"Development of the Cervical Omni-Directional Bending Response Apparatus (COBRA)"

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I. Background

A new device (Figure 1) has been developed and tested which measures the shape of the neck of anthropomorphic test dummies (ATD's) during impact in automotive crash testing. This device, named the Cervical Omni-directional Bending Response Apparatus or COBRA, is a twelve channel strain-based transducer which measures curvature in two perpendicular directions. The COBRA was developed in response to the need for more comprehensive data on the shape of the ATD neck during testing. The COBRA device represents an attempt to assess injury potential more completely than traditionally available neck instrumentation.

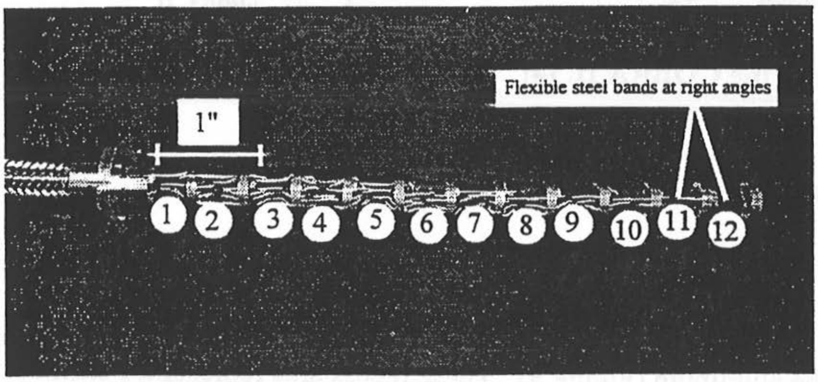

Figure 1. Cervical Omni-Directional Bending Response Apparatus (COBRA II). Strain gages are numbered. [3]

II. Description of the device and program

The COBRA is a twelve channel strain-based transducer which measures curvature in two perpendicular directions. The device was developed by NHTSA in cooperation with Robert A. Denton, Inc. An initial COBRA prototype was fabricated and tested. Results from those tests prompted a refinement in the design to a second prototype (COBRA II).

The COBRA II consists of twelve flexible steel bands oriented at right angles to each other and connected by aluminum disks (Figures 1,2). Upon each band is affixed four strain gages in a Wheatstone bridge arrangement, giving the device twelve total curvature measurement points (six for each bending plane). Each band is then potted in a flexible material [4]. The strain gages give output in terms of curvature or radius^{-1} (e.g. a radius of 2" is equivalent to a curvature of 0.5 in^{-1}).

A data acquisition and shape synthesis program was written to analyze the results. After curvature data have been collected during testing, a neck shape is produced using a specially developed software program. The program computes different neck shapes based on the sampling rate and the fact that gages measuring bending along one axis are separated at 1"

(25.4mm) intervals. A cubic curve fit routine was developed specifically for the COBRA II that computes the device's shape based on output of all the band sections. [3]

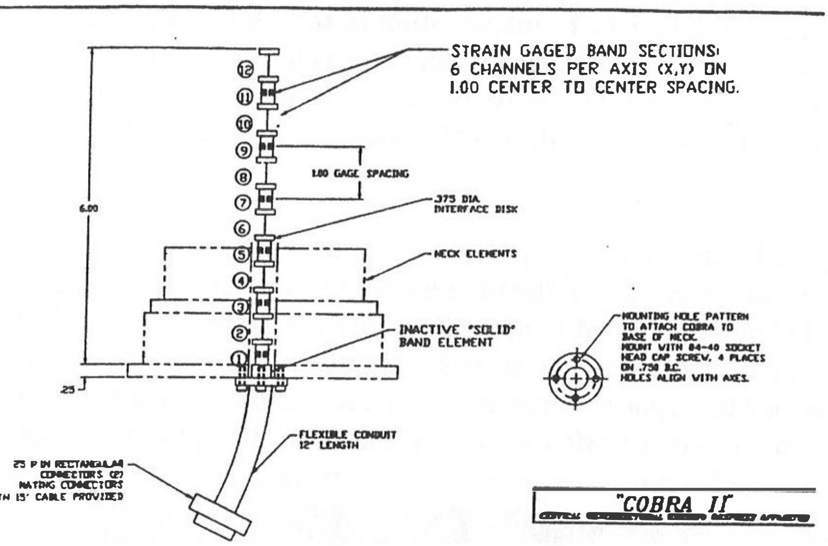

Figure 2. Schematic of the COBRA II. [4]

III. Testing

Both static and dynamic tests were performed using the COBRA II device.

