BioRID-IIc Rear Impact Crash Test Dummy

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ABSTRACT

The objective of this paper is to introduce a biofidelic crash test dummy designed specifically for the development and evaluation of seating systems that offer enhanced occupant protection in low speed rear impact collisions. The BioRID-II (Biofidelic Rear Impact Dummy) is designed to adequately predict human spine kinematics and response characteristics during rear impact loading conditions.

BioRID-II is based on the Hybrid III dummy but equipped with an articulated thoracic/lumbar spine and soft torso of silicon rubber. The head, arms and lower extremities are Hybrid III components. The pelvis is a modified version of the Hybrid III to allow for abdominal bulge and minimize femur joint flexion/extension resistance. The BioRID-II spine consist of 24 vertebrae that are connected by hinge joints and simulate each vertebrae in the human body from the C1 (skull interface) to the L5 (pelvis interface) positions. To replicate human-like head kinematics, the neck is equipped with cables to simulate anterior and posterior muscle response.

The dummy is available with a 3 or 6-channel upper neck force/moment transducer and acceleration measurements at four locations along the spine. The Hybrid III lower extremities allow for instrumentation in the femurs, lower legs and feet.

Data collected from human volunteer studies served as the basis for the kinematic response corridors in developing the BioRID dummy. The BioRID-II is currently being evaluated by several agencies and organizations around the world to better understand its biofidelic responses, durability, repeatability and overall benefit to accurately predict occupant injury and seat safety effectiveness.

INTRODUCTION

Since 1949, test manikins have been designed to evaluate acceleration and force levels exposed to human occupants during simulated crash configurations.

Since the early 1950's, specialized anthropomorphic test devices (ATD) have been called upon to evaluate a wide range of applications. They include:

- Aircraft ejection seats
- Underwater rescue procedures
- Wind blast simulations
- Land mine detonation
- Side impact crashes
- Rollover crashes

- Frontal impact crashes
- Infant carriers
- Child safety seats
- Pedestrian impacts
- Seat belt systems
- Air bag systems
- Seating systems
- Medical research
- Rescue training
- Aerospace travel

Test manikins to simulate animals have been developed over the years to study a variety of applications ranging from radiation treatments to aerospace travel and simulation of vehicle accidents involving animals. Some of the manikin animals include the Beagle Phantom, Chimpomorphic and Robo Roo.

Figure 1:Beagle Phantom

As technology advances in the field of electronics and materials so does the biofidelity of ATD's. New dummies (WorldSID, Thor, etc.) currently in development incorporate state-of-the-art materials, advanced sensors and human-like response characteristics.

In recent years, a lot of attention has been focused on the low speed rear impact vehicle collisions. As a result of rear impact conditions, the neck is quite often forced into a rapid extension-flexion motion. This rapid movement of the neck can cause soft tissue injuries, which are classified as minor or severe injuries such as vertebra fractures and spinal cord trauma. The most common injury is soft-tissue. The cost to treat this type of injury is very high as the recovery rate could vary from 2-3 months to several years depending on the occupant, impact parameters and treatment methods.

Considering the high rate of rear impact collision worldwide, the high cost of medical treatment and the potential for long term discomfort and pain for the victim it was decided to research, design and introduce a test dummy that accurately simulates a human response during a low speed rear impact collision.

In the late 1990's, Johan Davidsson from Chalmers University of Technology in Gotenborg, Sweden completed an in-depth study of low speed rear impact injury patterns with the goal to establish the basis for the development of a new test dummy to accurately predict spinal injury risk and evaluate safety devices intended to minimize spinal injuries during rear impact collisions.

As a result of Mr. Davidson's' work and countless studies prior to his project, the BioRID (Biofidelic Rear Impact Dummy) evolved.

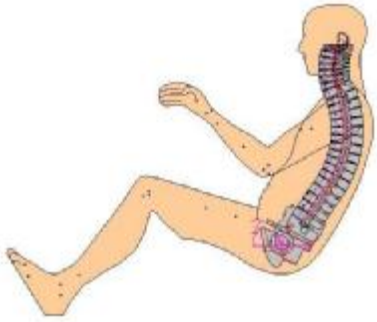

Figure 2: BioRID Fully Articulated Spine

BioRID DEVELOPMENT

Since the initial prototype in1999, the BioRID dummy has been under constant improvement and evaluation the following section will highlight some of the prototype stages of the dummy and the key features.

