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Development of an Advanced Head/Neck System for 5th Percentile Female Anthropomorphic Test Dummies

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ABSTRACT

This paper presents the development of an advanced dummy head/neck system which can be used with 5th percentile female crash test dummy. The system will become part of the 5th percentile female Thor dummy, currently under development. It can also be retrofitted to the standard 5th percentile female Hybrid III. An overview of the new head/neck system design is described in the paper. The biomechanical requirements for the neck response for the 5th percentile female have been scaled from the 50th percentile male response and these requirements are reviewed. The design methodology, which includes mechanical design, simulation, and component tests, is presented. Finally, results from preliminary quasi-static and dynamic testing of the new design are discussed and compared to the response of the 5th percentile female Hybrid III neck.

INTRODUCTION

Acording to the NASS data, over 22% of female occupants involved in tow away accidents are 1.58 meters (62 inches) in stature or less, and over 2.5% of these suffer serious or fatal injuries (Backaitis, 2003). The 5th percentile female size is thus representative of a significant proportion of occupants who suffer serious injuries. Furthermore, this point has been re-emphasized recently by the studies revealing that a number of deaths and serious injuries have occurred to small statured women because of deploying airbags in out-of-position environments. Head and neck injuries are among the injuries with severe consequences. An anthropomorphic test dummy (ATD) is often used as a tool to investigate and reduce this kind of injures. The limitations of the head/neck system of currently available dummies identify a need to develop a more biofidelic head/neck system for the current 5th percentile female ATD.

Over the years, different 50^{th} percentile male neck designs have been developed with various degrees of success. For example, a neck developed by General Motors (Foster et al., 1977) is used in the current Hybrid III dummy. By using scaling techniques (Schneider et. al, 1983; Mertz 1984; Eppinger et. al, 1984), the researchers developed the female neck based on its male counterpart. and its 5^{th} percentile female Hybrid III (Mertz, 1989; NHTSA, 1998) is developed based on these techniques. This female neck meets the scaled Mertz corridors, which correlate the moments around the occipital condyle joint with head angle relative to T1 (Mertz et al., 1973; Patrick and Chou, 1976). However, this neck did not have good agreement with respect to head kinematics when compared to results from volunteers tests conducted at the Naval Biodynamics Laboratory (NBDL) (Ewing et al., 1975). An advanced 50^{th} percentile male head/neck system , with improved biofidelity, was developed, and is part of the NHTSA frontal dummy known as THOR (White et al., 1996). The current version of THOR is known as THOR-Alpha. One of its main improvements was to use a spring/cable assembly exterior to the neck to simulate human neck muscular contribution during impact. The spring/cable design was meant to simulate proper excursions and lag which were seen in the NBDL volunteer experiments. The male THOR neck was evaluated by several research institutes such as TNO and JARI (Hoofman et al., 1998) and the results indicated that the neck substantially satisfied the frontal and lateral flexion requirements. However, additional improvement of the neck was still needed. For example, new experiments on volunteers have been conducted by several researchers in recent years (Davidsson et al., 1998; Ono et. al, 1999) and newly updated corridors were developed according to these data. Another area was in improving the anthropometry of the THOR-Alpha neck. In the THOR-Alpha neck, the location of the C7/T1 joint is not clearly delineated and it was thought that a properly defined T1 would help in the definition of any injury assessment using THOR. In addition, there appeared to be a need to retrofit the conventional Hybrid III dummy with the head/neck assembly from THOR. A similar retrofit has been done for the Hybrid III lower extremity by using the newly designed Thor-Lx and Thor-FLx (Shams et al.1999; Shams et al. 2002). In order to meet these new design criteria, a new THOR-Beta neck was developed and the basic properties of this neck design have been presented in the 2001 Workshop. A 5^{th} percentile female version of the THOR-Beta neck has now been developed as well, by scaling the male version. In this paper, the development of this 5^{th} percentile female head/neck system is discussed.

DESIGN REQUIREMENTS

The design requirements for the new 5^{th} female percentile head/neck system are similar to the 50^{th} percentile male THOR-Beta head/neck. The basic design requirements are matching human anthropometry, matching human neck responses in kinematics and dynamics, and meet the geometry constraints for retrofitting to the HIII ATD. First, the new neck needs to generally match the anthropomorphic landmarks for AATD (Schneider et. al., 1983) such as the occipital condyle (O.C.) joint and T1. The second important criterion is to match the dynamic and kinematic responses of this mechanical neck to the human responses. The current corridors of human head/neck responses in kinematics (Wismans and Spenny, 1983 Thunnisen et. al, 1995; Davidsson et al. 1998; Ono et. al, 1999; Ono et. al, 2001) are for the male. Therefore, scaling procedures (Mertz 1984; Eppinger et. al, 1984) have to be applied to obtain the corridors from these male versions. Two of these 5^{th} percentile female corridors in kinematics are shown in Figures 1 and 2 (flexion and lateral flexion). In addition, the scaled Mertz corridors (Mertz et al., 1973; Patrick and Chou, 1976) have been utilized as secondary requirements as well. Finally, as this neck is expected to retrofit into the Hybrid III, the current constraints in the Hybrid III head/neck complex have to be considered. These constraints include the neck length, a large horizontal offset from the neck base to the occipital condyle joint, and the location of the pitch change relative to the thoracic spine.