1. Static Tests

Static tests were performed in order to examine the ability of the device to produce known shapes. A fixture was fabricated which consisted of a an aluminum piece with varying curvature recesses routed into the aluminum (Figure 3). These recess arcs represented such curvatures as 12, 10, 8, and 6 inch radius of curvatures. The COBRA II was placed into each recess of known curvature and the shape was calculated using the curvatures recorded from each strain gage (Figure 4). In addition, an 'S' shaped recess was also available to assess the ability of the COBRA II to handle both positive and negative curvature data in the same test situation. Tests were performed in both the X and Y directions (Figures 5,6). These Figures show the generated shapes compared to the actual shapes.

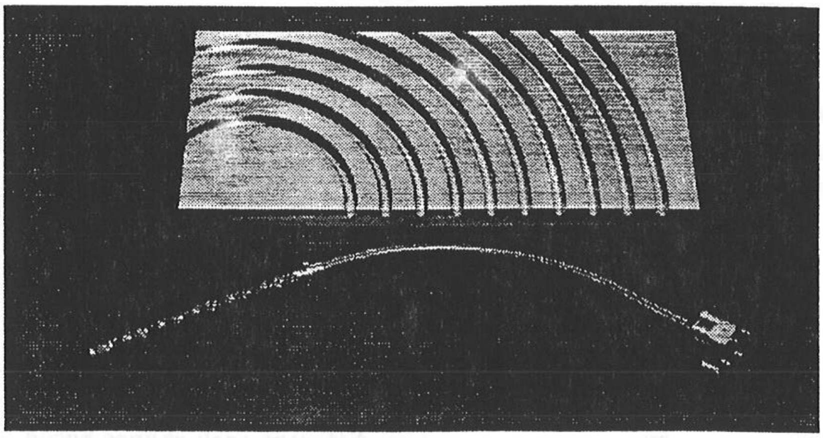

Figure 3. Test fixture for COBRA II static tests. [3]

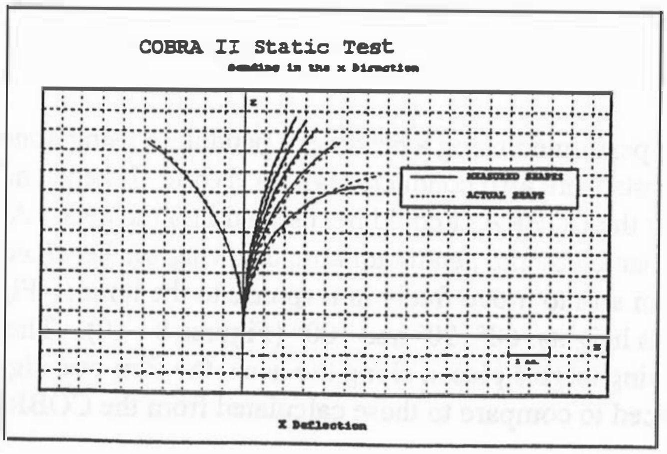

Figure 4. COBRA II static testing results for the X direction. [1]

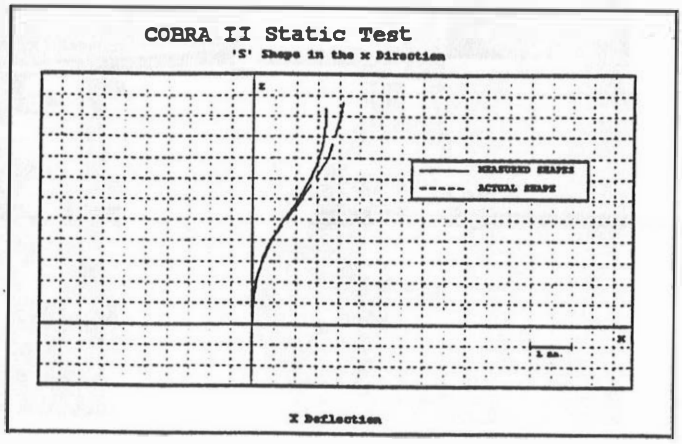

Figure 5. COBRA II static testing results for the X direction in bi-modal bending. [1]

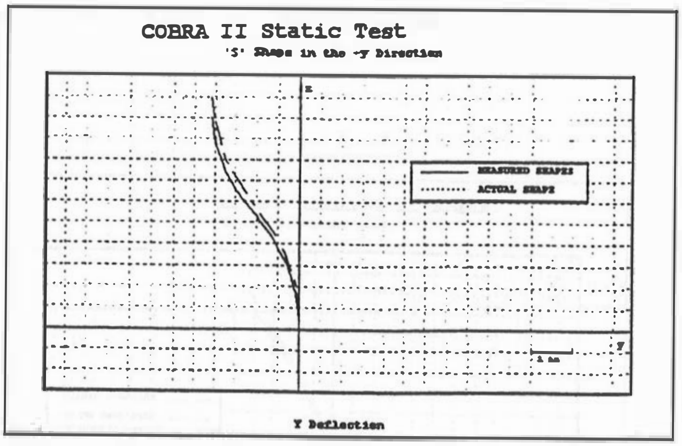

Figure 6. COBRA II static testing for the Y direction in bi-modal bending. [1]

