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DEVELOPMENT OF BELT FIT ASSESSMENT COMPONENTS FOR THE ASPECT MANIKIN

Matthew P. Reed
Michelle M. Lehto

University of Michigan Transportation Research Institute

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Final Report

by

Matthew P. Reed
Michelle M. Lehto

Biosciences Division
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16. Abstract

As part of the Automotive Seat and Package Evaluation and Comparison Tools (ASPECT) program, UMTRI researchers developed a new H-point manikin that is intended to replace the current SAE J826 manikin. The original manikin is used in many automotive applications, including as a platform for a seatbelt deployment test device (BTD). In the current project, components and procedures were developed to measure belt fit using the ASPECT manikin. Contoured lap and torso forms were constructed using anthropometric data from an earlier UMTRI study. Prototype forms were mounted on the ASPECT manikin for testing in a laboratory fixture and in vehicles. The testing demonstrated that the ASPECT BTD produces consistent measures of belt fit that vary in expected ways with belt geometry. Further research will be necessary to refine the installation procedures and to establish the relationships between ASPECT BTD measures and the distributions of occupant belt fit. This report was prepared under a contract between Biokinetics and UMTRI and constitutes the partial deliverable for Public Works and Government Services Public Works and Government Services, Contract Serial No. T8056-000048/001/SS.

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ABSTRACT

As part of the Automotive Seat and Package Evaluation and Comparison Tools (ASPECT) program, UMTRI researchers developed a new H-point manikin that is intended to replace the current SAE J826 manikin. The original manikin is used in many automotive applications, including as a platform for a seatbelt deployment test device (BTD). In the current project, components and procedures were developed to measure belt fit using the ASPECT manikin. Contoured lap and torso forms were constructed using anthropometric data from an earlier UMTRI study. Prototype forms were mounted on the ASPECT manikin for testing in a laboratory fixture and in vehicles. The testing demonstrated that the ASPECT BTD produces consistent measures of belt fit that vary in expected ways with belt geometry. Further research will be necessary to refine the installation procedures and to establish the relationships between ASPECT BTD measures and the distributions of occupant belt fit. This report was prepared under a contract between UMTRI and Biokinetics and Associates, Ltd. and constitutes the partial deliverable for Public Works and Government Services, Contract Serial No. T8056-000048/001/SS.

1.0 INTRODUCTION

A test device for measuring seatbelt fit was developed in the early 1980s (Newman et al. 1984; Shewchenko 1997a). The Belt Test Device (BTD), shown in Figure 1, consists of contoured metal forms that simulate the lap and chest of an occupant, mounted to a modified version of the SAE J826 H-point machine. The torso and lap forms were constructed to be representative of a midsize occupant, nominally midway between average male and average female body sizes. The manikin is installed in a vehicle seat using a modified version of the SAE J826 H-point machine installation procedure, and the seatbelt is routed over the manikin. The positions of the belts on the chest and lap forms are recorded by reference to numerical scales at the thigh-abdominal junction, sternum, and clavicle areas.

In the last few years, Transport Canada and automobile industry representatives have participated in efforts to develop an electronic version of the BTD in a CAD environment. One objective of this effort is to assess the feasibility of a belt-fit standard that provides for compliance certification using electronic tools, rather than a physical device. This software-based BTD is known as the EBTD. Concurrent with this effort, a group of auto manufacturers and seat suppliers supported an effort led by UMTRI to develop a replacement for the SAE J826 H-point machine. The Automotive Seat and Package Evaluation and Comparison Tools (ASPECT) program developed a new manikin, shown in Figure 2 (Reed et al. 1999). The ASPECT manikin is based on midsize male anthropometry and has an articulated lumbar spine that allows it to conform to modern automobile seats better than the original H-point machine. The ASPECT manikin is currently undergoing final design changes prior to being adopted in SAE Recommended Practice J826.

The ASPECT manikin is expected to replace the current H-point machine as an international standard for auto seat measurement over the next few years. An important part of the transition process is developing ASPECT versions of tools that were originally developed for use with the H-point machine. For example, a head form has been mounted to the H-point machine to measure head restraint geometry (Pedder and Gane 1995). A similar tool has been developed for the ASPECT manikin that can make comparable measurements as well as other measurements not possible with the old tool. Adding belt-fit measurement capability to the ASPECT manikin would provide a transition path for the applications of the current BTD.

This report describes the development of belt-fit-assessment components for the ASPECT manikin. After an initial feasibility assessment and preliminary model development, a prototype design for the components was completed and tested. Minor modifications based on test results were integrated into the final design. Preliminary test procedures were developed based on experience using the new BTD in vehicles and laboratory mockups.

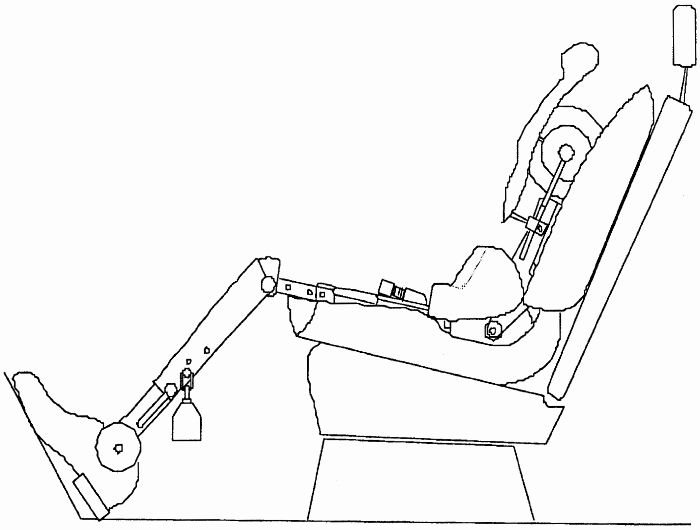


Figure 1. Current Belt Test Device (BTD) mounted on a modified SAE J826 H-point machine (Shewchenko 1997).

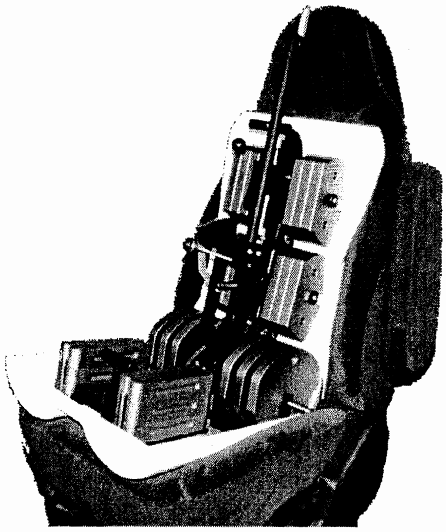


Figure 2. The ASPECT manikin prototype.

2.0 METHODS

2.1 Initial Feasibility Assessment

The program began with an initial study to determine the feasibility of adding belt fit components to the ASPECT manikin. As the ASPECT manikin hardware design was being finalized during the summer of 2000, the ASPECT BTD team coordinated with the SAE Human Accommodation and Design Devices Committee task group to ensure that the final manikin design was compatible with BTD requirements. In particular, the final ASPECT manikin could not have permanent fixtures or components that would interfere with the installation of the BTD forms.

A preliminary design for the ASPECT BTD components was developed to provide a basis for a feasibility assessment. The ASPECT manikin has rigid external shells that form the seat interaction surfaces. The posterior torso surface is comprised of three articulating shells, while the buttock and thigh surfaces are represented by a single piece. The back contours were developed from a CAD model of a midsize male occupant that was based on data collected at UMTRI in the mid-1980s. As part of a study to develop anthropometric standards for a new family of crash dummies, detailed measurements were made on twenty-five midsize men as they sat in an automobile driving posture (Schneider et al. 1985). One of the outcomes of that study was a full-size, three-dimensional model of the midsize male driver. As part of the ASPECT program, the model was digitally scanned to create a CAD model of a midsize male driver, shown in Figure 3.