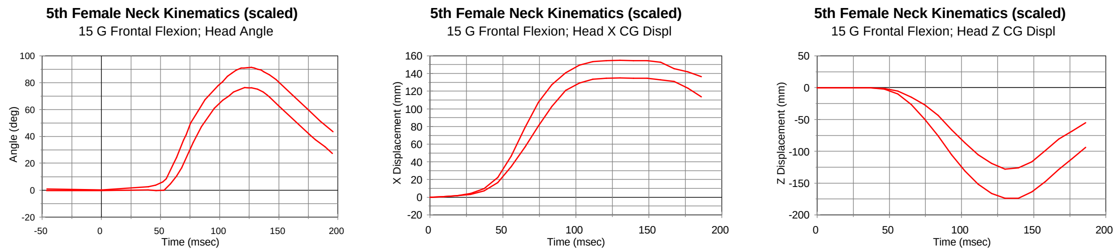

Figure 1: Kinematic corridors for 5th female neck in 15g flexion.

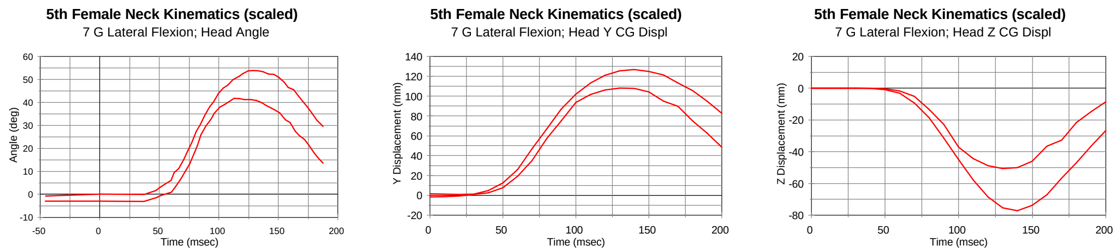

Figure 2: Kinematic corridors for 5% female neck in 7g lateral flexion.

DESIGN OVERVIEW

The new 5th percentile female head/neck system, called THOR-Beta, is based on its 50th percentile male counterpart. By using the requirements described in the previous section and standard scaling techniques, the new neck was designed and fabricated (see Figure 3).

Figure 3: 5th percentile female Thor-Beta neck

The principal design features of the new female Beta neck (similar to the features in the male Beta neck) are:

4 Pucks and Offset Geometry

The 4-puck neck agrees with the OC-T1 length derived from NBDL tests and the T1 is located at a well-defined rigid position. In addition, the new neck has to satisfy the design constraints in the current Hybrid III head-neck structure, which we described in the Design Requirements section. In order to do so, we modified the new shape with small angles in the bottom two of the four pucks. As a result, the new neck is offset from the top to the bottom. The gradual offset design is different from the Hybrid III one-step change, and the Beta neck resembles the curvature of the human neck structure.

Elliptical Puck Shape

The shape of the neck pucks in the 5th percentile female neck is elliptical. This shape is the same as the male version but the size is smaller. Lumped-mass simulations by using DYNAMAN (Shams et. al., 1992) were applied to estimate the size of the puck for this female neck. In order to have different responses in flexion and extension, a small wedge is designed for the two bottom pucks and Figure 4 shows the design for these wedge pucks. Because of the wedge, the stiffness at larger bending angles in extension will be greater than in flexion. The current material for the puck is Neoprene with 75A durometer.

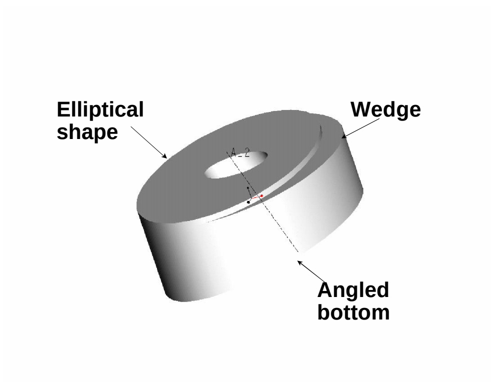

Figure 4: Puck with wedge

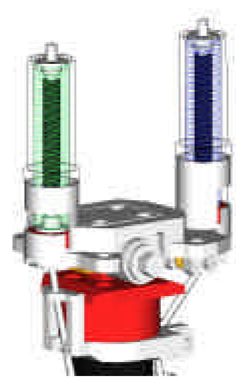

Figure 5: Spring/cable with rubber

Spring/Cable with Rubber Tube.

