7

CHEST BAND VALIDATION STUDIES IN SIDE IMPACT

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INTRODUCTION

There has been significant progress in understanding the mechanisms of side impact trauma in the automotive environment. There have been numerous tests conducted on human cadavers to obtain the tolerance of tissues exposed to side impact trauma. A specially designed test fixture (Heidelberg type test sled) has been used for this purpose. A number of different transducers have been used to record and to quantify the biomechanical parameters associated with side impact trauma. The standard injury indices presently in use consist of accelerometer information obtained from various components of the human body. More recently the NHTSA has investigated the use of the external peripheral instrument for deformation measurement, or more commonly referred to as the chest band. The current design of the chest band consists of 40 channels of full bridge strain gauge instrumentation on a metal band spaced at intervals of 25.4 mm. This chest band instrument has been validated and used successfully in frontal impact tests on human cadavers [3, 5, 6]. It is presently desirable to assess the validity and functionality of the chest band in side impact tests on human cadavers. The present study was undertaken to quantify the accuracy of the chest band instrument for use in side impact trauma assessment.

METHODS AND MATERIALS

The NHTSA side impact dummy (SID) was used as a surrogate. The SID was disassembled to obtain photographic access of the thorax. The head and neck as well as the outer skin and padding were removed. The surrogate was dressed in standard cotton pants and was seated on a Teflon coated platform. A 40 channel chest band was wrapped around the surrogate chest at the superior-most margin of the thorax girdle. Retroreflective circular markers (3 mm diameter) were placed on the superior edge of the chest band for maximum viewing by the camera. A set of retroreflective markers were also placed in the plane of the chest band for calibration purposes. A high-speed video camera (Kodak Corporation, CA) recorded the event at 4500 frames per second. The video camera captured the event motions in the transverse plane.

The SID preparation with 40 gauge chest band was impacted using a pendulum apparatus at speeds of 4.5, 5.6, and 6.7 m/s. Two impacting surfaces were used: a flat plate, and a rounded surface of approximately 13 cm radius. The 40 channels of chest band data were captured by a Digital Data Acquisition System (DSP Corporation, CA) at 12.5 kHz per channel. The data acquisition system and the high-speed video camera were synchronized with a single trigger mechanism.

Chest band contours were obtained for each test at intervals of 0.22 msec corresponding to each frame of the video information. The video information was transferred to a computer using a video capture board on a frame by frame basis. The anteroposterior and right to left chest dimensions were digitized on a frame by frame basis for each test. Values were obtained both from the data acquisition system of the chest band and from the video information, and results were compared. A select number of contours were obtained from the RBAND_PC program and compared to the video output for specific times throughout the loading event. The effect of missing gauges was also analyzed by using the RBAND_PC output for 40 channels and then removing selected channels of chest band information to determine the deviation in response. Chest band to video comparisons were done from a point just prior to impact and through the point of maximum chest compression.

RESULTS

General results for both the flat plate impactor tests and the rounded impactor reveal that the left to right dimension compressed and the anteroposterior dimension expanded (figure 1). The general response of the SID chest thorax to the impact revealed initial left to right chest compression with an outward curvature change in the anteroposterior direction (figure 2). The response of the mid sagittal AP dimension lagged behind the left to right response by about 5 msec (figure 3). The SID thorax responded to the rounded impactor with initial conforming of the chest to the impactor surface but the subsequent AP response was very similar to the flat plate impactor (figure 4). When comparing the video information to the R-band program output, there was generally good agreement with the maximum difference of dimensions being 2% or less.

The effect of reducing the number of gauges from 40 revealed generally what would be expected: that missing gauges directly at the site of maximum curvature change caused the maximum error in the response, and multiple gauges missing consecutively also caused a considerable deviation in response. When there were up to ten gauges missing but no two consecutive gauges, the response was still very acceptable with deviations of less than 5%.