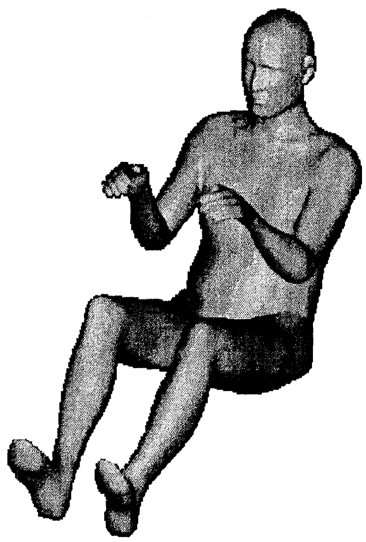


Figure 3. UMTRI midsize male CAD model.

The posterior torso surfaces of this model were used to create the back contour of the ASPECT manikin. As a consequence, there is an excellent fit between the back contours of the ASPECT manikin and the whole-body contour of the UMTRI midsize-male model. A preliminary design for the ASPECT BTD was constructed by aligning the UMTRI midsize-male CAD model with a model of the ASPECT manikin and sectioning it in the torso and lap areas. Figure 4 shows several views of the resulting model. The fore-aft position of the torso and lap forms is determined by landmark and external contour relationships from the ASPECT and UMTRI midsize-male datasets.

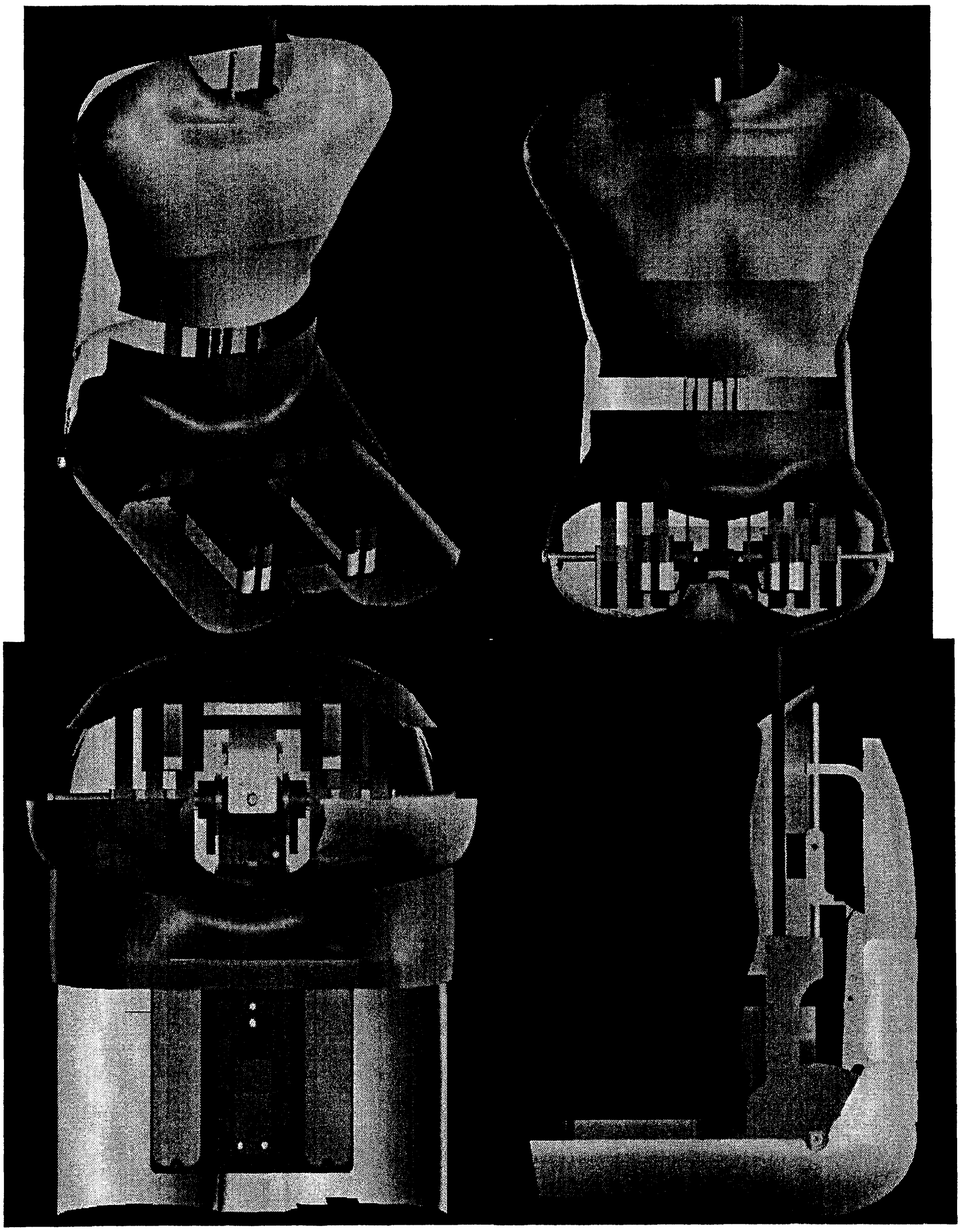


Figure 4. Preliminary concept for the ASPECT BTD. The side view shows a cutaway to reveal the fit between the lap and torso forms and the underlying manikin hardware.

The ASPECT manikin is manufactured by Technosports, Inc. of Livonia, Michigan. Their engineers are also active in the design of the manikin, providing both engineering and CAD services. In conjunction with that work, Technosports provided CAD support to the current project and developed the ASPECT BTD component hardware. After constructing the model shown in Figure 4, the clearances between the surface forms and the underlying hardware were examined.

Examination of this preliminary design concept suggested some issues that were addressed in the final implementation. The contour of the lap form in the ASIS region needed to be smoothed to ensure accurate and consistent belt routing. The potential for interference between the side of the shells and buckles in certain belt configurations was investigated in testing of the prototype. The belt deployment procedure was also studied to ensure that the manikin thigh weights did not interfere with the belt deployment around the manikin.

2.2 Design of the First-Generation Torso and Lap Forms

The preliminary CAD model was modified in several ways to develop the first hardware prototype. The torso form was shortened at the lower end to eliminate the outward-curving portion of the upper abdomen. On human occupants, this portion of the body is soft tissue that is readily deformed by posture changes or contact with the belt. The thigh-abdominal junction area of the lap form was modified to simplify the geometry and to reduce the surface curvature in the area of the anterior superior iliac spines (ASIS) of the pelvis. The simplified geometry is intended to improve belt routing and the repeatability of the belt-fit measurements.

The first hardware prototype lap and torso forms were produced by stereolithography, a rapid-prototyping method. The resulting plastic shells, shown in Figure 5, were mounted to an UMTRI prototype of the ASPECT manikin. The UMTRI prototype is functionally equivalent to the ASPECT manikin manufactured by Technosports, although the hardware has cosmetic differences.

The lap and torso forms together weigh only 2.6 kg (5.75 lb), or about three percent of the manikin weight. This small addition to the manikin weight does not change the manikin position in the seat significantly, and hence no reduction of the manikin weight is needed.

