ENHANCEMENT AND EVALUATION OF A SMALL FEMALE HYBRID III PREGNANT DUMMY

Youmei Zhao, Michiel van Ratingen, Chandler Yao,
George Brill, Steve Goldner, and Renbing Huang
First Technology Safety Systems

ABSTRACT

The MAMA-2B (Maternal Anthropomorphic Measurement Apparatus, version 2B), a small female Hybrid III pregnant dummy used to study the safety of a fetus and effects of seat belt and airbags has been evaluated and enhanced. Two IR-TRACCs (Infra-Red Telescoping Rod for the Assessment of Chest Compression) have been added to measure the chest deflection. A potentiometer was added to measure the IR-TRACC rotation. Two accelerometers have also been added for the chest Viscous Criterion (V*C) calculation. The water-filled abdomen bladder was evaluated. The center of gravity of the slouch posture of the dummy was estimated. Certification tests were conducted and the corridors have been proposed.

Keywords:
ABDOMEN, CENTER OF GRAVITY, DUMMIES, FRONTAL IMPACTS, HYBRID III

IT HAS BEEN ESTIMATED that two-thirds of all trauma during pregnancy is the result of motor vehicle crashes (Pearlman, 1997). However, few studies have examined pregnant anthropometry and the biomechanics of injury to the pregnant occupant in motor vehicle crashes. The original pregnant crash-test dummy, developed by Viano (1996) is limited by its non-biofidelic abdominal shape and stiffness. Jonathan D. Rupp et al (2001) developed the Hybrid III small female pregnant dummy known as MAMA-2B (Maternal Anthropomorphic Measurement Apparatus, version 2B) with a fluid-filled silicone rubber bladder to represent the human uterus at 30-weeks gestation, and incorporate anthropometry based on measurements of pregnant women in an automotive driving posture.

OBJECTIVES

The objectives of the enhanced MAMA-2B dummy development were to add more instrumentation, and to create the mass, CG, and certification test corridors for the production dummy.

DUMMY MASS AND CENTER OF GRAVITY

The mass distribution of the enhanced MAMA-2B dummy is the same as the first prototype MAMA-2B. The total mass of 128 lbs. is close to the weight selected by Viano et al (1996) for the original pregnant dummy. The center of gravity of the first prototype MAMA2B dummy was estimated (Rupp, J, D., et al. 2001). However the seated posture was not specified. It is necessary to define the seated posture and find the center of the gravity in that seated posture. It was decided to use the posture of the small-size female database from UMTRI (1983, Schneider L.W. et al.), which is the seated slouch posture, as the reference to determine the center of gravity of the MAMA-2B dummy. The 2-D H3 5th and MAMA-2B assembly drawings were overlapped on the UMTRI 5th shell by rotating the segments to match the UMTRI small-size female posture. The global coordinate XZ system in which the origin was at the H point was then created. The segment center of gravities were positioned to each segment based on their local coordinate system. Global dimensions of all the segment center of gravities were created in the global coordinate system. The whole body center of gravity of the MAMA-2B then was calculated using the following formulae:

$$Xmc = \frac{\sum_{i=1}^{n} MiXi}{\sum_{i=1}^{n} Mi} \qquad Zmc = \frac{\sum_{i=1}^{n} MiZi}{\sum_{i=1}^{n} Mi}$$

Where *Xmc* and *Zmc* are the whole body center of gravity location. *Mi, Xi,* and *Zi* are the mass and centers of gravity in the X and Z coordinates. Figure 1 displays the segment center of gravities, the whole H3 5th, and enhanced MAMA-2B dummy center of gravities in the global system.