DISCUSSION

This study has demonstrated the feasibility and the accuracy of using the chest band in the side impact environment. The accuracy in the measured AP and left to right dimensions was generally in good agreement with maximum deviations of 2% or less. The difference in the responses may be attributed to multiple causes. The video information was captured from analog video tape to a digital computer via a video capture board. Although the video information was captured to the computer, it was necessary to manually digitize the dimensions and the various points around the chest band. This manual digitization inevitably brings error into the results. Also as the SID thorax was being loaded the torso fell to the side and caused the chest band to be out of the horizontal plane in the latter half of the event. For this reason the comparisons between video and RBAND information was discontinued after the maximum change in the AP direction. Up to this point in time the SID thorax remained predominantly upright.

Previous studies have reported on the accuracy and use of the chest band for other types of loading environments. In the original article by Eppinger in 1989 the introduction and use of the chest band was described with a 10 channel band and the accuracy was estimated as one-quarter of an inch for the mode shapes experimentally induced [2]. This original article also recommended the addition of extra strain-gauge channels to increase the accuracy and the reproduction of more highly complex shapes. More recently, Cesari and Bouquet demonstrated good agreement between the chest band deformations and external potentiometers at locations on the chest during seatbelt loading in cadavers and the Hybrid III [1]. Use of the chest band is not just limited to the automotive environment. A recent article by Pintar, et.al., demonstrated the use and accuracy of the chest band in a runover experiment with porcine cadaver preparations [4]. They showed that the chest band accurately obtained chest deformations to within 3% compared to video motion analysis.

The chest band is appropriate instrument for obtaining deformation contours of various preparations. With the present number of channels (40) it demonstrates remarkable accuracy in various loading modes including side impact testing. Because of the number of channels of information and the required high sampling rates to obtain dynamic information, it may be impractical for extensive use in many laboratories. However, with developed expertise in using the chest band and the RBAND_PC software that comes with it, considerable new information will be obtained to enhance our understanding of trauma to the human body.

ACKNOWLEDGMENT

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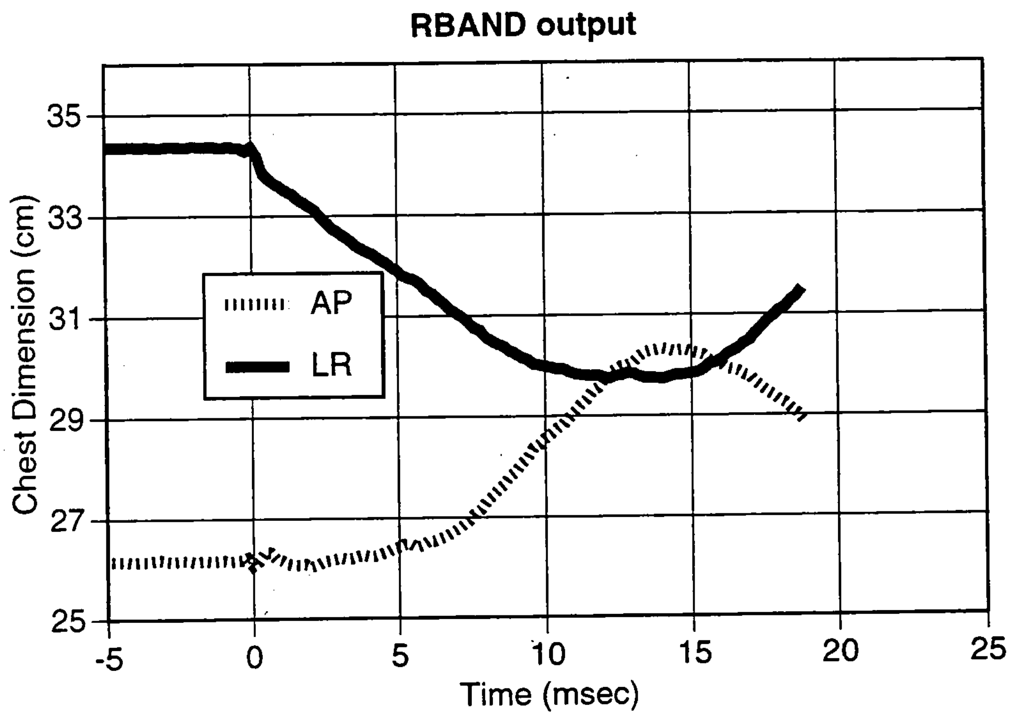

