BIORID II- TOOL FOR ANALYSING REAR IMPACTS

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Abstract

In rear impacts, the risk of injuries is two times higher than in frontal impacts [1].The most frequent injuries affect the cervical spine, called whiplash. To develop car seats concerning whiplash, a dummy is required, that can show the behavior of the spine. Standard dummies for frontal crashes like the Hybrid III are not able to copy the behavior of the human spine accurately. So Denton ATD and the Chalmers University developed a crash test dummy with an articulated spine, the BioRID II Dummy. In 2006 tests with car seat had been done. The result showed that lots of seats are not able to prevent whiplash injuries. In our project a numerical model of the BioRID II was developed to improve the protective characteristics of car seats. Therefore, the whole dummy was disassembled to capture its geometry. Based on the geometrical data our BioRID II model was created. Additionally, component tests have been done to improve the behavior of the model. For Sled tests, pelvis, arms, legs and jacket have been removed so the movement of the whole spine could be showed without influence of parts connected directly to the spine. Material tests of bumpers, flesh and other parts have been used to build up adequate material definitions.

Keywords: Rear Impact, BioRID, Simulation, Whiplash

Presenting Author's biography

Andreas Rieser. He was born on April, 21st, 1979 and has studied engineering (mechatronics) at the Technical University of Graz (1999 – 2004). Then he was engaged at the Vehicle Safety Institute VSI (Technical University of Graz; 2004 - 2005). Now, he is employed at the "Competence Center- The Virtual Vehicle" in Graz (VIF) and does his PHD (in cooperation with the Technical University of Graz, VSI), that will estimated be finished in autumn 2007.

1 Introduction

In rear impacts, the risk of injuries is two times higher than in frontal impacts [2]. The costs for insurance companies are quoted as 10% of the whole costs for personal injuries [3]. In Austria it has reached to 25 Mio Euro per year.

In 2007, the ÖAMTC tested 28 car seats of different producers. The result was, that only three seats could prevent whiplash.

Tab. 1 ÖAMTC seat test results [4]

Model	System	Result
Volvo V50	WHIPS	++
Volvo S80 (2007)	WHIOS	++
Saab 9-3	Reaktiv	++
Honda Civic	Reaktiv	+
Mazda 5	Passiv	+
Peugeot 307	Passiv	+
Ford Focus II	Passiv	+
Ford S-Max	Reaktiv	+
Opel Corsa	Passiv	+
Land Rover Discovery	Passiv	+
Subaru Legacy	Reaktiv	O
VW Passat	Reaktiv	O
Renault Clio	Passiv	O
Toyota Prius	WIL	O
Mercedes A- Class	Reaktiv	O
VW Golf	Reaktiv	O
Audi A6	Reaktiv	O
Mercedes C- Class	Proaktiv	~
Audi A4	Reaktiv	~
Fiat Grande Punto	Passiv	~
Lexus IS	WIL	~
Nissan Almera	Reaktvi	~
Citroen C1	Passiv	~
Toyota Yaris	WIL	~
BMW 3er	Passiv	~
Citroen C5	Passiv	~
VW Fox	Passiv	-
BMW 5er	Passiv	-

Rating:

++	Excellent
+	Very good
O	Good
~	Fair
-	Poor

The Chalmers University Of Technology (Sweden) and Denton ATD inc. had developed an anthropomorphic test device to analyze car seats concerning whiplash, the BioRID II [5].

Based on these facts, and with the background that no BioRID model had been available, a project began to build up a numerical model of the BioRID II dummy.

The aim of the project was to create a finite element model of the BioRID II in PAMCrash® in order to have a numerical tool for whiplash research.

Now we are able to study the influence of different changes in car seats on the risk for whiplash.

2 The BioRID II Dummy

The BioRID II dummy is based on the Hybrid III for front crashes but the construction of the torso is much more detailed to represent the behavior of a human body in rear impacts [6].

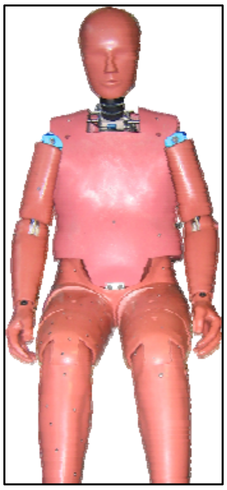


Fig. 1 The BioRID II Dummy

2.1 Torso

The BioRID II provides a completely articulated spine made of seven cervical, twelve thoracic and five lumbar vertebrae.