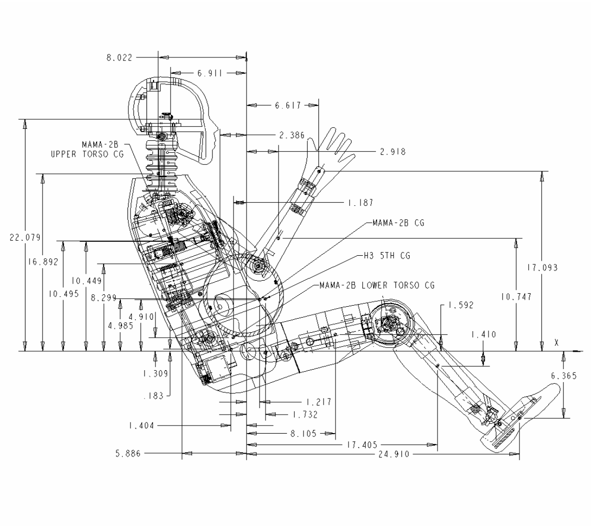

Fig. 1 - Global Segment and Whole dummy Cg Locations for H3 5th and MAMA-2B

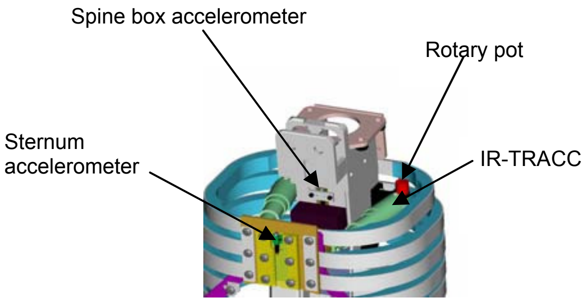

Fig. 2 - IR-TRACCs, Potentiometers, Sternum and Spine Box Accelerometers

INSTRUMENTATION

The chest deflection measurement was removed in the first prototype MAMA-2B dummy since the traditional transducer arm interferes with the abdomen bladder. Two IR-TRACCs, which use infrared light to measure the deflection between two points, were added to the enhanced MAMA-2B to measure the chest deflection. The front ends of the IR-TRACCs are attached to the inside plate of Rib #2 while the rear ends of IR-TRACCs are mounted on the sides of the spine box. A rotary potentiometer is assembled to the rear of the IR-TRACC to measure the rotation about the Z axis. Figure 2 shows this instrumentation.

Two accelerometers were also added to the dummy. One is mounted on the top front of the sternum and the other is mounted in front of the spine box as Figure 2 shows. The centers of the seismic masses of the two are aligned for the Viscous criterion (V*C) calculation, which is the product of the chest velocity and normalized compression of the chest (Eppinger RH. 1989). Two pressure transducers were glued to the inside posterior and anterior of the abdomen bladder. These sensors measure the pressures of the bladder during impact. As the standard Hybrid III 5th, the head, chest, and pelvis tri-axial accelerometers can be installed on the enhanced MAMA-2B. All the load cells for standard Hybrid III 5th female can be installed with exception of the lumbar spine load cell.

ABDOMEN EVALUATION

As in the first prototype MAMA-2B, the abdomen bladder in the enhanced MAMA-2B is an ellipsoidal bladder filled with water which represents the 30 week pregnant abdomen. The material is 50 +/-5 durometer silicone rubber. The upper and lower urethane cradles are glued to the bladder and attached to the spine box and the pelvis bone.

The rigid bar impact test was selected to evaluate the enhanced MAMA-2B dummy. Cavanaugh et al. (1986), later confirmed by Hardy and Schneider (2001) developed the rigid-bar impact response corridor, which was based on the force-deflection response of five un-embalmed cadaver abdomens impacted at approximately 6 m/s velocity. Hardy and Schneider developed the average 3 m/s rigid bar response. These corridors were equal stress, equal velocity scaled (Eppinger 1978) to develop the corridors for the MAMA-2B dummy by Rupp, J D. et al. (2001). The required rigid bar impactor in the Cavanaugh and Hardy test has a weight of 48 kg with a bar 25 mm in diameter. The first prototype dummy was tested at UMTRI using a linear impactor. Since most test labs do not have the linear impact fixture, FTSS developed a pendulum probe as displayed in Figure 3. An accelerometer is mounted on the rear of the test probe to calculate the impact force. The deflection data is obtained from the high speed imaging.