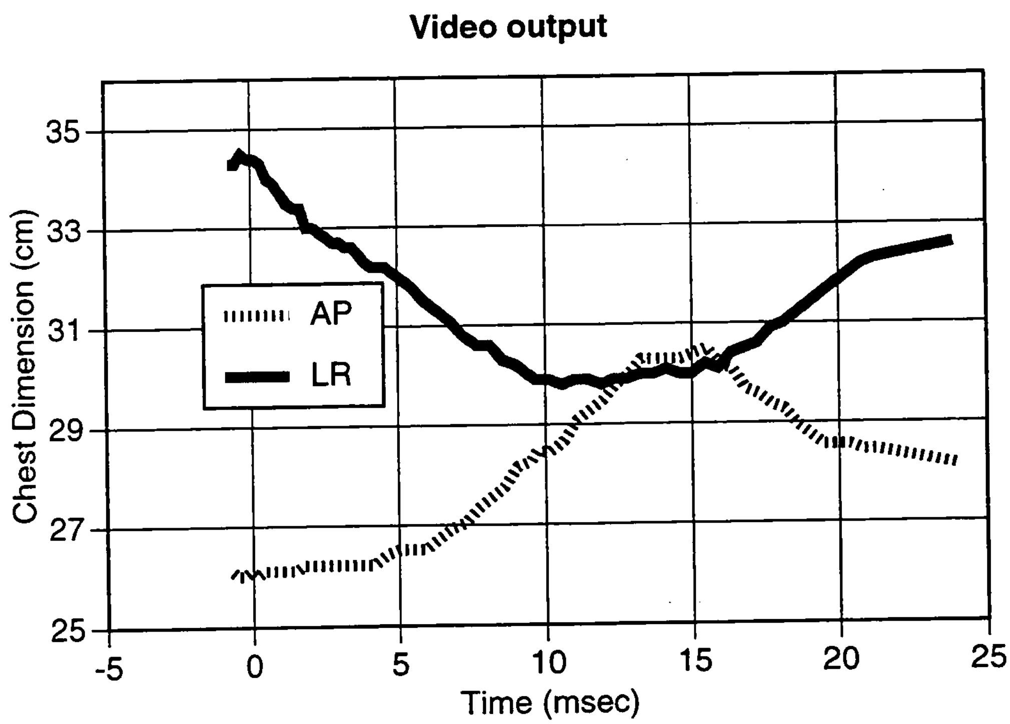

Figure 1: Examples of output from the RBAND computer program (top) and digitized video data (bottom) for a 6.7 m/s test with a flat-plate impactor.