The neck of the dummy is designed as a combination of springs and a rotational damper to simulate the behavior of the muscle system in the human neck. Additional there are pre-stressed rubber elements, called bumpers, between the vertebrae.

The thoracic and the lumbar spine are composed of vertebrae that are connected by torsion bolts.
These bolts are connected to each other in a way so that they accumulate to a single torsion spring. The result is a spring that operates from the connection between pelvis and spine up to the first thoracic spine.

In the front of the torso jacket sits a bubble that is filled with water. It should simulate inner organs.

This construction enables the dummy to mimic the typical movement of the human spine during rear impacts.

2.2 The neck

The neck of the BioRID II is the trickiest section of the dummy.

It includes not only the spring-damper system for the muscle simulation but also pre-tensioned rubber elements called bumpers.

For the spring-damper system three steel cables run through all cervical and the first three thoracic vertebrae.

Two cables connect the occipital vertebra to springs that are mounted in sleeves at the bottom of the torso. The springs reinforce at the third thoracic vertebra, so they produce a pretension in the neck within the bumper.

The third cable runs down from the occipital vertebra at the front, surrounds a rotational damper and runs back to the occipital vertebra at the rear. There is no pre-tension in the damper cable.

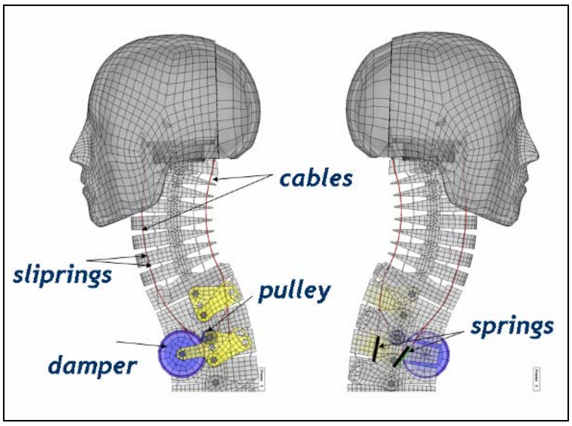


Fig. 2 The neck of the BioRID II Dummy

2.3 Behavior in rear impacts

The typical movement of the human neck in rear impacts can be split into three essential phases [7].

In the first phase, the head moves back without any rotation.

Then, the head starts rotating backwards, this movement ends generally with the contact with the head rest.

In the last phase, the head rotates forward.

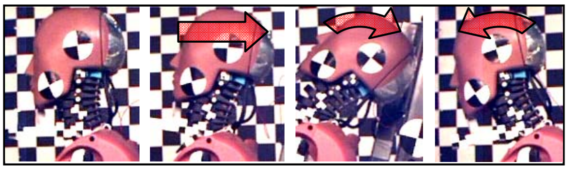


Fig. 3 Movement of the head

To simulate these movements, it was necessary to build a very detailed model of the dummy.

3 Development of the model

To begin with, it was necessary to digitize the whole geometry. It was decided to use an optical 3D-scanner, so it could be ensured to have the right geometry of the available dummy.

The dummy was provided by the Vehicle Safety Institute of the Technical University Of Graz. This dummy was later also used for the component tests and the sled tests with the whole dummy.

3.1 Capturing the geometries

To capture the geometries the ATOS III scanner (GOM®) provided by the Tools and Forming Institute of the Technical University Of Graz was used (see fig. 4). It is able to scan geometries contact less. This was beneficial for scanning the rubber parts.

Fig. 4 ATOS III- scanner (GOM®)

To ensure the correct position of the parts in the total model, a scan of the whole, assembled dummy was done.

In a next step, a scan of the assembled spine was done to measure the correct configuration of the vertebrae. For this, the same dummy position was used as for the full dummy scan. The spine was fixed by a special designed rack. After that the jacket was removed. So the spine could be scanned as if it would be mounted in the jacket.

In fig. 5 the comparision of measurement (yellow) and mesh is shown.

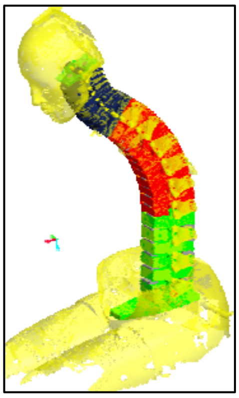


Fig. 5 Comparison CAD data to measurment

The last step was the complete disassembly of the whole dummy to record the single part geometries. Therefore every single part of the dummy was removed, including the vertebrae. Also the bones have been pulled out of the flesh parts of arms and legs.
Simultaneously the weight of the parts was acquired to get a realistic allocation of mass in the model.