Overall, the results of the testing performed using the COBRA II device showed excellent correlation with the measured shapes. The static test results produced from the constant curvature shapes were within 2mm of the actual shape. The 'S' shapes generated from the program also showed good results and were within 5mm of the actual shape for Y bending and 8mm of the actual shape for X bending. The 'S' shapes are extreme examples of the shape of the neck during impact conditions which produce bi-modal bending.[1]

2. Dynamic Tests

Dynamic tests were performed using a head/neck pendulum using a modified Hybrid II head and neck. Subsequent tests were also conducted with a Hybrid III head and neck. The neck cable was removed so that the COBRA II could be inserted into the neck. A 6" thickness of aluminum honeycomb was impacted by the pendulum arm, allowing the head/neck complex attached to the base of the pendulum arm to move freely in response to the impact (Figure 7). The pendulum was raised to various heights: 60°, 90° and 100° (Figures 8 - 10). The tests were recorded on high speed film. Using targets placed along the neck, the film was digitized and shapes were subsequently produced to compare to those calculated from the COBRA II data.[1]

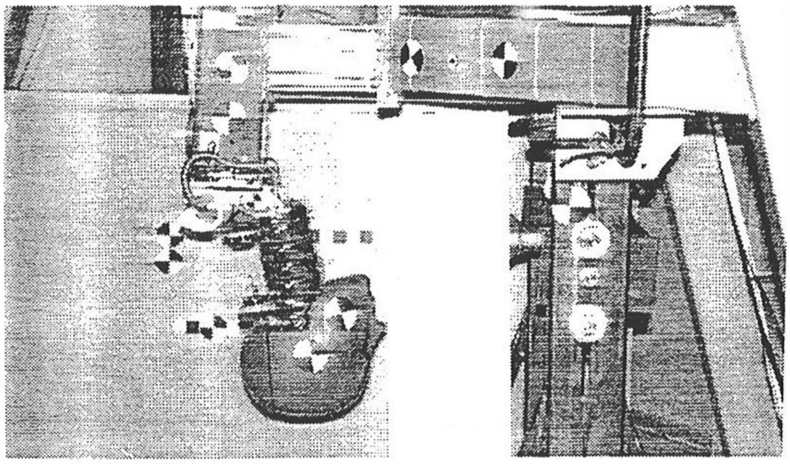

Figure 7. Pendulum test setup for COBRA II dynamic tests. The COBRA II is inserted into the neck. Targets on the neck are digitized for comparison with shapes measured from COBRA II.

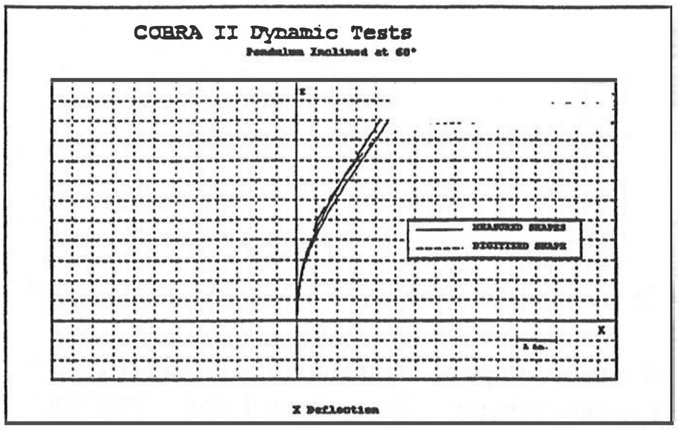

Figure 8. Measured neck shape at maximum deflection compared to (film) digitized shape. Pendulum raised to 60° inclination. [1]

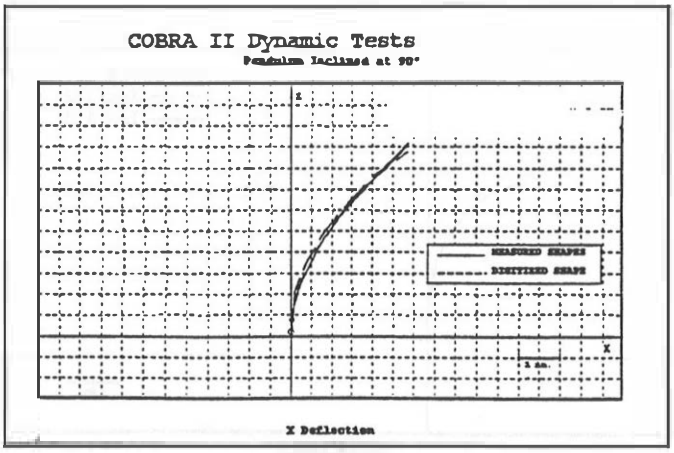

Figure 9. Measured neck shape at maximum deflection compared to (film) digitized shape. Pendulum raised to 90° inclination. [1]