The spring/cable assembly is connected to the neck column to simulate human neck muscular contribution during impact. There are two sets of spring/cables (front and rear) in this female neck, and is a scaled version of the male Beta neck (Figure 5). As in the male neck, a rubber tube is inserted within the spring to prevent the sharp increase in load that may be caused by bottoming of the steel spring. The combination of rubber and spring should make the response more biofidelic and also possibly prevent possible cable damage.

Cam/Rubber Mechanism for the OC Joint

The OC joint in the dummy is meant to mimic the neck segment between the OC and the C2 vertebra in the human. A metal cam/rubber mechanism, as shown in Figure 6, is used for the design of the OC joint in the 5th percentile female neck. The rubber shape can be easily used to control the characteristics of OC. FE simulations, using LS-DYNA, were performed to obtain the approximate dimensions and sketch the design. Once a prototype assembly was built, it was tested to verify its response. Based on the results, the design was modified to provide a more biofidelic moment-angle property at the OC joint. The FE model, which is utilized for this approach, is shown in Figure 7. The result from the static tests for this OC design is discussed in a later section.

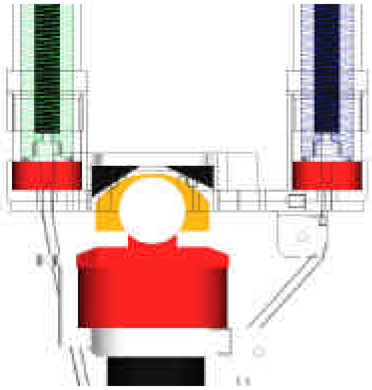

Figure 6: Design of OC joint.

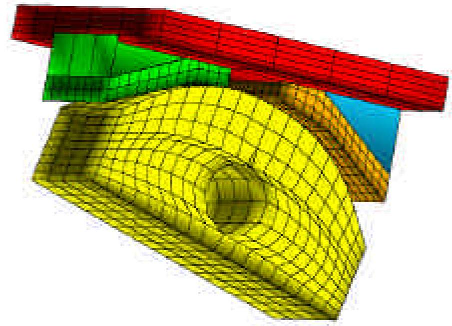

Figure 7: FE model used in OC joint design

Central Compliant Rubber Bushing

Figure 8 shows the design of the central compliant bushing. The main purpose of this design is to allow the neck to extend in the longitudinal direction (Z), in much the same way a human neck will react during impact. The bushing located within the lower neck load cell is shown in the figure. In the original design, the bushing is made of rigid Delrin. In the new design, a piece of rubber is used to replace it. The central cable will push to compress the rubber during motion and develop the Z extension. Tests to examine the effect of the central compliant rubber bushing will be described later in the paper.

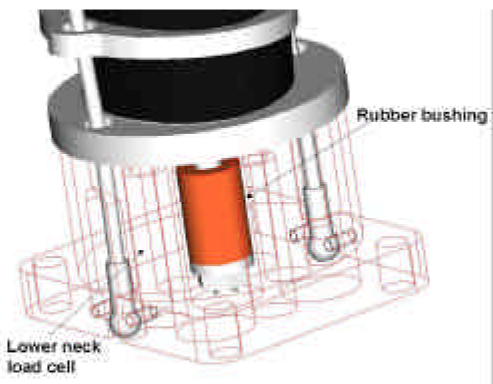

Figure 8: Compliant rubber bushing

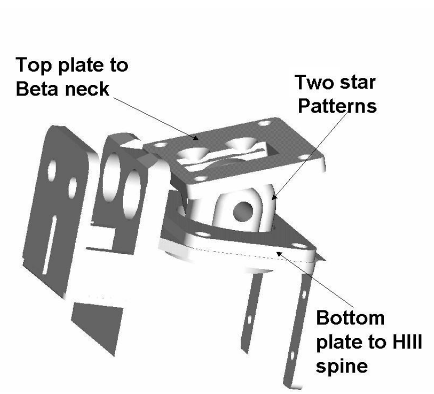

Figure 9: Pitch changing mechanism

Adapter to Connect Hybrid III

One of objectives for the 5th percentile female neck is to retrofit to the current Hybrid III 5th percentile female dummy. In order to do so, an adapter between this neck and Hybrid III 5th percentile female dummy is needed. A pitch change mechanism, similar to the one designed for the 50th percentile male neck retrofit, can serve this purpose. The new design of the pitch change mechanism is depicted in Figure 9. This mechanism is capable of rotating every 3 degrees. By using this design feature, the dummy sitting posture can be adjusted and allow retrofitting to the spine of the Hybrid III.

