Manual of the Models Provided in the Course HL2035 Biomechanics and Neuronics

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1. Introduction

Computer models are introduced more and more into the biomechanics field. Within the impact biomechanics, different types of computer models of the human are used such as the finite element (FE) models or rigid body models. The choice of model is strongly dependent on the application. Rigid body models are often used to study kinematics whereas if the aim is to study injury on tissue level, finite element models are used. There exist several different finite element models of the human body, e.g. Global Human Body Consortium (GHBMC) model (https://www.elemance.com/models/) and the Total Human Model for Safety (THUMS) (https://www.jsol-cae.com/en/product/structure/thums/feature/). These models can be built up of several millions of elements, which required powerful computers to have a reasonable calculation time. There are also simpler models, which are not as demanding of computer power and can be calculated on a regular CPU. Due to time and computer restriction a simplified model of a human surrogate will be used in this course project, the FE model of the dummy model called Hybrid III. The Hybrid III 50th percentile Male Crash Test Dummy according to the manufacturer is "the most widely used crash test dummy in the world for the evaluation of automotive safety restraint system in frontal crash testing" (Humanetics, 2019). The dummy model has been used in other applications also such as medical and sport equipment, e.g. in helmet performance testing (Bland et al., 2018).

LSTC has developed a model of this dummy model, which you can learn more about in the manual (Guha et al., 2008). For this project, some modifications of the previous model have been made. The model for the project only includes the upper body and a model of the brain tissue of the two hemispheres together with the falx have been added.

The aim of this manual is to introduce the Hybrid III model provided for the project in the course HL2035 Biomechanics and Neuronic. The manual also includes a short description of simplified models of impacting surfaces and a helmet model. You are within this project free to modify the models and add other models to the simulations. The models presented in this manual are the baseline models for the project.

2. Units

The units for the models are meter, seconds and kilogram. Column (a) in the LS Dyna Keyword Manual (LSTC, 2012).

3. About the Models

Within the course, 4 different models are provided to the students: Hybrid III dummy model, helmet model, and two different impact surfaces (Figure 1). A short description of the models is presented below.

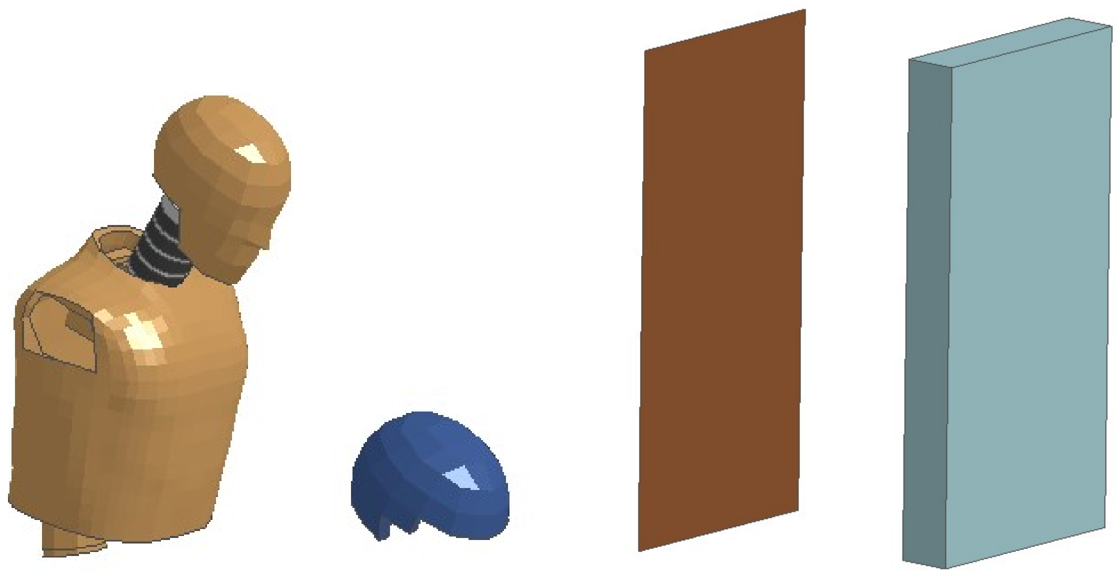

Figure 1. *The different models provided (HIII dummy, helmet, impact surface of shell elements and impact surface of shell and solid elements)*

Main_File

There are different key-files for the different models, which make it easy to add and remove different parts via the keyword *INCLUDE in the main-file (Named as Main_File.k).

For example, in the default Main_File.k that you can download via the Canvas page, four individual files are incorporated via the keyword *INCLUDE, i.e. HIII_dummy.k, HIII_dummy_Head.k, Helmet.k, Rink_Board.k. As a typical practice, replace the Rink_Board.k as the Ground.k in Main_File.k, and then observe the difference of the impact surfaces by importing the Main_File.k into LS PrePost.

In addition, the Main_File.k also includes different keywords that define the database and control cards, the contact between parts found in different key-files, and the velocity of the dummy model.