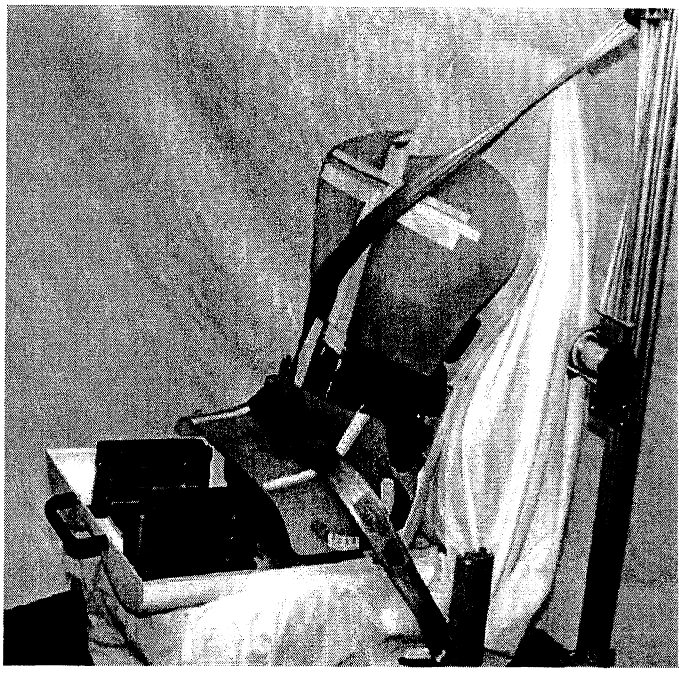


Figure 5. First-generation prototype lap and torso forms applied to a prototype ASPECT manikin.

An important consideration in the development of the BTD forms was the manner in which the forms are mounted to the manikin. The torso form has four points of attachment to the torso of the manikin. A fork at the base of the form slides into two grooves in the H-point saddle of the manikin (see Figures 5 and 10). Two rods in the chest area connect the torso form to a weight-hanger bar in the torso of the manikin to provide lateral stability. Initially, the mounting hardware for the torso form was designed so that the torso form angle could be set independent of the manikin back angle. However, further analysis of vehicle occupant posture data demonstrated that acceptable accuracy in chest position could be obtained with a direct linkage between the manikin back angle and the BTD torso form.

Two options were considered for mounting the lap form. One option was to allow the lap form to pivot at the hips, to simulate a range of pelvis orientations. The second option, the one used in the final design, was to attach the lap form rigidly to the buttock/thigh pan of the manikin. Because of concerns that the first option would introduce unwanted variability in the belt fit readings, the rigid attachment was chosen. One concern, however, is that the rigid attachment to the buttock/thigh pan means that the belt-fit scale readings are potentially dependent on the cushion angle of the seat. This issue is addressed below.

2.3 Prototype Testing

The prototype testing was intended to detect any problems that would affect the use of the ASPECT BTD for in-vehicle testing, to develop appropriate belt fit scales, and to create a preliminary installation procedure. A laboratory fixture was constructed that allowed belt anchorage locations to be moved over a wide range, as shown in Figure 6. Initial testing focused on belt routing procedures and positions for the belt fit scales.

Testing was conducted at a range of seat back recline angles. Testing was also conducted in the front and rear seats of several vehicles. Multiple trials were conducted in some conditions to assess the repeatability of the measures.

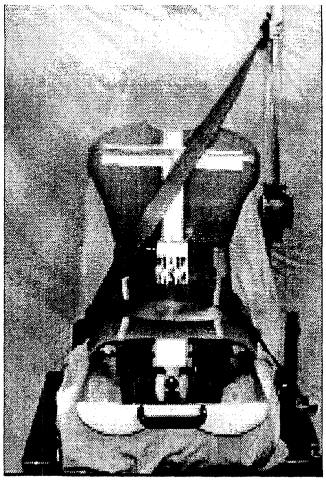


Figure 6. Laboratory fixture for testing prototype BTD forms.

2.4 Installation Procedures

The lab testing, conducted in the laboratory fixture shown in Figure 6, was intended (1) to assist in the development of installation procedures, (2) to determine if the BTD measures were sensitive to belt anchorage locations, and (3) to determine if the measurements were repeatable. The appendix describes the installation procedures, which are based on the procedures used with the original BTD (Shewchenko 1997b).

The belt-fit measurement begins with a standard ASPECT manikin installation. Adjustable seat components, such as bolsters and lumbar supports, are set to their lowest or minimally intrusive position. For seats with adjustable seatback angles, the seatback is adjusted to produce a manikin-measured seatback angle of 22 degrees in front seats and 25 degrees in rear seats. This differs from the previous procedures, which specified that the seat back should be set to the manufacturer's specified angle or to 25 degrees. Seats that have vertical adjustment as well as cushion angle adjustment should initially be placed in the full-down position. Then, without changing the seat cushion angle, the seat should be raised to the mid-height position for testing. This differs from the current procedure, which specifies that seats should be tested in the full-down position. UMTRI data show that the middle seat height is a more representative position in most vehicles. Seats with cushion angle adjustment that is tied to seat height should be placed in the center of the adjustment range. Additional detail on seat preparation and specifications for various seat adjustments will be necessary as the procedures are developed further.

The original BTD procedures specify that front seats with fore-aft adjustment should be measured with the seat at the center of the fore-aft adjustment range. Testing at a single position does not quantify the extent to which belt fit varies with seat position. Further, research at UMTRI has demonstrated that the middle seat track position is not a consistent predictor of driver-selected seat positions across vehicles (Manary et al. 1998;

Reed et al. 2001). One alternative, presented in the appendix, is to test at the full rear position and a point 150 mm forward of full rear. However, a better approach would be to test at two positions that span a large percentage of the driver-selected seat position distribution (e.g., 10th to 90th percentiles) and which are determined independent of the manufacturer-specified reference points. The procedures for such positioning could be adapted from the UMTRI ATD positioning procedures (Reed et al. 2001).

The ASPECT manikin is used without leg and thigh segments. Although supplementary thigh, leg, and shoe tools are provided with the manikin, they are not needed for basic seat measurements and are not used with the BTD components. The manikin is installed according to the standard procedures, which call for sequential installation of weights and standardized force application (see appendix). The BTD components are then installed, starting with the torso form. The belt is deployed using the procedures developed for the original BTD (Shewchenko 1997b).

When the belt deployment is complete, the points where the belt crosses the scales on the lap and torso forms are recorded to quantify the belt fit, as shown in Figure 7. The lap form scales are parallel to the midline at the locations of the ASIS (234 mm apart). The scales read in centimeters from a reference point that is 10 cm forward of the ASIS along the contour of the lap form. Hence, a reading of 10 cm indicates that the belt edge passes directly over the ASIS reference point on the lap form. On the torso form, the scales measure with respect to a reference point on the midline that is 450 mm above the H-point along the manikin torso line. Symmetrical scales extend to the left and right, and a vertical scale extends down from the reference point. The torso belt fit is quantified by the vertical and lateral scale readings where the lower edge of the torso belt crosses the scales.

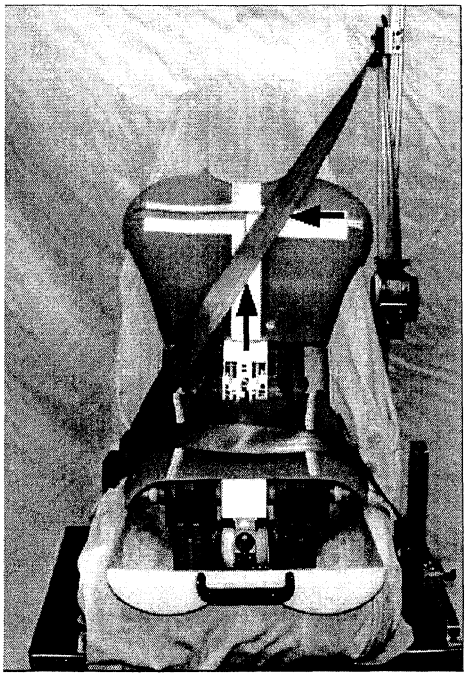


Figure 7. Reading belt fit from the lap and torso scales. Arrows indicate locations where the scales are read.