To get an adequate base for meshing the scanned data have been translated into CAD data.
Therefore the point clouds out of the measuring device have been repaired because of several positions in the parts where measuring was not possible. Then the corrected data have been translated into surfaces. In a last step, the data were used to build up a whole model in Pro/Engineer.

These CAD model was used as base for the meshes of the FE model.

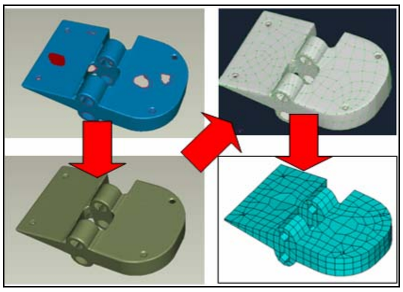


Fig. 6 The way from measurement to mesh

3.2 Building the mesh

Based on the CAD data most of the parts could be meshed.

First, every single part was built as an FE model based on the CAD data.

The jacket of the torso (flesh) has been a special case. To do a complete scan of a part by GOM® it is necessary to turn it around. Because of its soft material it was not possible to turn it around without deformation.

So it was necessary to use a combination of x-ray and manual measure methods to get the geometry and finally the mesh of this part.

3.2.1 Simulation

In the simulation, it was necessary to pay special attention to the neck. Several complex mechanisms have to be simulated there. It was essential to get an adequate model of the neck because of its fundamental function at the rear impact.

The cable elements had to be guided through all the vertebrae. Because of the discrete setup of FE models the redirection before and after a vertebra would cause vibrations in the model that won't happen in reality.

PAMCrash® provided a solution for this problem: Sliprings.

The benefit of sliprings compared to contacts is the possibility to get a continuous flow of the cable elements through the contact point by shifting element length between different elements [8].

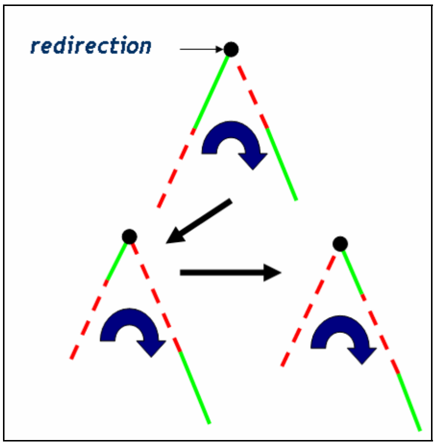


Fig. 7 Functionality of sliprings

For the damping wheel the specifications of the dummy have been used.

The other important details of the cervical spine are the bumpers.

They are made of an elastic material. Two different materials with different hardnesses have been used.

Beam elements were used to simulate the pretension in the bumpers.

4 Validation of the model

To validate the model several different tests had been done, with individual components and also the whole dummy.

4.1 Component tests

In a first step single components have been tested. The behavior of the damper was given by the dummy manual [9], so it was unnecessary to test it.

To get the stiffness of the springs for the muscle simulation simple static tests with different masses have been done.

The most significant validation tests were done with the whole torso without arms, legs and pelvis.

Therefore, the torso was mounted onto rack that was driven by a sled system (DSD Linz).

The torso was rigidly connected to the rack by fixing the pelvis connection plate at the end of the spine to the rack. The rack provided a back rest consisting of a steel tube and a variable, rigid head rest.

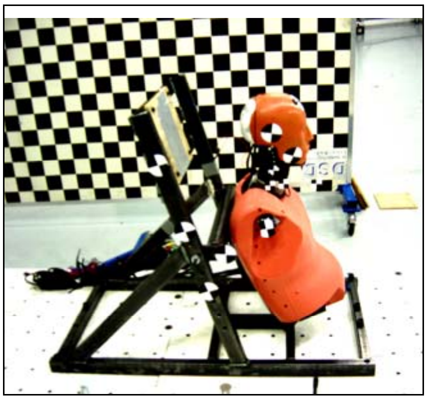


Fig. 8 Rack for component tests with torso

The pulse used was a 100ms long 5g trapezoid pulse (see fig. 9).