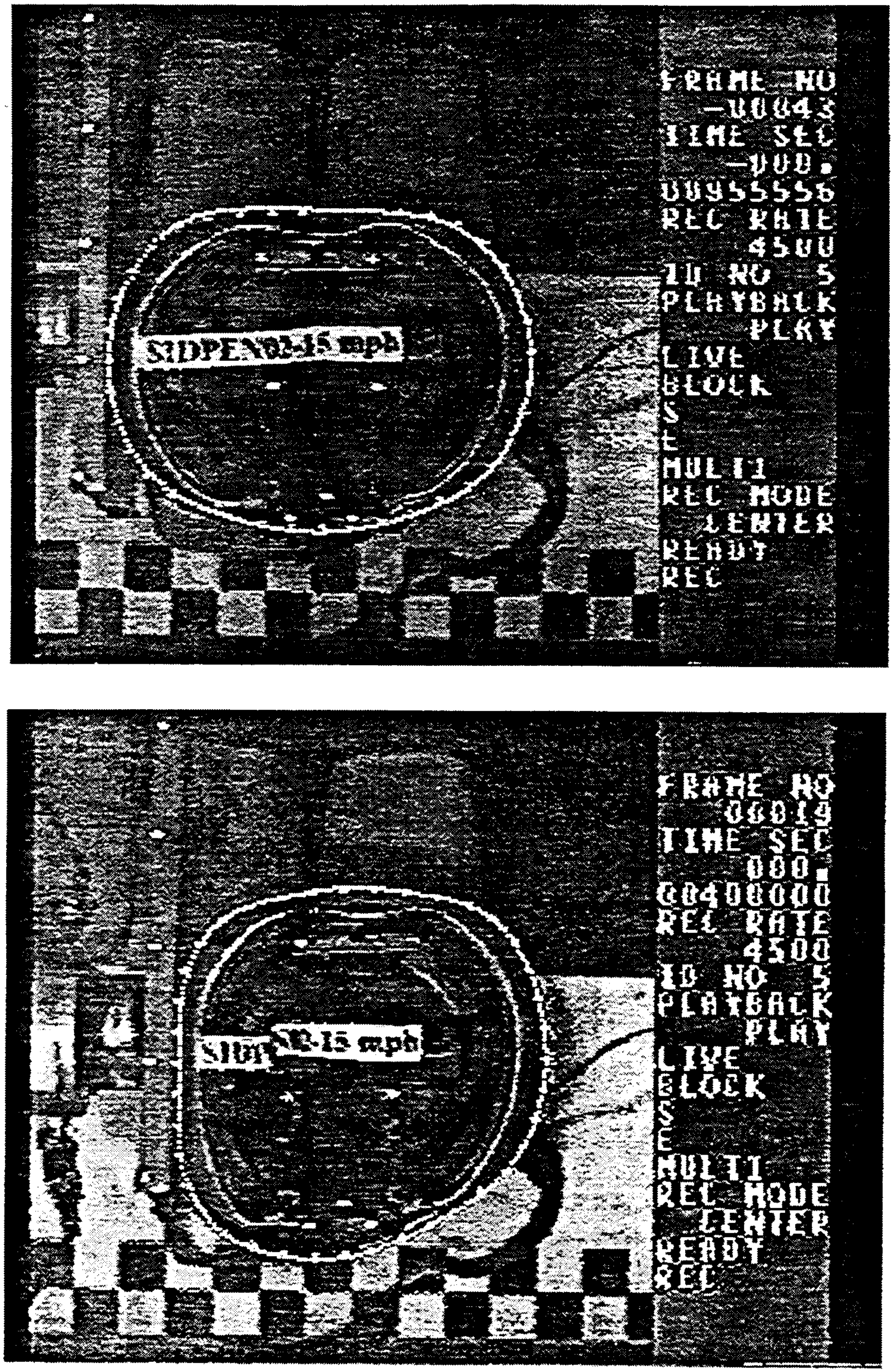

Figure 2: Captured frames of video from a 6.7 m/s flat-plate impactor test. The lighter overlay line is the output from the RBAND program.