The enhanced MAMA-2B 001 dummy was tested at the FTSS lab and the UMTRI lab for both 6.0 m/s and 3.0 m/s tests. In the 6 m/s test, the enhanced MAMA-2B force-deflection response is in the Cavanaugh corridor as Figure 4 displays. The curve shape is very close to the UMTRI prototype

MAMA-2B. In the 3 m/s test the deflection of the FTSS MAMA-2B is very close to the Hardy response up to 50 mm. After that, the FTSS abdomen is stiffer and has more force than the Hardy response.

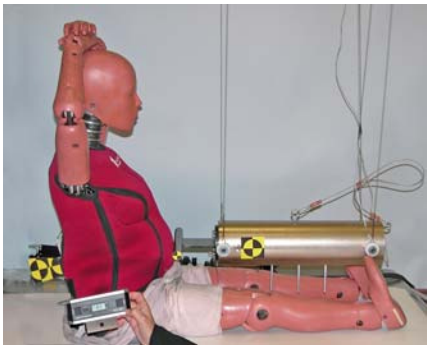

Fig. 3 – Abdomen Bar Impact

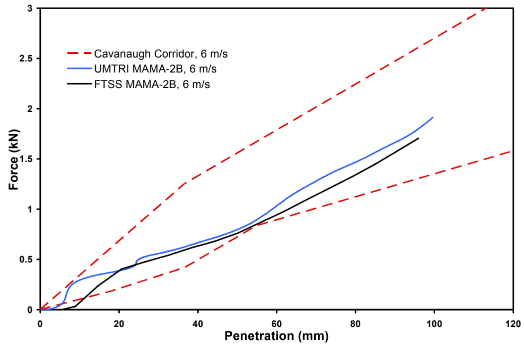

Fig. 4 - Rigid Bar Abdomen Impact at 6 m/s velocity

Quasi-static compression tests were conducted on the abdomen bladder. Studying the pressure vs. deflection, it was found that the bladder stiffness, thickness, and position in the dummy are the critical factors to affect the force-deflection response.

CHEST DEFLECTION AND TEST

The chest deflection is measured in the Hybrid III 5th dummy by the transducer arm mechanism. A ball mounted on the top of the transducer arm is restrained in the sternum slot. As the sternum is compressed, the transducer arm rotates and the ball slides up and down in the sternum slot. The arm rotation is measured and the chest deflection is then calculated as the ball displacement along the X axis. This mechanism does not measure the deflection at a fixed point.

In the enhanced MAMA-2B dummy, two 2-D IR-TRACCs, parallel to rib #2, are incorporated in the upper thorax area. As the sternum deflects, the IR-TRACC provides measurement of the absolute length of the IR-TRACC (vector magnitude) and the rotary potentiometer provides measurement of the absolute angle around the Z axis of the IR-TRACC (vector angle). This device is more accurate than the transducer arm device, since the deflection from point to point can be measured and X and Y displacements can be calculated.

The thorax calibration impact test was conducted using the same impact probe as the H3 5th dummy, with a mass of 13.97 kg, and a 152.4 inch diameter impact face. The test probe velocity is 6.71 m/s at time of impact, the same as in the Hybrid III 5th dummy. Instead of impacting between ribs #3 and #4, MAMA-2B is impacted between ribs #1 and #2 to avoid contact with the abdomen bladder. Figure 6 shows the force deflection comparison between the MAMA-2B and Hybrid III 5th dummies. Both force and deflection are within Hybrid III 5th corridor, which is the same as the first MAMA-2B prototype.

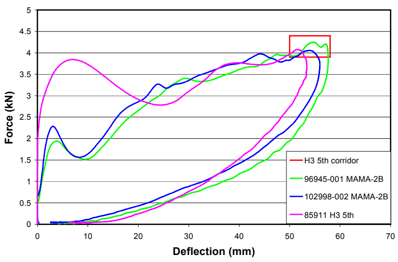

Fig. 5 - 6.71 m/s Chest Impact Force Deflection Comparison of MAMA-2B and H3 5th dummies