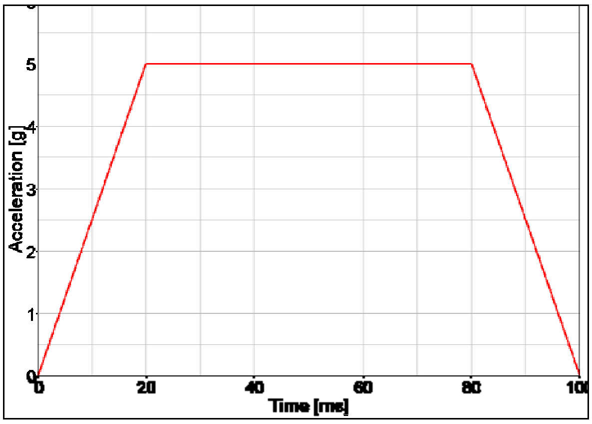
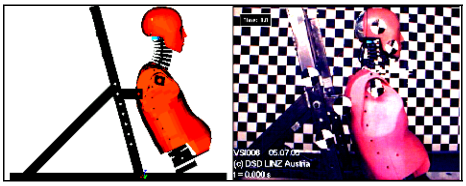


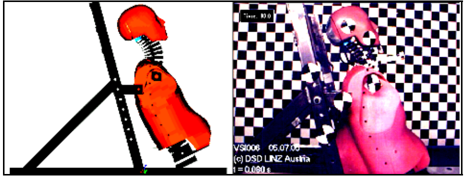
Fig. 9 Sled pulse for component test

The following picture sequence (fig. 10) shows a comparison between simulation and testing video.

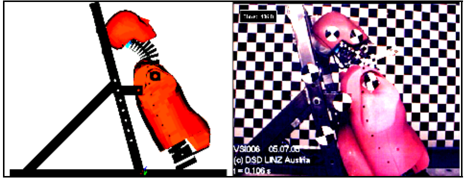
As an example, the test with the largest distance between head and head rest has been used to show the good correlation between simulation and testing.



t = 0 [ms]



t = 80 [ms]



t = 106 [ms]
(time of head to head rest contact)

Fig. 10 Comparison – simulation – real test

Fig. 11 shows the comparison of acceleration sensors at the dummy (head, C4 = fourth cervical vertebra, T1 = first thoracic vertebra, T8 = 8th thoracic vertebra) in test and simulation.

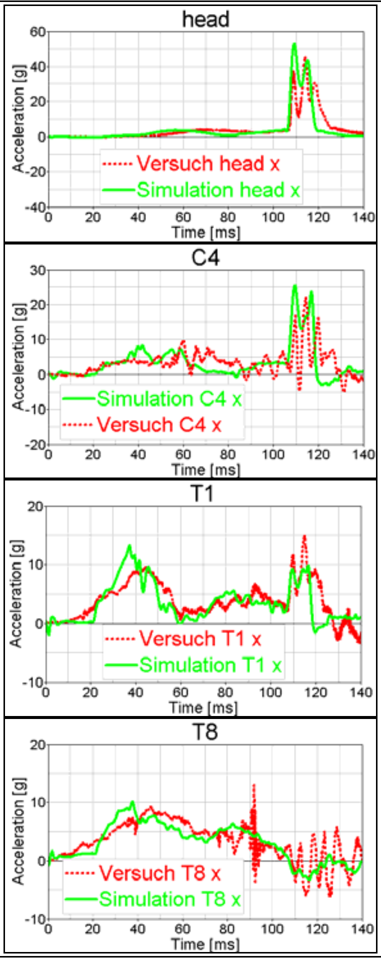


Fig. 11 Comparison of accelerations (simulation vs. test)

4.2 Material tests

To unterstand the behavior of the used materials several tests have been done.

For the contact between dummy and its environment the jacket is very important. It represents a very big part of the contact surfaces and it is directly mounted to the spine.
It consists of a very soft material, so it was decided to test its material.

For the behavior of the spine the bumpers are very important, especially the bumpers of the cervical spine.

Between the cervical vertebrae there are bumpers made of two different materials with a different stiffness, so both were tested.

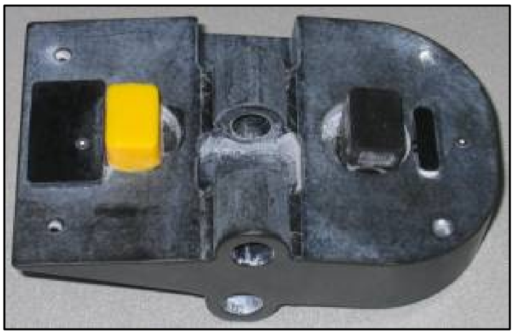


Fig. 12 Cervical vertebra with bumpers

The material tests had been done by A.P.E. (leoben, Austria). Later in the project, material tests have been done by the Competence Center- The Virtual Vehicle (Austria).

4.3 Tests with the whole dummy

To validate the whole dummy, seat models and test data have been provided by our project partner.

Based on these data, the whole dummy was validated.

The results of these simulations are not available for publication now.

5 References

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