3.0 RESULTS

3.1 Laboratory Evaluations

3.1.1 Repeatability

To evaluate the repeatability of the BTD measurements, the ASPECT BTD was installed in the laboratory fixture five times, using the procedures in the appendix. Table 1 shows the scale readings. Three trials were performed in direct succession, removing the manikin from the seat each time but not allowing any further time for the seat to recover. Twenty-four hours elapsed between trials three and four, and trial five was conducted immediately after trial four. Experiments with the ASPECT manikin have shown that the seat should remain unweighted for at least one hour between measurements to obtain consistent H-point results. Table 1 shows that the BTD scale readings are generally consistent for repeated measurements, but may be affected by seat rest time.

Table 1
Repeated Measurements in One Belt Configuration

Trial	Seat Rest Time Prior to Trial	Inboard Lap Scale Reading (cm)	Outboard Lap Scale Reading (cm)	Vertical Torso Scale Reading (cm)	Horizontal Torso Scale Reading (cm)
1	24 hours	14.6	15.7	9.8	7.4
2	no rest	14.5	15.3	9.3	6.9
3	no rest	14.4	15.5	10.0	7.4
4	24 hours	15.3	14.6	9.3	7.0
5	no rest	15.3	14.6	10.3	7.7

3.1.2 Cushion Angle Effects

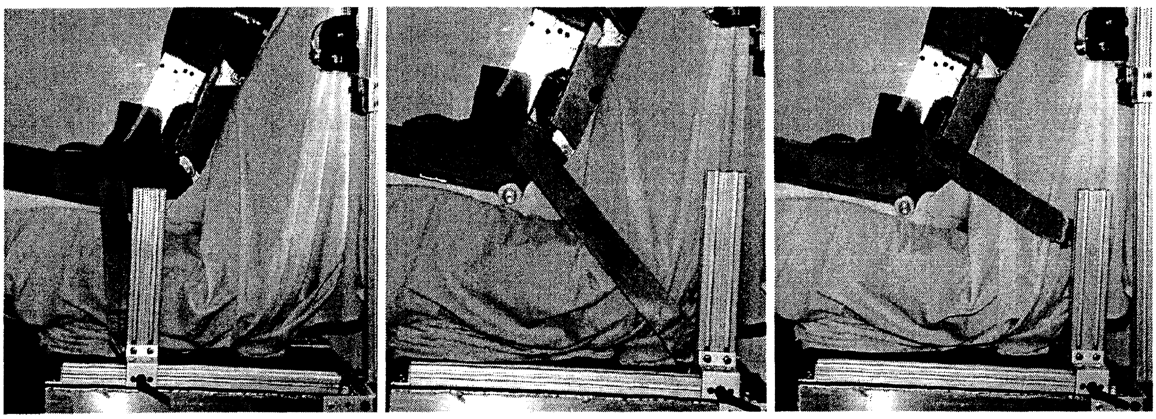
Because the lap form is rigidly attached to the buttock/thigh pan of the manikin, changes in seat cushion angle have the potential to affect the readings from the lap form scales. Table 2 lists outboard lap form scale readings from three different belt configurations at three different cushion angles. The belt configurations are shown in Figure 8. Five trials were performed in each test condition by repeating the belt routing only (the manikin was not reinstalled).

The belt configurations affected the outboard lap form scale readings substantially. From configuration A (belt near vertical) to configuration C (belt angle closer to horizontal), the scale reading changed from an average of 10.5 cm to 16.4 cm. If the scale is read to the nearest 0.5 cm, as recommended in the preliminary procedure (see appendix), approximately 12 scale reading levels would separate configuration A from configuration C. Surprisingly, the scale readings were not sensitive to cushion angle. The range from 10 to 20 degrees spans about 90 percent of actual vehicle cushion angles, so these results suggest that ASPECT BTD results do not need to be adjusted for cushion angle. Additional experimentation in a wider range of test conditions will be necessary to confirm these findings.

The repeatability of the belt deployments in this laboratory setting was excellent. The data in Tables 1 and 2 suggest that variability in BTD scale readings will be due primarily to variability in manikin installation, and not to differences in belt routing. Because the ASPECT manikin repeatability is better than the previous manikin, particularly for seats with prominent lumbar supports, the repeatability of the ASPECT BTD is expected to improve on the performance of the original BTD.

Table 2
Effects of Cushion Angle and Anchorage Location on Lap Form Scale Readings

Belt Configuration	Seat Cushion Angle (degrees)	Outboard Lap Form Scale Reading (cm)					
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Mean (sd)
A	10	10.9	10.7	10.8	10.8	10.7	10.8 (0.08)
A	15	10.4	10.4	10.3	10.4	10.5	10.4 (0.07)
A	20	10.7	10.7	10.8	10.8	10.7	10.7 (0.05)
B	10	14.6	14.5	14.4	14.5	14.4	14.5 (0.08)
B	15	14.5	14.6	14.6	14.6	14.6	14.6 (0.04)
B	20	14.9	14.8	14.7	14.7	14.8	14.8 (0.08)
C	10	16.4	16.4	16.5	16.5	16.5	16.5 (0.05)
C	15	16.3	16.3	16.2	16.3	16.3	16.3 (0.04)
C	20	16.5	16.4	16.5	16.5	16.5	16.5 (0.04)



A B C

Figure 8. Side views of three lap belt configurations, produced by changing the lower outboard belt anchorage location.

3.2 In-Vehicle Evaluations

In-vehicle testing was conducted to determine if installing the BTD in vehicle seats posed problems not noted in the laboratory testing. Manikin installations in vehicles are always more difficult than laboratory installations because of space constraints, but the ASPECT manikin is much easier to install than the original H-point manikin and BTD. In particular, the legs and feet of the original H-point manikin created many problems during installation. The legless ASPECT manikin procedure eliminates those issues.

Aligning the manikin with the long axis of the vehicle is sometimes problematic, particularly in rear seats. Careful attention to manikin positioning can ensure that the manikin is square to the vehicle grid. A more difficult problem arises in rear seats that have asymmetrical contouring. Often, the outboard seating position of a rear bench seat will have a higher bolster on the outboard side of the cushion than on the inboard side. In some seats, this contouring will make it difficult to level the manikin. With the old manikin, the legs could be used to prop the manikin in a level position, although this non-standard procedure would yield suspect measures. One reasonable solution with the ASPECT BTD is to attempt to level the manikin and to complete the BTD measurements in the most level position attainable, recording the actual lateral angle if different from zero.

In-vehicle evaluations did not reveal any problems with the BTD components. Considerably more testing in a wide range of vehicle types will be necessary to ensure that the ASPECT BTD can be used in all vehicles.