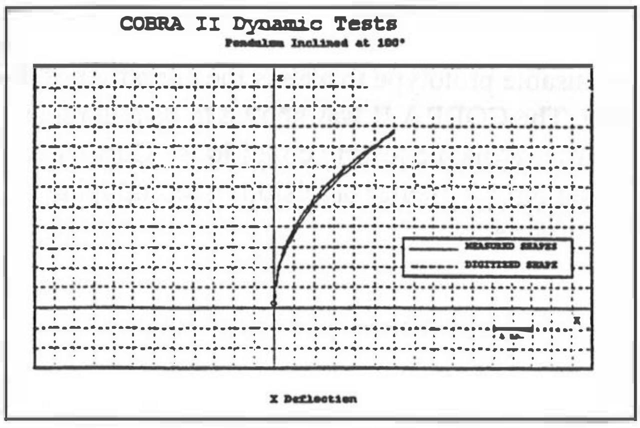

Figure 10. Measured neck shape at maximum deflection compared to (film) digitized shape. Pendulum raised to 100° inclination. [1]

The dynamic tests also showed very good correlation to the shapes digitized from the film data. However, in general, the shapes measured by the COBRA II transducer were not as curved as those produced from the film. This was probably due to the fact that the shape of the COBRA was not perfectly mimicking the shape of the neck due to the size of the center of the hole in the Hybrid II neck. The neck hole has a diameter 4mm larger than the diameter of the COBRA II. This extra room would allow the COBRA to experience a slightly different curvature compared to the film.[1]

Additional testing with the COBRA II utilized tests with the Hybrid III head/neck. In these tests, the head oriented frontally (nose towards the honeycomb), head/neck oriented 45° left , and head/neck oriented 45° right on the pendulum fixture. Three tests were also performed with the head impacting a steering wheel in the frontal orientation. The COBRA II was removed from the neck intermittently to check for signs of deformation. The repeatability of these tests further indicated the robustness of the device to withstand dynamic situations (Figure 11).

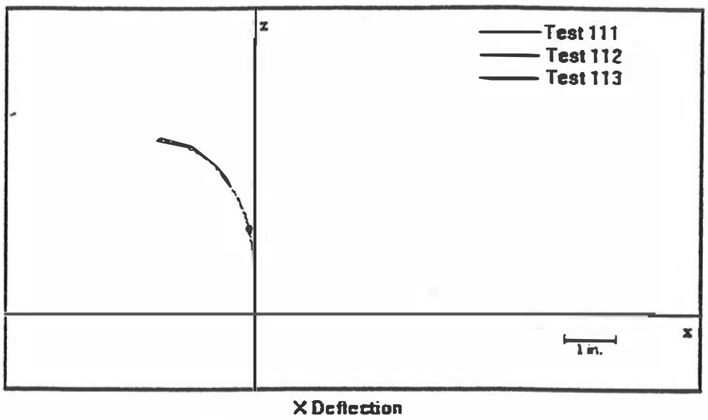

Figure 11. Three COBRA II pendulum tests with neck oriented 45° oblique. Results indicate the robustness and repeatability of the device.

IV. Conclusions

The COBRA II represents a usable prototype to assess the curvature of the cervical spine during an impact event. In addition, The COBRA II was shown to be a durable instrument, giving repeatable results under rigorous dynamic testing conditions. Current activity is concentrating on expanding the processing program for greater precision in reproducing the shape. Additional dynamic tests will also be performed.

References

1. Garrett, T.M., "Development of a Kinematic Measurement System for the Cervical Spine." (Master's Thesis) The Ohio State University, Columbus, OH: 1996.

2. Garrett, T.M., and Saul, R., "Evaluation of a Neck Shape Measurement Device Under Static Conditions." Event Report VRTC-88-0108, Vehicle Research and Test Center, East Liberty, OH: 1995.

3. Therrien, D.J., and Pritz, H.B., "Evaluation of a Neck Shape Measurement Device Under Dynamic Conditions." Event Report (Unpublished), Vehicle Research and Test Center. East Liberty, OH: 1996.

4. Therrien, D.J., and Pritz, H.B., "Cervical Omni-Directional Bending Response Apparatus (COBRA) User Manual." Event Report (Unpublished), Vehicle Research and Test Center. East Liberty, OH: 1996.