All keywords are explained in the Keyword Manual

Hybrid III Dummy Model

The Hybrid III (HIII) model is a modified version of the HIII model developed by LSTC (Guha et al., 2008). In this project only the upper body is included. The mass of the upper body is initially set to 1/3 of the body mass. The head is built up of a rigid skull, an outer scalp and two brain hemispheres, which are separated by the falx. The different part name, material and element formulation for all the parts in the HIII dummy is presented in Appendix 1. On the Canvas page of the course you can find helpful information about how you can modify the models.

Helmet Model

The helmet is modelled with an outer shell and an inner foam material. The inner nodes of the helmet share nodes with the scalp. Therefore, no contact is required to be defined between the foam material of the helmet and the scalp.

The foam material is modelled with material model *MAT_MODIFIED_HONEYCOMB in LS DYNA, which makes it possible to add the shear properties of the helmet. The stiffness of the foam material in the model is governed by the material curve included in the material model (Curve ID 1000009 for the compression properties and ID 32 for the shear properties). The foam material is assumed to be isotropic. The material curves are taken from experimental testing of expanded polystyrene (EPS) at low strain rates, see (Fahlstedt et al., 2014).

The helmet shell is modelled with a thickness of 4.7 mm with an elastic material model. The Young's modulus is set to 1.6 GPa, which are within the range for Acrylonitrile Butadiene Styrene (ABS) (Matweb, 2019).

Impact Surfaces

As baseline models, two different surfaces are provided, one modelled with solid and shell elements and another model modelled with only shell elements. In the combined model the shell elements are modelled with a rigid material and constrained in all directions both in translation and rotation. The solid elements are modelled with an elastic material, where the Young's modulus has been set to a random value of 6.5 GPa, which can be altered to fit your project. In the model with only shell elements, the motion of the board is restricted by the keyword *BOUNDARY_SPC in all directions. The shell elements have a thickness of 1 cm and model as elastic with the same Young's modulus as for the solid elements.

4. Post Processing

The brain tissue response in the form of brain tissue strain can be visualized in LS PrePost by using Fringe Component, Green, 1st principal strain. A fringe of the model is then shown. If you want to plot the values element per element you chose Post, History, Scalar, mark the elements and then press plot. To the head is there also an accelerometer attached. By choosing ASCII, nodout, #8 and then the suitable kinematics. These three processes are also illustrated with movies on the Canvas page under Project Assignment – Computer models.

Even when the simulation is not finished or terminated with error, the outputted d3plot can still be imported into LS PrePost.

Appendix 1. The Models

In Table 1 a short description of the models is shown. The material models and element formulation for the different parts are specified.

Table 1. A summary of the different parts in the models

Part ID	Part Name	Section ID	Element formulation	Material ID	Material Model
11	Scalp	11	Fully integrated S/R solid	11	*MAT_VISCOELASTIC
91	Part 91	91	Fully integrated S/R solid	91	*MAT_RIGID
301	Brain Right Hemisphere	301	Fully integrated S/R solid	1	*MAT_OGDEN_RUBBER
302	Brain Left Hemisphere	301	Fully integrated S/R solid	1	*MAT_OGDEN_RUBBER
312	Falx	312	Belytschko-Tsay shell (1 mm)	1006	*MAT_SIMPLIFIED_RUBBER/FOAM
12	Skin of upper body	12	Fully integrated S/R solid	12	*MAT_RIGID
13	Outer surface for skin of the upper body	13	Belytschko-Tsay shell (1 mm)	13	*MAT_RIGID
39	Rigid body defining the lower lumbar area	39	Fully integrated S/R solid	39	*MAT_RIGID
40	Rigid body defining the lower lumbar area.1	40	Fully integrated S/R solid	40	*MAT_RIGID
41	Rigid body defining the lower lumbar area.2	41	Belytschko-Tsay shell (1 mm)	41	*MAT_RIGID
92	Part 92	92	Fully integrated S/R solid	92	*MAT_RIGID
94	Rotational Spring for extraction of neck moment (c.f. deforc)	94	Discrete (torsion)	94	*MAT_SPRING_NONLINEAR_ELASTIC
95	Rotational Damper	95	Discrete (torsion)	95	*MAT_DAMPER_VISCOUS
8100001	NECKSUP	8100001	1 point corotational solid	8100001	*MAT_RIGID

8100002	HEADSUP	8100002	1 point corotational solid	8100002	*MAT_RIGID
8100003	NECK_3	8100003	1 point corotational solid	8100003	*MAT_RIGID
8100004	NECK_2	8100004	1 point corotational solid	8100004	*MAT_RIGID
8100005	NECK_1	8100005	1 point corotational solid	8100005	*MAT_RIGID
8100006	NODJTCTR	8100006	1 point corotational solid	8100006	*MAT_RIGID
8100007	NE_COMS1	8100007	1 point corotational solid	8100007	*MAT_RIGID
8100008	NE_COMS2	8100008	1 point corotational solid	8100008	*MAT_RIGID
8100012	NECKNULL	8100012	Belytschko-Tsay shell (0.5 mm)	8100012	*MAT_NULL
8100014		8100014	Discrete (translation)	8100014	*MAT_DAMPER_VISCOUS