BioRID P1

- Torso molded from silicon rubber
- Modified pedestrian H-III pelvis
- Thoracic & lumbar vertebrae were constructed on aluminum
- Neck design similar to RID neck
- Muscle substitutes acted between T1 and head base
- No damper assembly

ASTC-RID

- Similar to BioRID P1
- No torsion pins in the thoracic or lumbar spine
- No muscle substitutes

BioRID P2

- Torso molded in silicon rubber.
- Water filled abdominal cavity
- Modified H-III standard pelvis
- All vertebrae constructed of POM plastic
- Torsion pins unique to the lumbar and thoracic regions
- Muscle substitute consisted of a damper in parallel with spring

BioRID I (A,B and C)

- Similar to BioRID-P2 design
- Dummies delivered to partners within the consortium for evaluation

BioRID P3

- Torso molded in silicon rubber
- Water filled abdominal cavity
- Modified H-III standard pelvis
- Common torsion pins for the lumbar and thoracic spine regions
- Muscle substitute consisted of a single damper mounted in parallel with a flexor and an extensor spring
- Muscle substitute connected at T3 and base of the skull w/ the load distributed to T1, T2 and T3.

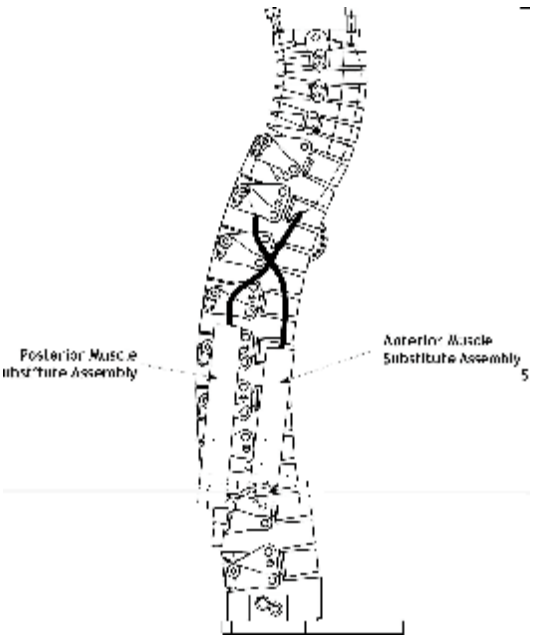

Figure 3: Muscle Substitute Spring Hsg.

BioRID-II

- First production release dummy.
- Design very similar to the P3 ATD.

BioRID-II (ver. A, B and C)

- These build levels represent slight changes in the dummy to improve a wide variety features for improved performance, handling, calibration, instrumentation, positioning, etc.
- BioRID-IIc is the current production build level as of March 2002.

BioRID-IIc Assembly & Instrumentation

The section will highlight the key features of the current production BioRID-IIc ATD, including instrumentation.

Head

Modified Hybrid III 50th% head assembly. The skull base and ballast are modified to accommodate the upper neck load cell and tensioning cables for the neck muscle substitutes.

Instrumentation available includes a 3-axis upper neck load cell or 6-axis upper neck load cell, linear and angular head acceleration.

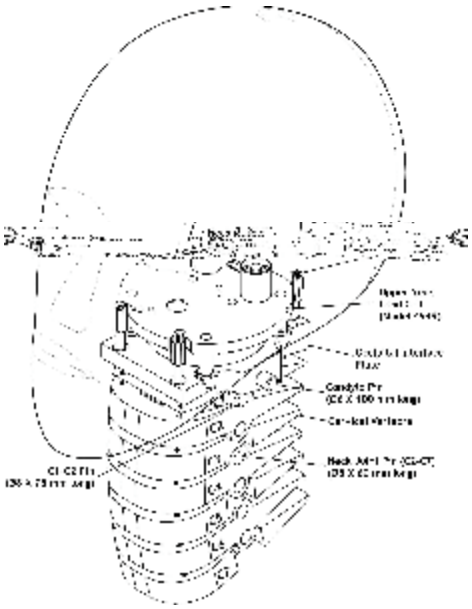

Figure 4: Head Assembly w/ Load Cell

Upper Torso

The upper torso consists of a one-piece molded silicone thorax flesh. Included in the flesh are reinforced plates for attachment of the arms, abdominal cavity, abdominal valve and spine-torso interface. The torso flesh is attached to the spine with interface pins. The dummy has no ribs. The abdomen is water filled for proper mass distribution.