Apart from above features, a modified nine-accelerometer-array system is designed for the 5th percentile female head/neck system. This system includes one main 7-accelerometer fixture (see Figure 10), which can measure head accelerations in the 7 directions (three at CG, two at rear, and two at side), and a small 2-accelerometer unit located at the top of head. By utilizing this geometric array, the 3-D motion of the head/neck system can be analyzed. Figure 10 shows the head/neck system installed in the 5th percentile female THOR and a photo of the 5th percentile female THOR with this head/neck system is shown in Figure 11.

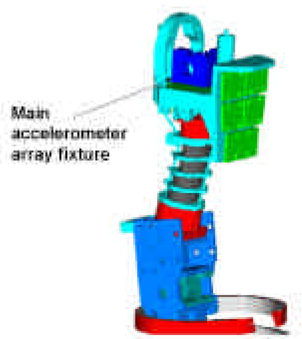

Figure 10: Head/neck system on 5% female Thor spine. Figure 11: 5% female Thor

PRELIMINARY TESTS

Several tests were conducted to validate this 5th percentile female head/neck system. They are:

Static Bending Test

Static bending tests in flexion, extension, and lateral flexion were performed to verify the new design. In the static tests, the 5th percentile female THOR-Beta neck was tested without front and rear cable installed. The basic setup is to fix the bottom of neck (lower neck load cell) and pull a cable connected to the top of the neck (at the hole for the O.C. pin) to bend the neck. A tilt sensor was installed on top of the neck to measure the bending angle. The neck in these tests was bent around 40 degree in flexion and extension, and 30 degree in the lateral direction. The results from the new neck tests in flexion, extension, and the lateral directions are shown in Table 1.

Table 1. Comparison For Static Bending Moment Results For Beta Female And Male Necks

	Flexion Moment at 40E (N-m)	Lateral Flexion Moment at 30E (N-m)	Extension Moment at 40E (N-m)
5% female beta neck	18	32	19
50% male beta neck	30	55	35
Ratio (female/male)	0.60	0.58	0.54

According to the above table, the responses in flexion and extension were slightly different. This kind of response was expected because of the wedge design. In addition, torsion in the Z axis was seen during lateral tests because of the offset between the head and the bottom of the neck. Again, these results showed that the special design features such as the wedge and offset for the beta neck were working properly. The size of the neck plays an important role in its response. We can estimate the responses for a 5th percentile female neck from the 50th percentile male neck by using scaling. In order to evaluate the static bending responses for the current 5th percentile female neck, the results for the 50th percentile male beta necks are listed in Table 1 as well. The Table shows the stiffness ratios of the new 5th percentile female neck to the 50th percentile male neck in all three directions are around 0.54 ~ 0.6, which are within 10% from the expected ratio (0.55). Thus the overall results seem reasonable.

OC Joint Static Test

In order to validate the cam/rubber mechanism used in the OC joint design for the female neck, a static test was set up and shown in Figure 12. Under this testing setup, the characteristics at the OC joint can be measured by using the upper neck load cell. The test results are compared to biomechanical data from Duke University and shown in Figure 13. The Duke biomechanical data were obtained from cadaver tests, and the range of motion for these data will be greater than a living volunteer.

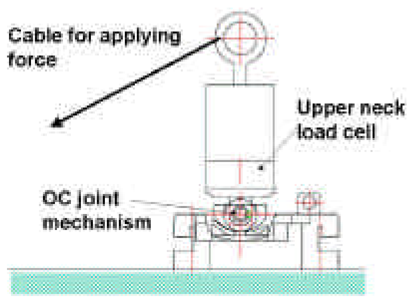

Figure 12: OC static test setup

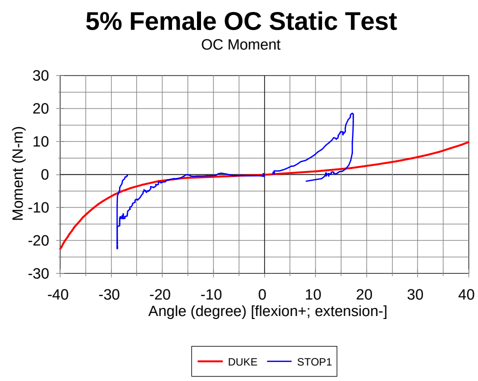

Figure 13: 5% female neck OC property

In Figure 13, the blue line is the OC moment-angle response of the current 5th percentile female neck and the red line shows the data obtained from Duke. The graph indicates that the range of motion at the OC can reach 17 degrees in flexion and 29 degrees in extension. The joint produces a continuous response and matched the lower end of the response from Duke. Obviously, the rubber stop at the OC joint didn't allow the maximum angles in flexion and extension, as seen in the Duke data, to be reached.