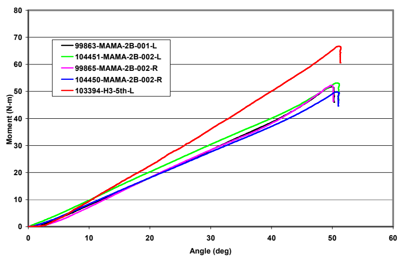

Fig. 6 – Hip Range of Motion Comparison

HIP JOINT RANGE OF MOTION TEST

The inspection test, hip joint range of motion test is required in the Hybrid III 5th dummy. This test monitors the moment vs. angle relationship of the femur and pelvis when the femur is rotated toward the pelvis. Tests were conducted on the two enhanced MAMA-2B dummies to examine the hip joint performance and the corridor was created. Since there is a cut on the pelvis flesh for the room of the abdomen, less moment was obtained compared with the H3 5th dummy as in Figure 6. The proposed angle-moment corridor was created.

CONCLUSION

Two enhanced dummies were tested. A total of 48 whole body impact tests were conducted, which included 30 rigid-bar abdomen impact tests and 18 chest impact tests. 8 hip joint range of motion tests and 42 quasi-static abdomen bladder compression tests were performed.

The enhanced MAMA-2B has the same abdomen and chest response as the MAMA-2B prototype. The 2-D IR-TRACC performed well in the thorax impact tests. In the hip joint range of motion test, the moment was lower than the Hybrid III 5th dummy. The thorax impact and hip joint range of motion test corridors were proposed. The 3.0 m/s rigid-bar abdomen impact test is suggested to be the abdomen calibration test in the future. An internal abdomen compression measurement device needs to be developed to replace the expensive external measurement device.

Due to the limited time of this study there is not enough data from sled or full scale vehicle tests for the enhanced dummy. Two dummies were sold and data will be available in the near future.

ACKNOWLEDGMENTS

The authors would like to thank Jonathan D. Rupp and several UMTRI staff members for their engineering supports. Appreciation is expressed to Thanh Nghi, Joe McInnis, Robert Kimes, Ronnie Neri, Danny Guck, Dave Smith, Dan Adams, Marcus Di Giorgio, Dawn Pope, and Richard Moore, of First Technology Safety Systems, Inc. for the project development. Finally the authors would like to gratefully acknowledge the contributions of Alix Mary Weekes from the Motor Insurance Repair Research Centre (Thatcham), who is one of the customers of the enhanced MAMA-2B dummy for feeding back many very useful suggestions.

References

Eppinger, R.H., Prediction of thoracic injury using measurable parameters. Proceedings of the 6th International Technical Conference on Experimental Safety Vehicles. (1978) pp. 770-780.

Eppinger R.H., On the Development of a Deformation Measurement System and its Application toward Developing Mechanically Based Injury Indices, Proceedings of the Thirty-Third Stapp Car Crash Conference, (1989) pp 21-28, SAE paper No. 892426

Cavanaugh, J.M., Nyquist, G. W., Goldberg, S. J., and King, A.I., Lower abdominal tolerance and response. Proceedings of the 30th Stapp Car Crash Conference, (1986) pp. 41-63

Hardy, W.N and Schneider, L.W., Abdominal Impact Response to Rigid-Bar,
Seatbelt, and Airbag Loading, Proceedings of the 45th Stapp Car Crash Conference. (2001),

Pearlman MD, Motor vehicle crashes, pregnancy loss and preterm labor, International Journal of Gynecology and Obstetrics, (1997) pp 57, 127-132.

Rupp, J, D., Shneider L.W., Klinich, K.D., Steve Moss, Jennifer Zhou, Pearlman M.D., Shneider L., Development and Test of a Prototype Pregnant Abdomen for he Small-Female Hybrid III ATD, Proceedings of the 45th Stapp Car Crash Conference, (2001)

Schneider L.W., D. H. Robbins, M.A. Pflug, R.G. Snyder, Development of Anthropometrically based Design Specifications for an Advanced Adult Anthropomorphic Dummy Family, Volume 1-3, UMTRI-83-53-1, (1983)

Viano, D., Smrcka, J., Jedrzejczak, E., Deng, B.,Kempf, P, and Pearlman, M.D, Belt and airbag testing with a pregnant Hybrid III female dummy. Proceedings of the 15th Experimental Safety Vehicles Conference, Paper No. 96-S1-O-03. (1996)