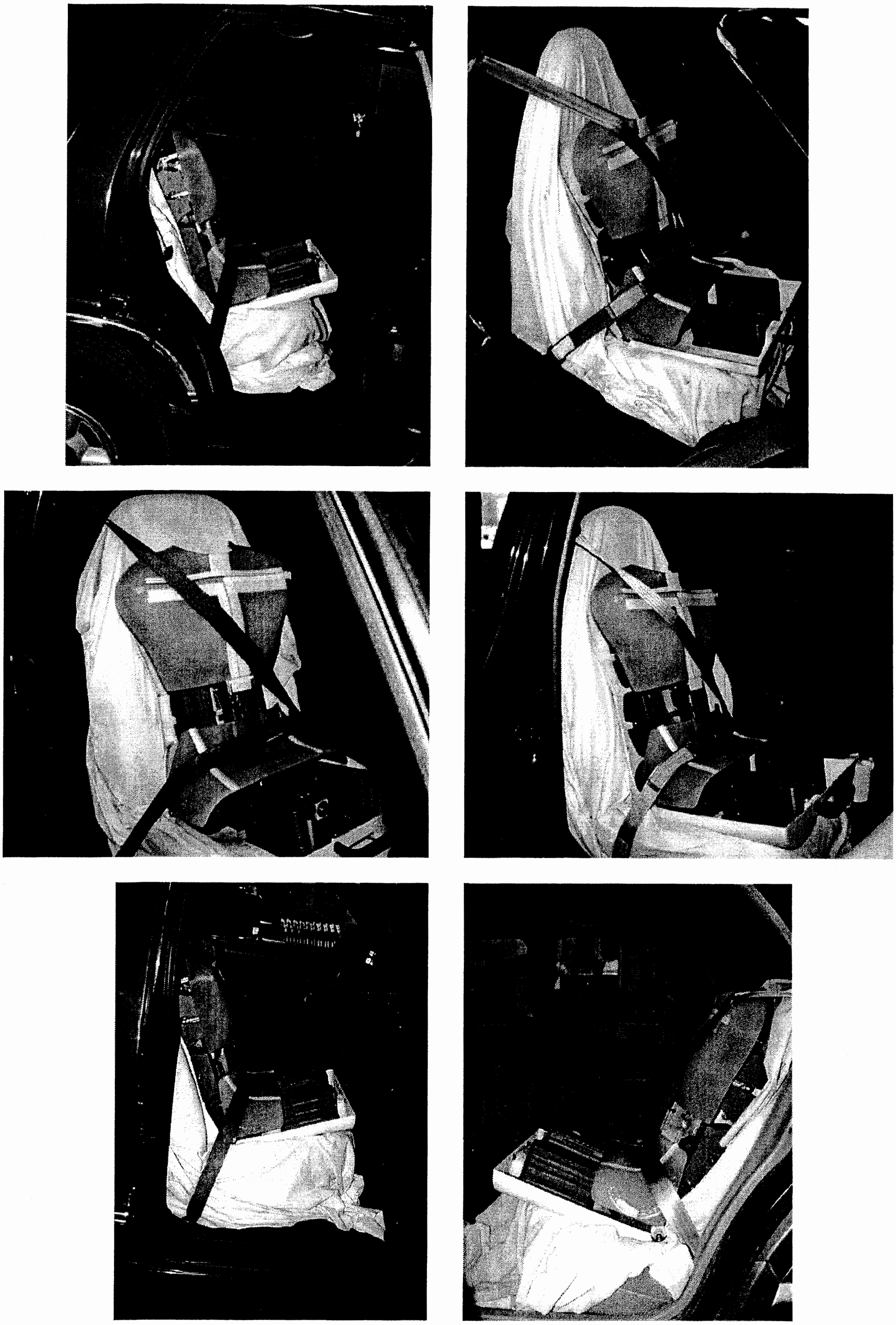


Figure 9. ASPECT BTD installed in several vehicle seats.

3.3 Final Prototype Features

Figure 10 shows the CAD model of the final prototype forms. The final forms differ in several ways from the first-generation prototypes evaluated at UMTRI.

- The revised torso form is flatter laterally across the upper chest and shoulder area to improve torso belt routing.
- The top edge of the torso form extends over the shoulders to improve interaction with seat-integrated belt systems.
- The torso form transitions into the lower neck to provide realistic routing for belts that would contact a midsize-male occupant's neck.
- The locations of the ASIS surface landmarks are molded into the lap form to facilitate accurate scale positioning.
- The location of the intersection of the torso form scales is marked on the form to facilitate accurate scale positioning.
- The lap and torso forms have mounting pads on the inside surfaces to facilitate accurate positioning during hardware assembly.

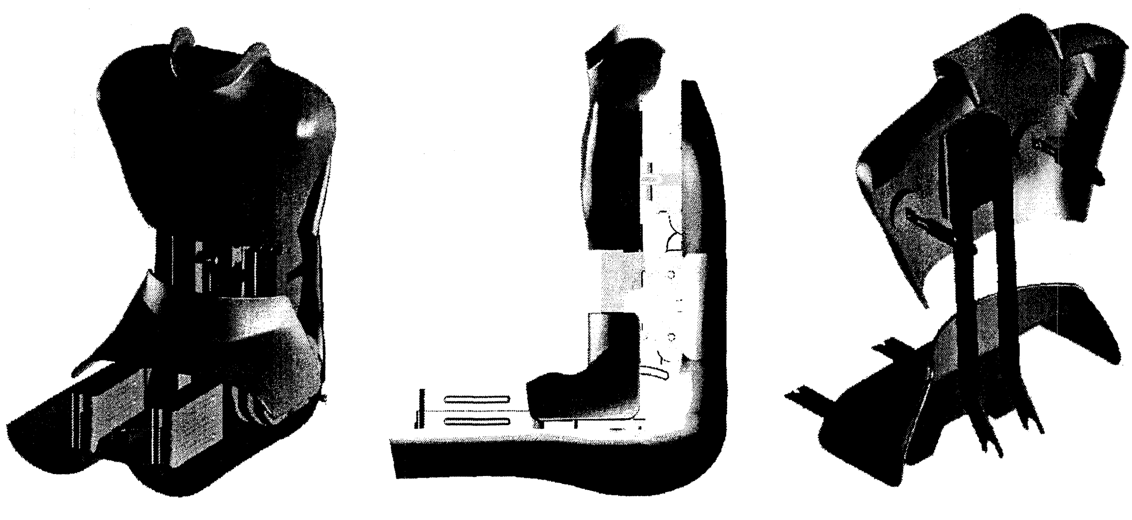


Figure 10. CAD model of final prototype BTD components.

Figure 11 shows the final prototype constructed by Technosports. The surface is coated with a smooth finish to facilitate repeatable belt installation. The scales are decals applied with reference to marks molded into the surface. The lap form is mounted using two quick-release fasteners; the torso form is mounted as shown in Figure 10.