Dynamic Pendulum Test

Dynamic pendulum tests in frontal flexion, extension, and lateral flexion were conducted to study the dynamic behavior of the new female neck. The setup is shown in Figure 14. In these tests, the head-neck assembly was dropped from a specified angle into a contact plate covered by a foam block. The peak deceleration is controlled by choosing different drop angles for the pendulum arm. The peak decelerations for the impact pulses in all three directions for this series of tests are shown in Table 2.

Accelerometers were installed on the pendulum and at the head CG to measure the pendulum deceleration and head acceleration, respectively. A potentiometer was used on the pendulum arm to measure the rotation of pendulum. By differentiating the reading from this potentiometer, the impact velocity can be obtained. In addition, the instrumentation, which included one upper neck load cell, two spring load cells (front and rear), and one potentiometer at the OC, were installed for measuring the moment at the OC. The kinematics of the head is one of the important variables from the pendulum tests. A high-speed camera was used to catch the motion of this new head/neck system.

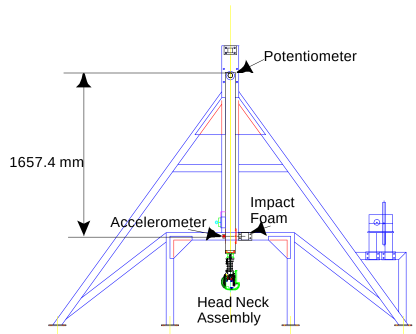

Figure 14: Dynamic pendulum setup

Table 2. Peak Deceleration And Duration For Dynamic Pendulum Tests

	Flexion	Lateral Flexion	Extension
Peak Deceleration (g)	27	17	4
Duration (ms)	40	45	120

Response in Kinematics

For comparison, the 5th percentile female Hybrid III head/neck system without instrumentation was tested under the same setup described above. Since the high-speed camera was used in the tests, the motion of head/neck system was recorded every 2 msec. Figures 15, 16, and 17 show both necks at maximum flexion, lateral flexion, and extension, respectively.