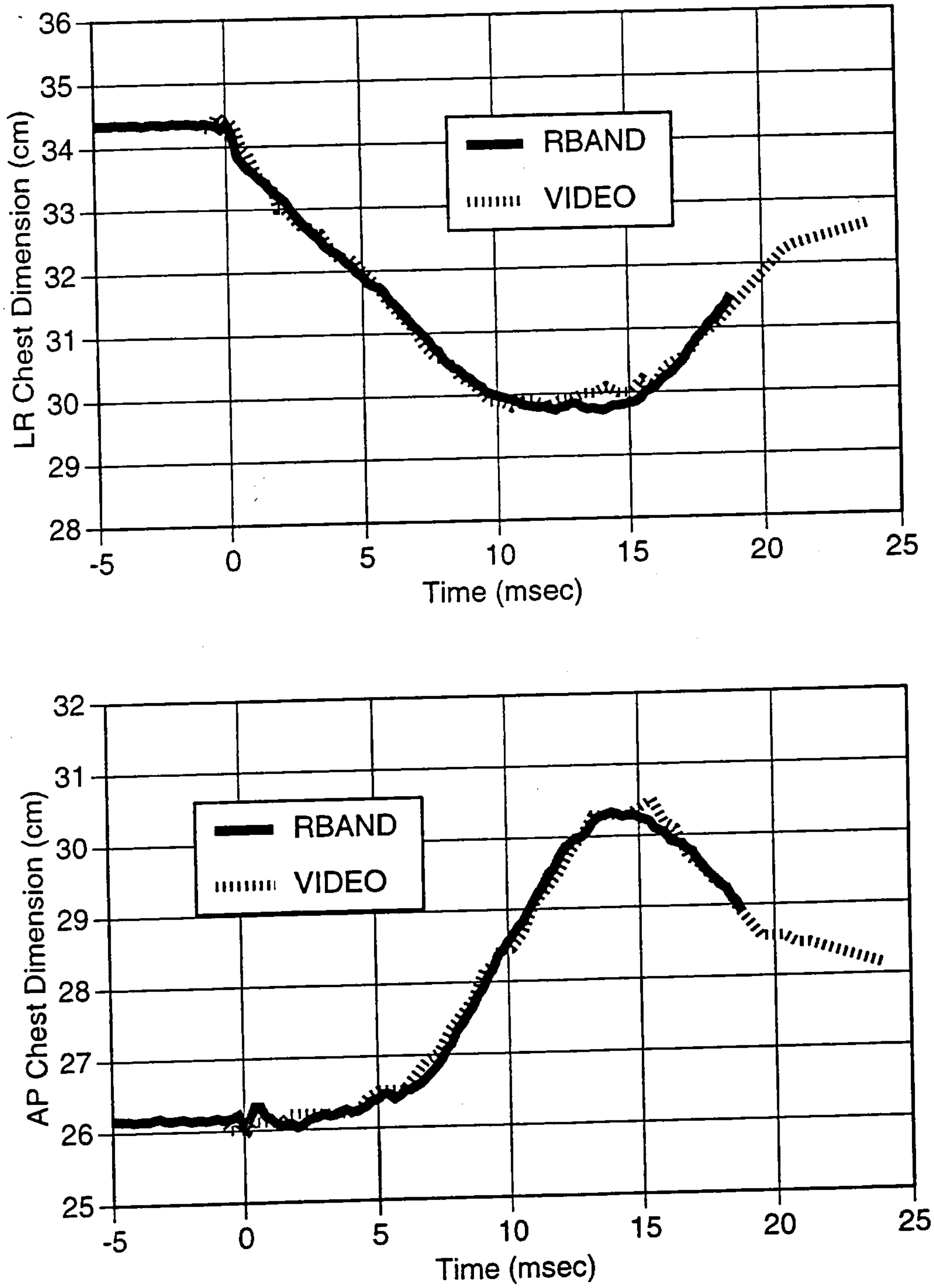

Figure 3: Examples of output comparing video data to RBAND computer program output for both left-to-right dimension (top) and antero-posterior dimension (bottom) for a 6.7 m/s test with a flat-plate impactor.