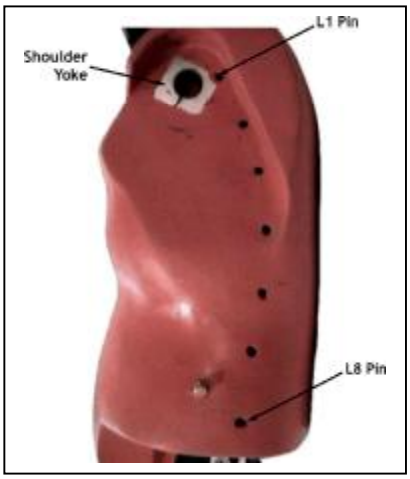

Figure 5: Torso Flesh

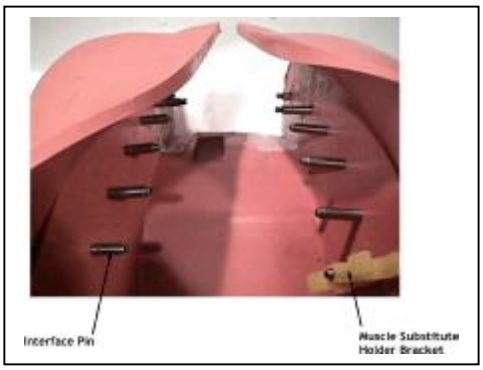

Figure 6: Torso Flesh w/ interface pins

The spine assembly is fully articulated and consists of seven cervical (C1-C7), twelve thoracic (T1-T12) and five lumbar (L1-L5) vertebrae, the same as the human body. The top cervical vertebrae (C1) connects to the head assembly by an occipital interface plate. The superior thoracic vertebrae (T1) mates to the cervical and thoracic vertebrae. It is contoured as a cervical vertebrae on the upper side and a thoracic vertebrae on the lower side. The superior lumbar vertebrae (L1) is

similar to the top thoracic vertebrae in its design to mate the two sections. The lowest lumbar (L5) connects the spine to the pelvis through a sacrum lumbar and pelvis interface plate.

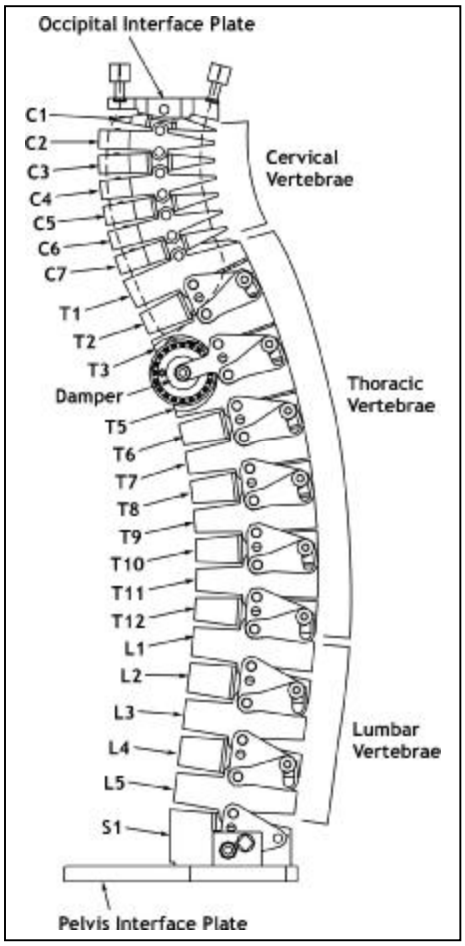

Figure 7: Spine Assembly

Each vertebra for the BioRID is made a durable plastic and is connected with pins at each joint to allow angular motion in the sagittal plane only. Rubber blocks are glued to the top of each vertebra to simulate the compressive resistance of the muscles and vertebral body between each human vertebra.