5% Female Thor **5% Female Hybrid III**

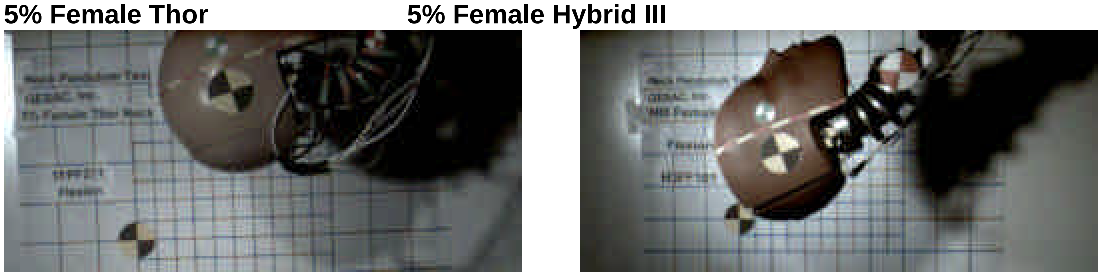

Figure 15: Comparison of maximum motion for pendulum tests in flexion

5% Female Thor **5% Female Hybrid III**

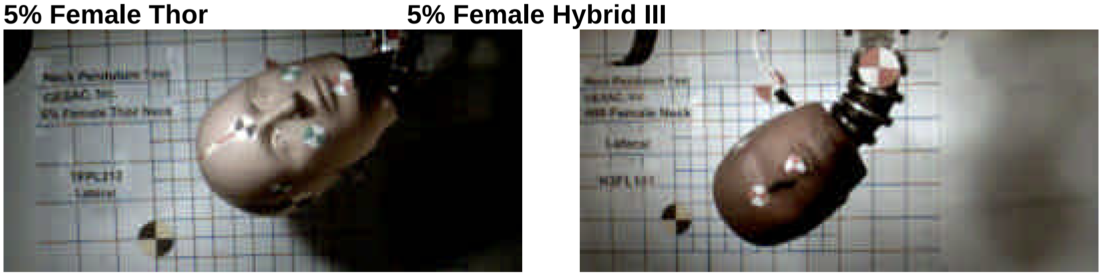

Figure 16: Comparison of maximum motion for pendulum tests in lateral flexion

5% Female Thor **5% Female Hybrid III**

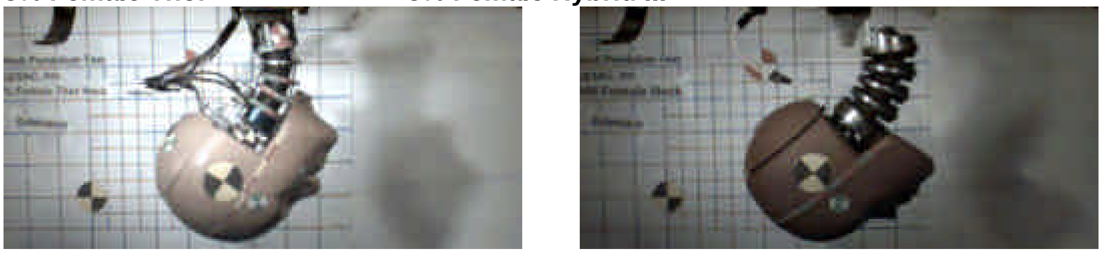

Figure 17: Comparison of maximum motion for pendulum tests in extension

By digitizing the pictures from the high-speed camera, the kinematic results can be obtained. The maximum displacements for both necks in flexion, lateral flexion, and extension are listed in Table 3. According to the figures above and Table 3, the 5th percentile female THOR neck produces greater displacements than the 5th percentile female Hybrid III in flexion and lateral flexion. For extension, the head CG rotation angle for Hybrid III is higher than THOR and the head displacements are similar to THOR. The time to reach the peak value for the 5th percentile female THOR neck is longer than Hybrid III except for extension. In extension, the times are similar for both necks.

Table 3. Comparison For Peak Results In Kinematics For 5% Female Thor And HIII Head/Neck Systems In Pendulum Tests

	Flexion			Lateral Flexion			Extension		
	Head angle (deg)	Head CG displacement (mm)		Head Angle (deg)	Head CG displacement (mm)		Head angle (deg)	Head CG displacement (mm)	
		X	Z		Y	Z		X	Z
5% female Thor	72 (74ms)	168	166	69 (70ms)	207	152	36 (120ms)	115	23
5% female HIII	68 (50ms)	148	123	52 (54ms)	138	69	45 (120ms)	106	32

In addition, tests to examine how the rubber in the central cable worked were performed as well. The tests were 4g extension pendulum tests. The 5th percentile female THOR neck with a rigid insert and with a rubber insert was tested. The results are shown in Table 4. According to the Table, the angle and displacements were similar for both configurations, but the test with the rubber compliant element had slightly higher numbers. The rubber compliant helped to delay the peak response.

Table 4. Results For Testing 5% Female Thor Head/Neck With Rigid Insert And Rubber Insert

	Head angle (deg)	Head displacement (mm)		Time (ms)
		X	Z	
Rigid insert	36	115	23	120
Rubber insert	37	130	21	126

Moment at OC

In all the necks, loads measured by the neck load cell is at a point offset from the O.C. joint. Thus a correction to the total moment has to be made due to the contribution of the shear force. In the case of the THOR necks, forces due to the two spring/cables would also contribute to the moment at O.C joint. In the tests conducted at GESAC, the computations for the total moment at the O.C. are carried out by a program called THORTEST, which was developed to post-process various instrumentation data collected by THOR. Results from this series were computed by using this program and the peak moments at O.C. joint are given in Table 5 for both 5th percentile female and 50th percentile male THOR-Beta head/neck systems in flexion, lateral flexion, and extension. In addition, the ratios between 5th percentile female and 50th percentile male Beta necks are listed as well. According to the table, the ratios in flexion and lateral flexion are around 0.6 and are close to the scale factor (0.55) used for designing the 5th percentile female THOR neck. However, the ratio in extension is lower than the scale factor in this series of low-energy tests (4g; 120ms). It suggests that tuning the design in extension might be needed for the 5th percentile female neck.

Table 5. Peak Oc Moments For Both 5% Female And 50% Male Thor-Beta Head/Neck System In Dynamic Pendulum Tests

	Flexion (N-m)	Lateral Flexion (N-m)	Extension (N-m)
5% female beta neck	36	21	-9
50% male beta neck	62	35	-24
Ratio (female/male)	0.58	0.60	0.38

Repeated dynamic tests were conducted with the new neck. Figures 18 and 19 shows the O.C. moment responses in lateral flexion and extension in repeated tests. The graphs indicate that the new neck has good repeatability. Durability was also fair, with the neck being subjected to pendulum tests without failure over 30 times.

