrid III dummy; with the production neck and with the softer, more biofidelic neck (modified with lower-durometer neck nodding blocks and discs).

Test Fixture: The pendulum test fixture has been described previously in a 2008 paper presented to NHTSA (1).

Instrumentation: The dummy neck was instrumented with upper and lower neck load cells that measured axial neck force Fz and moments Mx and My. Data was filtered in accordance with SAE recommended procedures. Instrumentation also included real-time and high-speed rear and lateral view cameras equipped with tracking software to analyze head-neck motion and neck flexion ange. Preflexion neck angles were measured with an inclinometer at the posterior neck (erect=90°). String potentiometers attached to the

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platen and dummy recorded platen drop height and head, upper neck, lower neck, and lumbar spine fore-and-aft motion, respectively.

Test Protocol: In these tests, a rotational pendulum-driven weighted platen struck the head of the dummy head-neck-torso-pelvis assembly suspended approximately 5 cm (2”) above a production vehicle seat. Using bungee cords, the dummy was set to have a torso angle of 10° relative to the vertical and head-neck angle of 17° relative to the torso at initial platen contact resulting in a total angle relative to the vertical of 27°. This setup represents the preflexed head-neck orientation of the human in a rollover crash when inverted with the head in contact with the vehicle roof. The dummy was held in place by a breakable attachment that allowed the dummy to fall after initial head contact with the platen. The rotational pendulum was set to impact the head of the dummy when horizontal and moved through an angle of 10° when depressing the head of the dummy by a maximum of 15.2 cm (6”). The fixture included an adjustable arresting stop for the pendulum arm. The pendulum was dropped to achieve head impact at 11.3 kph (7 mph) with a pendulum displacement (stroke) of 5 cm (2”) to 15.2 cm (6”) before being arrested. The stroke after head contact in the test was analogous to the extent of roof crush in a rollover crash.

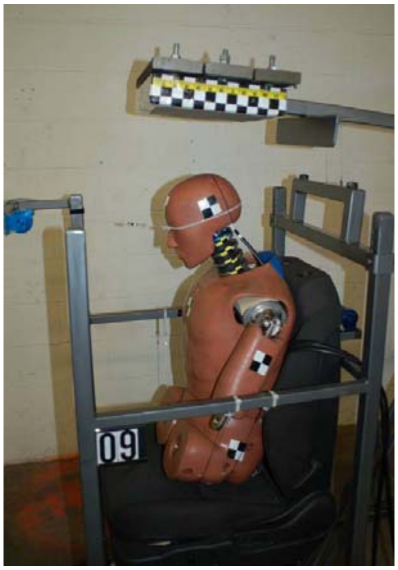

Figure 1: Test Setup

Matched-Pair Tests: Tests were performed with the modified dummy neck preflexed relative to the roof intrusion at an angle that approached the limit of neck’s free range of motion in flexion (approximated here as 35° to the horizontal), where the effects of musculature, the disc, and stretched ligaments dictat+ed the neck bending stiffness. All of the tests were conducted with the same platen weight and platen drop height. The allowable platen stroke distances after initial contact were varied. The platen was permitted to drop an additional 2”, 4”, and 6” after head impact.

The test matrix and results are summarized in Table 1, where "P" and "S" refer to the production and softer prototype necks, respectively.

RESULTS

Figures 2 and 3 show normalized lower neck bending moment M_y time histories.

In the pendulum tests, the amplitude of peak neck force was dependent upon the change in speed experienced by the dummy. Altering the stroke of the platen (i.e., the distance it continues to fall after the initial head impact) did not alter the peak compressive neck load. However, the duration of the lower neck moment and bending varied with stroke from 40 to 95 ms increasing the probability of neck flexion injury. Note the effect of the seat interaction with more than 2” of stroke. Tests performed with the low-durometer neck more closely replicated the human neck.

Table 1. Test Matrix and Peak Value Test Results

Test #	Platen Stroke (in/cm)	Platen Drop Height (in/cm)	Platen Weight (lb/kg)	Neck Angle (deg)	Peak Lower Neck Fz (N)	Peak Lower Neck My (Nm)
P-1	2 / 5.1	18 / 45.7	95 / 43	60	-4,276	272
P-2	6 / 15.2	18 / 45.7	95 / 43	60	-4,602	287
P-4	4 / 10.2	18 / 45.7	95 / 43	60	-4,425	282
S-3	4 / 10.2	18 / 45.7	95 / 43	60	-2,442	194
S-4	6 / 15.2	18 / 45.7	95 / 43	60	-2,299	181
S-5	2 / 5.1	18 / 45.7	95 / 43	60	-2,350	195

CONCLUSIONS

The low-durometer neck proved to be a reasonable preliminary working level parameter neck; it has a more humanlike response than the production Hybrid III neck. The lower neck bending moment M_y is shown in Figures 2 and 3. In each test the dummy was suspended 5 cm (2”) above the seat with breakaway cords. The dummies fall onto the seat with the buttocks compressing the seat cushion to about 1”.

REFERENCES

1. JG Paver, et al., “Development of Rollover Injury Assessment Instrumentation and Criteria,” Proceedings of the 36th International Workshop on Injury Biomechanics Research, 2008.

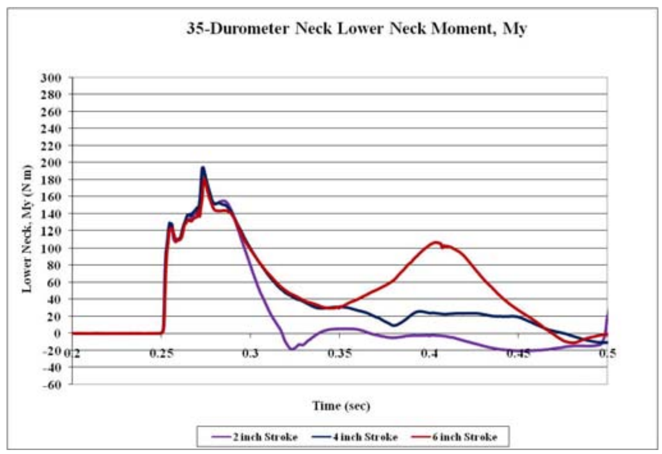

Figure 2: 35-Durometer Neck.

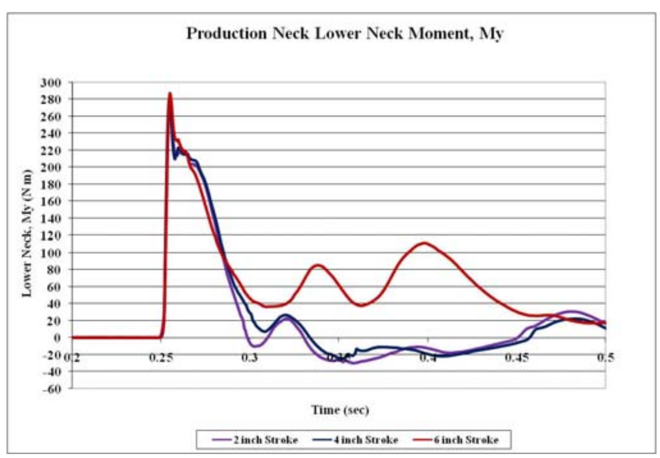

Figure 3. Production Neck.

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