For biofidelic neck response, tensioning cables (commonly referred to as muscle substitutes) have been designed into the neck region of the spine. Three cables originate at the top of the neck with threaded adjustments for controlling cable tension. One cable goes through the cervical vertebra and around a damper assembly at the T4 vertebra, then backs through the vertebra to the top of the neck. The remaining two cables also start at the top of the neck but, terminate at two spring-loaded cable tension housings mounted on the right side of the torso.

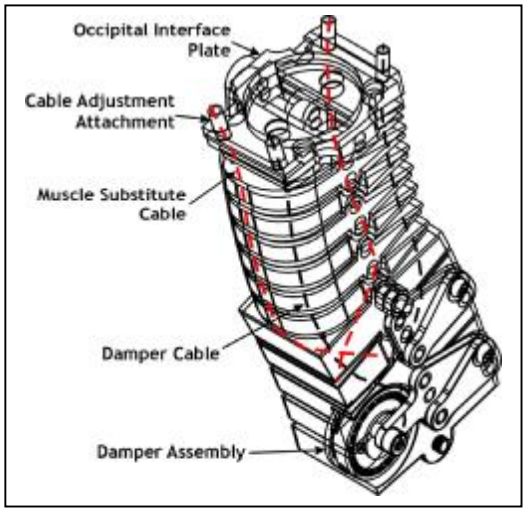

Figure 8: Neck Tension Cables

Pelvis

The pelvis is a modified H-III 50th% assembly. Accelerometers can be mounted in the pelvis.

Leg Assembly

The standard Hybrid III 50TH % leg assembly is used on the dummy. By using standard Hybrid III legs, the dummy is capable of measuring femur, tibia and ankle loads.

Instrumentation
The dummy is currently designed to accommodate the following instrumentation:

- 3-axis or 6-axis upper neck load cell
- Accelerometers at the head, thorax (C4, T1, T8, L1) and pelvis locations
- 6-axis upper femur load cell
- 6-axis femur load cell
- 2-channel knee clevis load cell
- 5-channel tibia load cells
- 5-channel ankle load cell

A lower neck and lumbar spine load cell are currently in the design phase.

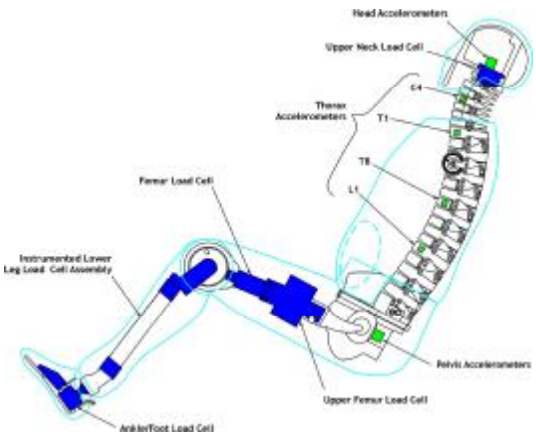

Figure 9: Instrumentation Options

SUMMARY

A new dummy, BioRID-IIc, has been developed for low speed rear impact testing. The development and performance of the dummy has been compared to those of human volunteer studies. The BioRID-IIc is the only dummy available with a fully articulated spine assembly. Neck muscle substitutes represent the posterior and anterior muscles in the human neck. Standard or modified Hybrid III components make up the head, arms, pelvis and leg assemblies. Instrumentation is available to collect upper neck force and moment data in addition to numerous accelerometer locations from the head to the pelvis.

BioRID-IIc is currently being used by several agencies throughout the world for occupant neck injury assessment and active head restraint design effectiveness during rear impact collisions. As with all new product development, the BioRID-IIc dummy is continuously being evaluated and improvements incorporated to ensure a biofidelic, reliable and durable product is available for all types of rear impact research and studies.

REFERENCES

Davidsson, Johan (2000) “Development of a Mechanical Model for Rear Impacts: Evaluation of Volunteer Response and Validation of the Model”, Chalmers University of Technology, Goteborg, Sweden.

Denton ATD, Inc. (2002) “BioRID II User’s Guide”