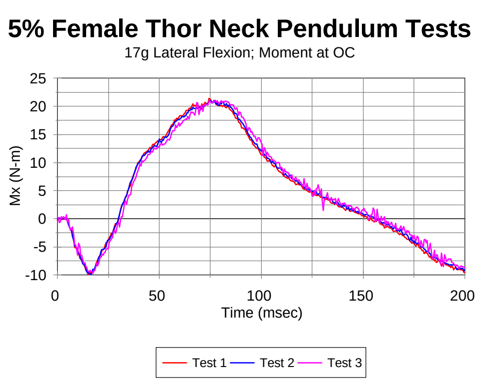

Figure 18: OC moment for the 5% female Thor head/neck in lateral pendulum tests

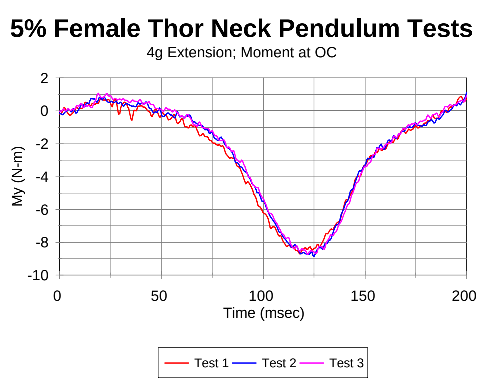

Figure 19: OC moment for the 5% female Thor head/neck in extension pendulum tests

CONCLUSIONS AND FUTURE WORK

A new 5th percentile female head/neck system for THOR and Hybrid III has been fabricated. The test results indicate that the new 5th percentile female head/neck system responds kinematically in a more biofidelic manner than the standard Hybrid III system in flexion and lateral flexion. The response in extension appears to be similar. These results indicate that the new 5th percentile female head/neck system may have a more realistic interaction with an airbag in out-of-position tests. The new rubber/cam mechanism for the O.C. produced a continuous response and it matches well with quasi-static human response. With this new mechanism, the OC - C2 characteristics can be adjusted easily. The additional central compliance in the female neck demonstrated that it is capable of being used to tune the response time. Furthermore, some Z rotation was generated during lateral flexion because of the special geometry of the neck. The new neck was subjected to over 30 dynamic tests and the tests showed that the neck is durable and repeatable.

Although the overall results were encouraging, some additional improvement and further validation of the new neck are still needed. The current and future plan for this project will include tuning the OC properties based on the latest biomechanical data and examining additional flexibility below T1. Additional tests with a HyGe sled with head/neck assembly only and with the full dummy, and out-of-position airbag tests, are planned in the future.

ACKNOWLEDGMENTS

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REFERENCES

BACKAITIS, S. (2003) Personal communication.

DAVIDSSON, J., DEUTSCHER, C., HELL, W., LOVSUND, P., SVENSSON, M.Y. (1998) “Human Volunteer Kinematics in Rear-End Sled Collisions,” 1998 IRCOBI, pp.289-301.

EPPINGER, R., MARCUS, J., MORGAN, J. (1984). “Development of Dummy and Injury Index for NHTSA’s Thoracic Side Impact Protection Research Program,” the 27th Stapp Car Crash Conference, SAE# 840885.

EWING, C.L., THOMAS, D.J., LUSTICK, L., BECKER, E, WILLIAMS, G, MUZZY, W.H. (1975) “The Effect of the Initial Position of the Head and Neck on the Dynamic Response of the Human Head and Neck to gx Impact Acceleration,” the 19th Stapp Carsh Conference, SAE# 751157.

FOSTER, J.K, KORTGE, J.O, WOLANIM, M.J. (1977) “Hybrid III- A Biomechanically-Based Crash Test,” the 21st Stapp Car Crash Conference, SAE# 770938, pp975-1014

HOOFMAN, M., RATINGEN, M, WISMANS, J. (1998) “Evaluation of the Dynamic and Kinemetic Performance of the Thor Dummy: Neck Performance,” 1998 IRCOBI, pp 497-508

MERTZ, H., IRWIN, A., MELVIN, J., ET AL. (1989) “Size, Weight, and Biomechanical Impact Response Requirements for Adult Size Small Female and Large Male Dummies,” SAE Paper No. 890756, Society of Automotive Engineers, Warrendale, PA.

MERTZ, H. (1984) “A Procedure of Normalizing Impact Response Data.” SAE# 840884. Society of Automotive Engineers, Warrendale, PA.

MERTZ, H.J., NEATHERY, R.F., CULVER, C.C., (1973) " Performance Requirements and Characteristics of Mechanical Neck," Huamn Impact Response: Measurement and Simulation ed. by King, W.F. and Mertz, H.J., Plenum Press, New York.

NHTSA (2003) Special Crash Investigation Program (SCI), Washington, D.C. USDOT, Available: http://www-nrd.nhsta.dot.gov/departments/nrd-30/ncsa/sci.html

NHTSA. (1998). Technical Report: Development and Evaluation of the Hybrid III Fifth Percentile Female Crash Test Dummy (H-IIISF). Office of Crashworthiness Standards and Vehicle Research and Test Center.