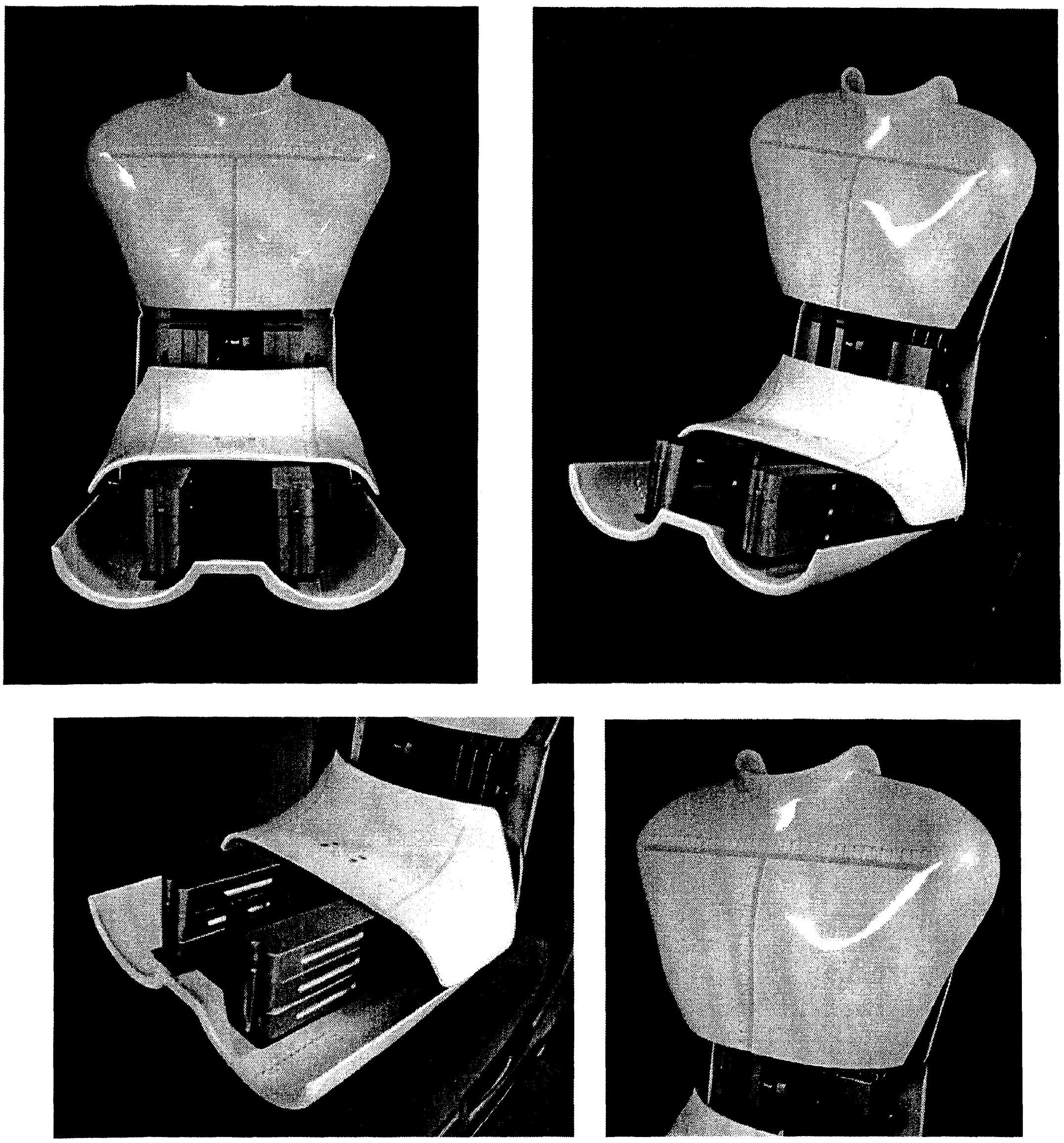


Figure 11. Final prototype forms constructed by Technosports.

4.0 DISCUSSION

ASPECT BTD Design

The ASPECT BTD components were developed in a short-duration, small-scale research and development program. Although the anthropometric basis for the lap and torso forms is well established, no validation of the measures obtained from the ASPECT BTD has been performed. In particular, the relationship between ASPECT BTD measures and occupant belt fit has not been established. Considerably more work will be necessary to complete the development of the installation procedures and to provide meaningful interpretation of the scale readings.

Pelvis Angle in Rear Seats

The ASPECT BTD responds to vehicle and seat geometry manner that is different from the original BTD. In rear seats with limited legroom, the legs of the original BTD would elevate the front of the manikin buttock/thigh pan, simultaneously changing the orientation of the lap form and the ASIS-scale readings. The original BTD was not affected by seat cushion angle, except when the fore-aft positions of the manikin's feet were unrestricted.

In contrast, the ASPECT-BTD measurements are independent of legroom, seat height, or other package dimensions. By design, the ASPECT manikin measures the seat geometry independent of the package. As in the original BTD, the ASPECT BTD lap form moves with the buttock/thigh pan. However, the ASPECT buttock/thigh pan orientation is determined by interaction with the seat cushion. The angle of the manikin thigh line is termed seat cushion angle and is a measure of seat geometry.

During the development of the ASPECT BTD, some people familiar with the behavior of the original BTD expressed concern that the lack of response of the ASPECT BTD to restricted legroom would lead to unrealistic belt fit assessments in rear seats. The assumption is that elevated thighs lead to more reclined pelvis orientations, as reflected by the change in the orientation of the lap form on the original BTD.

UMTRI data on occupant posture and position do not support the assumption that pelvis angles in rear seats are substantially different from those in front seats, or that restricted legroom causes more reclined pelvis postures. ASIS-to-eye distances and orientations for rear-seat passengers are not changed significantly when legroom is restricted, suggesting that the torso posture remains unchanged. Elevated thigh angles caused by restricted leg room may even produce more upright pelvis angles, rather than more reclined, because more body weight is concentrated under the buttocks, pushing the ischial tuberosities into the seat and allowing the lumbar support to provide greater stability to the pelvis. A study of passenger postures now underway at UMTRI will definitively address the question of how pelvis postures are affected by restricted legroom.

What the ASPECT BTD Measures

The ASPECT BTD represents a single, midsize male body size in one or a few seat positions. The resulting belt-fit measures are intended to be typical of the belt fit that a similarly sized person would experience, but a occupant population would experience a wide range of belt fit in the same vehicle seat. The ASPECT BTD is intended to provide measures that are consistently related to the distribution of the quality of belt fit that an occupant population would experience.

In a basic sense, the ASPECT BTD measures belt anchorage locations. The linear scales on the manikin are sensitive to the angles at which the belt traverses the lap and torso forms. Anchorage locations at any distance from the manikin, but producing the same belt angles, will produce the same belt fit scores. Testing in multiple seat positions would provide some measure of the anchorage distance as well as angle, thereby providing a better assessment of population belt fit distributions for front seats. The purpose of the ASPECT BTD is to detect belt anchorage locations and routing that would produce poor belt fit in an unacceptably large number of occupants. Poor belt fit could be defined in many ways, but one way to define belt fit is with respect to the angles with which the belt traverses a person's body. For the side-view angle of the lap belt, an angle that is too shallow (anchorage too high and/or too far rearward) is undesirable because of the risk of submarining. Angles that are too vertical are undesirable because the effective stiffness of the belt is reduced, allowing excessive occupant translation during a crash. For the torso portion of the belt, front-view angles that are too vertical can lead to discomfort for shorter occupants. Front-view angles too far from vertical may not provide adequate torso restraint for tall, thin occupants.

It is important to stress that the ASPECT BTD does not measure where the belt will contact any particular person's body. For example, the positioning of the belt relative to the lap form of the ASPECT BTD is not intended to be directly predictive of the average lap belt positioning for a midsize male occupant. Rather, the ASPECT BTD measures are intended to be sensitive to changes in belt geometry that would change the distribution of belt fit for the occupant population.

Outline of a Validation Study

The BTD measures that define the boundaries between good and poor belt geometries must be determined through testing with a large number of occupants. A validation study is essential to interpreting the belt fit readings obtained from the BTD. Such a study should include the following steps:

1. Measure the belt fit obtained by a large sample of people with diverse body sizes in a laboratory mockup. Test conditions should span a wide range of belt configurations and should include adjustable front seats as well as fixed rear seats. Belt fit should be quantified by the locations of the belts with respect to the occupant's anatomy and the angles with which the belts leave the sitter's body. The test conditions should include rear seats with restricted leg room.