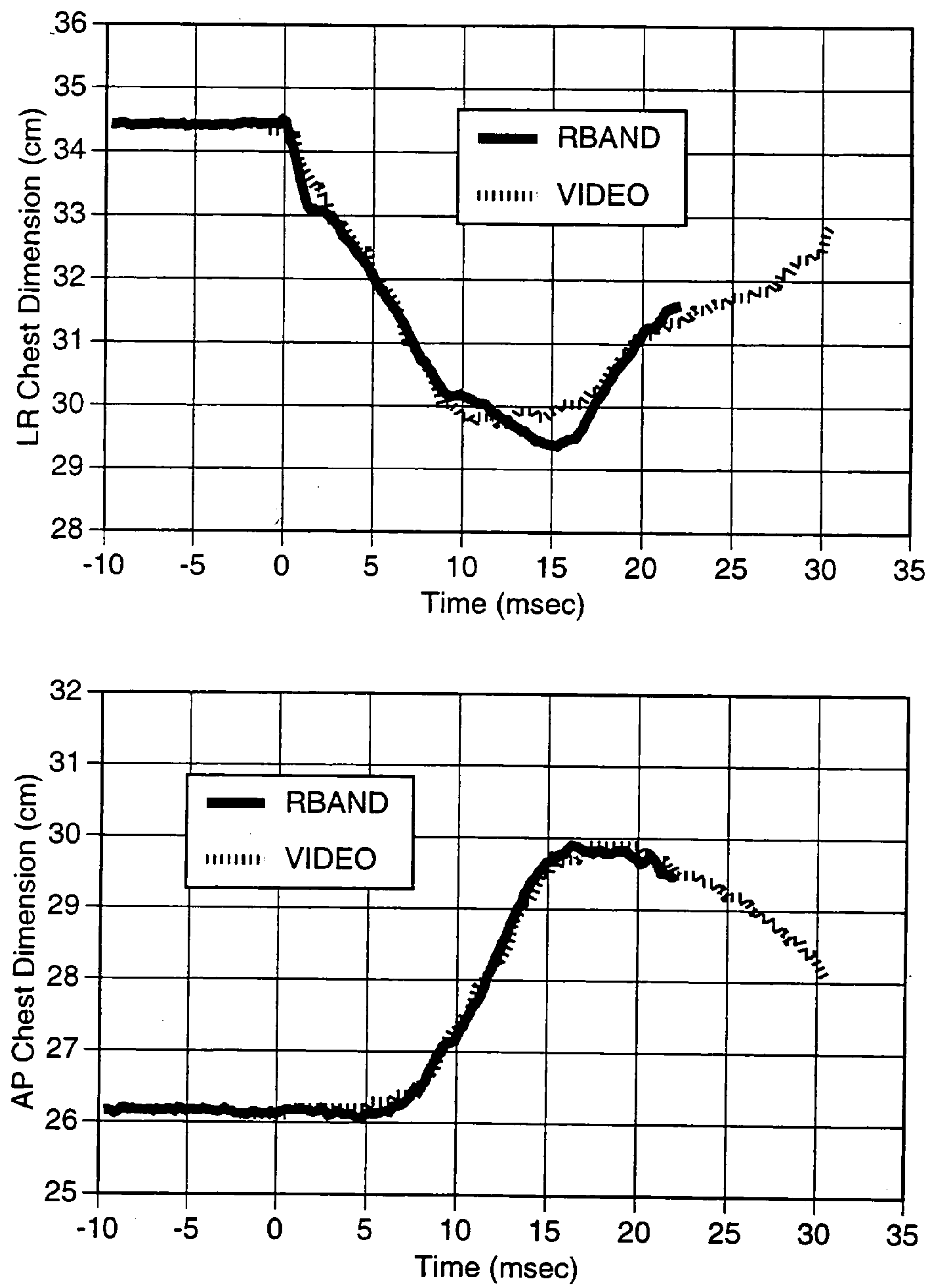

Figure 4: Examples of output comparing video data to RBAND computer program output for both left-to-right dimension (top) and antero-posterior dimension (bottom) for a 6.7 m/s test with a rounded impactor.

DISCUSSION

PAPER: **Chest Band Validation Studies For Side Impact**

PRESENTER: Frank Pintar, Medical College of Wisconsin

QUESTION: Guy Nusholtz, Chrysler Corporation

Have you tried looking at velocities? I've noticed that some of the differences in your displacements seem to be very sharp peaked. Have you tried differentiating the curves and compared the video velocity to the velocity of the chest band?

ANSWER: I haven't done that yet. That's a good suggestion. We'll have to go back there. On the computation, there is a lot to do here but since we've done the experiments, now we can go back and do that.

Q: OK. Thank you.

Q: Kathy Klinich, TRC

When you use the chest band in frontal impacts, you usually take the origin at the back. Are you moving that to the side now or do you still have it there?

A: In these particular analyses, I did use the spine/sternum designation.

Q: It looked like a couple times in the video that the chest band didn't conform closely to the dummy's thorax in certain parts of the impact and it kind of jumped away from the dummy's flesh and I was wondering if you tried it on the side. Once I noticed, then I started looking and it always seemed to stick better on the non-struck side.

A: Are you talking computationally?

Q: Yes, computationally.

A: Put the spine sternum points on the left to right versus the other?

Q: Yes.

A: We haven't tried that but I know it will give you the same contour but it might align them better. You can see some of them were just misaligned. You can probably take them and align them properly but we can try that too.

Q: Thank you.