ONO, K., INAMI, S., KANEOKA, K., GOTOU, T., KISANUKI, Y., SAKUMA, S., MIKI, K. (1999) "Relationship between Localized Spine Deformation and Cervical Vertebral Motions for Low Speed Rear Impact Using Human Volunteers," 1999 IRCOBI, pp149-164.

ONO, K., KANEOKA, K., SUN, E., TAKHOUNTS, E., EPPINGER, R. (2001) "The Biomechanical Response of Human Cervical Spine to Direct Loading of the Head," 2001 IRCOBI, pp.189-199

PATRICK, L.M., CHOU, C.C. (1976) "Response of the Human Neck in Flexion, Extension, and Lateral Flexion," Vehicle Research Institute Report No. YRI-7-3, Society of Automotive Engineers, Warrendale, PA

SCHNEIDER, L., ROBBINS, D., PFLUG, M., AND SNYDER, R. (1983). Development of Anthropometrically Based Design Specifications for an Advanced Adult Anthropomorphic Dummy Family. UMTRI, Report No. UMTRI-83-53-1.

SHAMS, T., BEACH, D., HUANG, T.J., RANGARAJAN, N. HAFFNER, M. (2002) " Development of Thor-FLx: A Biofidelic Lower Extemity for Use with 5th Percentile Female Crash Test Dummy," Stapp Car Crash Journal, Vol. 46, SAE# 2002-22-0014, pp267-284.

SHAMS, T., BEACH, D., WHITE, RP, RANGARAJAN, N. HAFFNER, M., EPPINGER, R., PRITZ, H, KUPPA, S., BEEBE, M. (1999) " Development and Design of Thor-Lx: The Thor Lower Extemity," the 43rd Stapp Car Crash Conference, SAE# 99SC09, pp141-160.

SHAMS, T., WEERAPPULI, D, SHARMA, D., NURSE, R., RANGARAJAN, N. (1992) DYNAMAN User's Manual Version 3.0, GESAC Report# GESAC-92-08.

THUNNISEN, J., WISMANS, J., EWING, C.L., THOMAS, D.J. (1995) "Human Volunteer Head/Neck Response in Frontal Flexion: A New Analysis," the 39th Stapp Car Crash Conference, SAE Paper # 952721.

WHITE, RP, ZHAO, Y, RANGARAJAN, N., HAFFNER, M. EPPINGER, R., KLEINBERGER, M. (1996) " Development of an Instrumented Biofidelic Neck for NHTSA," the 15th ESV, paper# 96-S10-W19, pp1728-1740.

WISMANS, J., SPENNY, CH (1983) " Performance Requirements for Mechanical Necks in Lateral Flexion," the 27th Stapp Car Crash Conferernce, SAE paper# 831613, pp 137-148.

DISCUSSION

PAPER: **Development of an Advanced Head/Neck System for 5th Percentile Female Crash Test Dummies**

PRESENTER: ***Dr. Tsai-Jeon Hung, GESAC Inc.***

QUESTION: Is your new OC joint?

ANSWER: (inaudible)...almost the same...

Q: Is it beneath the OC joint?

A: Yeah.

Q: Typically not good practice to put a load cell between two sprigs. You have a spring at the neck and you have a spring at the OC joint. And, you didn't show any moment rotation curves there or moment time curves. Is there any oscillation in the moment measured by the upper neck also?

A: Actually, we have a method to calculate the OC out there because we got the force of the spring cable. At the OC load cell, we compensate through. We go to the OC junction. We got a method to calculate that.

Q: But do you see any oscillation in the moment?

A: Well, this one–We just–We didn't see a lot oscillation. We got...We got a 2 peak out there, not just one peak.

Q: So you do have an oscillation.

A: Yeah.

Q: Okay. Thank you.

Q: *Guy Nusholtz, Daimler/Chrysler*
Just primarily, a question of clarification. Are you planning to try and change the dummy so it does meet the two corridors, or did you say that it just wasn't possible?

A: I guess, that was impossible to measure the view corridor, but I guess that meets up with quinesgot (?) I-9...The most appropriate, the data for both this–for the dummy, for a dummy because they was a human..., but we're just waiting for the...

Q: So, you can't meet the due corridor?

A: No.

Q: So, you're much stiffer than what the due corridor.
The second question is: You mentioned T1. Are you planning to do something like what's in the Biorid where you have an entire flexible spine? If you're gonna include the flexibility? Or, are you going to have some other scheme?

A: Might be. Might be the other scheme because, like, the battery–They have too much, like the metal-to-metal thing up there, so we don't want to happen...

Q: Well, you run into the problem of m+1, you know T1 flexibility. Then, what about T2? What about T3?

A: Yeah. There was less section T1. I mean, probably we still like the cold session for the lead property.

Q: So, you'll have some way–You're gonna try to somehow get the compliance of the thoracic spine–

A: Yes.

Q: Okay. Thank you.