2. Analyze the data to obtain statistical models that predict the distributions of belt fit parameters (anatomical positions of belts and belt angles) as a function of occupant characteristics (stature, weight, gender, etc.) and belt system characteristics (anchorage locations, stalk type, etc.)

3. Record ASPECT BTD readings in each of the test conditions.

4. Construct statistical models that predict the distributions of occupant belt fit parameters using BTD measures instead of direct representations of anchorage locations.

5. Develop and apply biomechanical criteria to establish categories of belt fit. For example, lap belt angle might be divided into zones that are unacceptable, acceptable, and good.

The information from the validation study will allow safety engineers and policy makers to establish BTD criteria for belt fit. For example, safety standards might specify that the BTD measures on the lap belt must fall within a range that the validation data indicate will result in 95 percent of occupants achieving "acceptable" or better belt fit.

E-BTD

The Joint Working Group on Abdominal Injury Reduction is overseeing development of a software tool for belt fit assessment. The E-BTD simulates the original BTD in an interactive computer graphics environment. The objective of the working group is to develop a tool that would allow manufacturers to demonstrate compliance with belt fit design guidelines using a software tool rather than a physical test.

The ASPECT BTD can readily be integrated into this approach. In fact, the process should be easier with the ASPECT BTD. A complete, standard CAD description of the ASPECT manikin and the BTD forms is available, whereas a reverse-engineering approach was required with the original BTD. The ASPECT BTD is also used without legs, substantially simplifying the installation procedure, both physically and in software. The belt routing algorithms that have been developed for the current E-BTD should be applicable without modification to a simulation of the ASPECT BTD.

Conclusions

This program has completed development of torso and lap forms that attach to the ASPECT manikin. When the ASPECT BTD is installed according to the specified procedures, scales on the torso and lap forms provide quantitative information about the seat belt geometry. The preliminary test results presented in this report suggest that the ASPECT BTD measures are consistent and vary with belt geometry an a manner that should be related to distributions of human belt fit. However, a substantial testing and validation effort will be required to establish test procedures for the ASPECT BTD and belt assessment criteria based on ASPECT BTD measures.

5.0 REFERENCES

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APPENDIX

PRELIMINARY INSTALLATION PROCEDURES

These procedures are based on the Operational Manual for the Belt Deployment Test Device (Shewchenko 1997b), with additions and modifications necessary for the ASPECT BTD. Readers should refer to Shewchenko (1997) for definition of terms. The procedure is preliminary -- further work will be necessary to develop a complete installation method that covers all contingencies.

Positioning and Measurement Procedure for the Belt Deployment Test Device (BTD).

Revised for use with the ASPECT Manikin

Preliminary Adjustments

1. **Prepare the BTD.**

   Check that the BTD is in good working order. Ensure that all bolts are tight and that there is no lateral play between the seat back and pan, and no lateral or vertical play with the torso form and lap form when attached to the seat back and pan, respectively. The lumbar support prominence indicator on the ASPECT manikin should be removed to avoid interference with belt routing.

2. **Set up the vehicle.**

   Position the vehicle on a level surface in the test attitude and stabilize with floor jacks. The test attitude is defined with the vehicle at curb weight (100 percent of all fluid capacities) and all tires inflated to the manufacturer's specifications as listed on the vehicle's tire placard. The test environment should be at normal ambient conditions (15°C - 25°C, 25% - 75% RH). Record vehicle data on the data sheets.

3. **Adjust the steering wheel.**

   For the first seat – driver positions, adjustable steering wheels should be placed at the highest locked position.

4. Adjust the torso belt anchor.

If the B-pillar or C-pillar torso belt anchor is adjustable it should be placed at the nominal design position for the 50^{th} percentile male occupant. If not specified it should be placed in its locked middle position or at the next highest position if there is no mid-position. Record seat belt data on the data sheets.

5. Adjust the lumbar support.

If the seat is equipped with an adjustable lumbar support it should be set at its lowest or least prominent position.

6. Adjust the lateral and thigh supports.

If the seat is equipped with adjustable lateral back supports or lateral thigh supports, they should be open or set as wide as possible. If the seat is equipped with an adjustable thigh support, it should be adjusted to be coplanar with the rest of the seat to the extent possible.

7. Adjust the seat cushion angle.

If the seat cushion angle is adjustable via the same mechanism used to adjust the seat height (e.g., front and rear height adjusters on the seat), the seat should be tested at the angle obtained when the seat is in the full-down position. If the cushion angle adjustment is independent of seat height adjustment, the angle should be set at the center of the adjustment range.

8. Adjust the seat vertically.

If the seat is separately adjustable in the vertical direction, it should be set at the mid-height position attainable at the fore-aft test position.

9. Move the seat to the test position.

Seats with fore-aft adjustment are tested in the full-rear position and at a position 150 mm forward of the full-rear position. To obtain the second test position, move the seat forward along the seat track from the full-rear position, maintaining the cushion angle and vertical adjustment position, until the seat has translated horizontally 150 mm.

10. Adjust the seat back angle.

Set the seat back angle for seats that are adjustable.

First Seat Measurements - Outboard and Center Position: Set the seat back angle to 22±1 degrees, as measured by the ASPECT manikin. If the initial installation results in an angle that is less than 21 or more than 23 degrees, the manikin must be removed from the seat and reinstalled.

Second Seat Measurements - Outboard and Center Positions: If the seat back angle of a second seat is adjustable, set the angle to 25 degrees, as measured by the ASPECT manikin, or to the angle closest to 25 degrees that is attainable.

11. Condition the seat.

Sufficient time shall be allowed to ensure the seat material reaches room temperature. Avoid extreme temperature variations. If the seat has never been sat upon, a 68 kg – 79 kg (150 lb – 175 lb) person shall sit on it twice for 1 minute to flex the cushion and back. All seat assemblies are to remain unloaded for a minimum period of an hour prior to the installation of the BTD.

BTD Positioning Procedure

The following positioning procedures apply to first and second seats in passenger vehicles equipped with active and automatic belt restraint systems.

1. Install the ASPECT manikin.

The ASPECT manikin should be placed in the vehicle seat according to the most current installation procedures (see attached). Note that the manikin should be aligned with the seat centerline. Lock the torso linkage. Record seat back angle and seat cushion angle. [NB: This procedure should reference SAE J826 after the ASPECT manikin is approved as an SAE Recommended Practice.]

2. Attach the torso form.

Attach the BTD torso form by sliding the lower portion onto the H-point saddle. Push the two top connections onto the ends of the top torso weight hangers.

3. Attach the lap form.

Lower the lap form onto the mounting bracket until it is seated and level.

Belt Deployment and Measurement Procedures

1. Deploy the belt.

Active belt systems: Hold the latch plate in position on the belt and deploy the belt.

Type 2 Belt Systems: Bring the latch down from the stowed position to the surface of the torso form at the end of the clavicle. Then bring the latch to the inboard front corner of the manikin seat pan following a straight path. The path is defined by a line connecting a point coincident with the latch plate on the torso form with a second point at the inboard corner of the seat pan (see Figure A1). It is important that the latch does not deviate from this path. After reaching the corner, move the latch plate directly to the buckle following a straight path defined by a line connecting the corner of the seat pan to the buckle (see Figure A2). Insert the latch plate in the buckle. Release the flexible stalk and buckle if applicable. See the next section if fouling of the belt occurs.

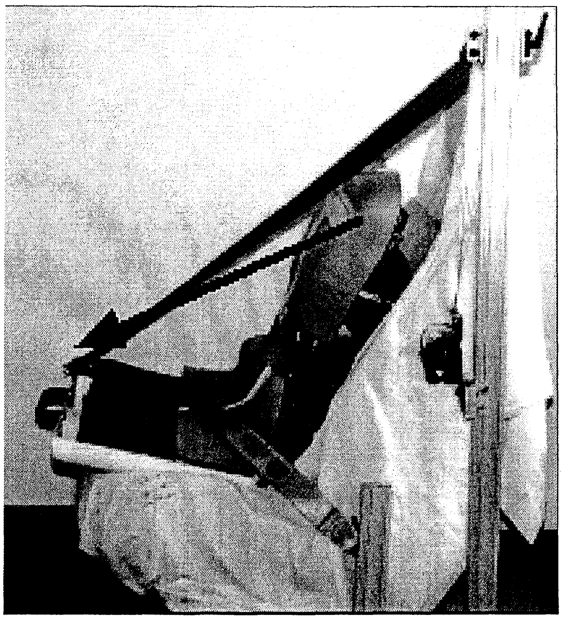

Figure A1. Latch plate movement path for deployment of the torso belt.

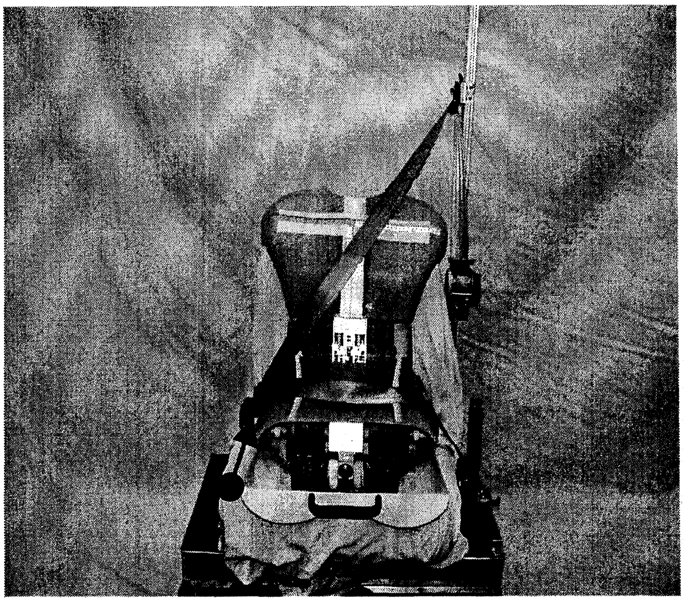

Figure A2. Latch plate movement path for attachment of the latch to the buckle.

Type 1 Belt Systems: Bring the latch from the stowed position to the inboard front corner of the manikin seat pan following a straight path. The path is defined by a line connecting the latch plate in the stowed position to the inboard corner of the seat pan. Then bring the latch to the buckle, again following as straight a path as possible defined by a line connecting the seat pan corner to the buckle. Insert the latch plate in the buckle. Release the flexible stalk and buckle. See the next section if fouling of the belt occurs.

Automatic Belt Restraint Systems: Install the latch plate in the buckle through the open window with the door closed. Gently open and close the door.

2. Actions for belt fouling.

If the lap belt fouls with the front vertical face of the lap form, or the torso belt fouls with the edge of the torso form or seat, or if either belt is twisted, repeat the measuring procedures from the previous section until the belt lays flat on the lap and torso forms. Should twisting or fouling persist, manually guide the belt over the obstacle when deploying the belt. For automatic systems do this through the open window. The belt must always be deployed in a straight path as defined previously.

3. Tension the belt.

Apply a tensioning load of 50 N (11 lb) to the belt according to the following procedures. Release the tensioning load and repeat for a total of three times.

Type 2 Belt Systems with a Single Retractor: Remove the slack in the lap belt by tensioning the torso belt in the direction of the torso belt. Apply the tensioning load as close as possible to the torso belt retractor. If this is not possible, apply the tensioning load to the torso belt as close as possible to the B-pillar loop along the path of the belt. Care should be taken to prevent lateral movement of the belt.

Type 2 Belt Systems with Dual Retractors: First tension the lap belt and then the torso belt. The tensioning load should be applied as close as possible to the retractors and along the path of the belt at this location. Care should be taken to prevent lateral movement of the belts.

Type 1 Belt Systems with Retractors: Apply tension to the belt as close as possible to the retractors and along the path of the belt at this location. Care should be taken to prevent lateral movement of the belt.

Type 1 Belt System without Retractors: Apply tension to the belt as close as possible to the latch plate along the path of the belt at this location. Care should be taken to prevent lateral movement of the belt.

4. **Record the lap belt measurements.**

Record the location that the lap belt crosses the lap form scales. Record the measurements at the top edge of the lap belt at both the left and right scales (see Figure A3). Read the scales to the nearest 0.5 cm.

5. **Record the torso belt measures.**

Record the distances vertically and horizontally from the origin of the torso scales to the outboard edge of the torso belt as shown in Figure A3. Record the scale readings to the nearest 0.5 cm.

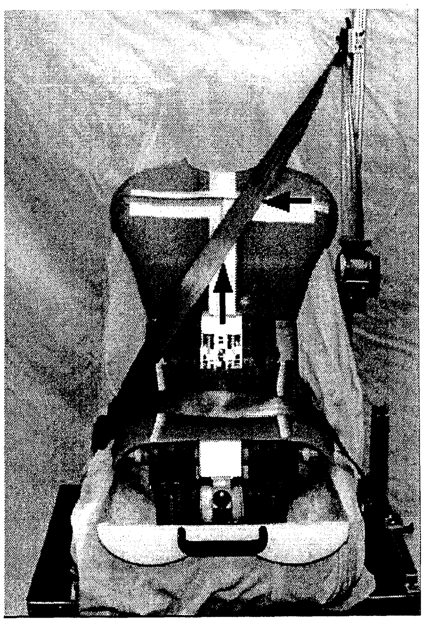

Figure A3. The lap belt scale measurements are made at the top/rearward edge of the lap belt. Torso scales are read at the lower edge of the belt. Read the scales to the nearest 0.5 cm.

ASPECT Manikin Installation Procedure

These procedures were abstracted from UMTRI documentation of the ASPECT manikin installation procedures. A task group of the SAE Human Accommodation and Design Devices Committee is currently working on a final version of the procedures to be included in SAE Recommended Practice J826. The final version of the ASPECT BTD procedures should reference SAE J826.

1. Place the buttock/thigh section of the manikin in the seat with the back of the pan lightly against the seat back and visually center laterally with respect to the seat cushion. Flex the articulation of the torso section of the manikin to -10 mm of lumbar support and lock the torso articulation. Drop the torso section into the H-point saddle on the buttock/thigh section and slide both locking cylinders inward to lock the torso section in place.

2. Unlock the torso and level the manikin laterally.

3. Load the buttock/thigh section by installing pelvis weights and thigh weights in pairs working out from both sides of the manikin centerline. In all cases, weights should be installed in a sequence that moves forward and/or upward and from the H-point. After loading two pelvis weights and two thigh weights, level the manikin laterally and apply a rearward force on the buttock/thigh pan twice using the supplied tool. Press the tool firmly into the force application site until it clicks.

4. Repeat the previous step until all 6 pelvis and all 6 thigh weights have been used.

5. Load the manikin torso section by installing abdomen weights and thorax weights in pairs working out from both sides of the manikin centerline. (Note that the torso linkage is unlocked during this step.) Weights should be installed in a sequence that moves upward from the H-Point. After loading each set of two abdomen weights and two thorax weights, apply a rearward force at the torso force application site twice using the supplied tool.

6. Repeat the previous step until all 6 abdomen and all 6 thorax weights have been installed. Lock the torso articulation.

(BTD component installations begin at this point.)