HUMAN INJURY EVALUATION
USING HUMOS RADIOSS FINITE ELEMENT MODEL

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IN THE CONTEXT OF ROAD SAFETY, dummies have been widely used as a mean to validate car developments in terms of occupant security. Nevertheless, these criterion showed limitation concerning the interpretation of injury. It induces the development of human body model. So, this paper consist to show how the Human Model for Safety (HUMOS) can be considered as a new tool to the definition of injury criteria in finding medical meanings of typical numerical validation tests. In a first part a general overview of the HUMOS model is presented. Then analysis of specific parameters of the HUMOS validation test was performed in order to show which parameters can be studied in a such numerical model to identify potential injuries on anatomical component.

PART 1. HUMOS MODEL OVERVIEW

The HUMOS model consist of a frozen 50\textsuperscript{th} percentile adult male in driving position. Serial sections were performed with a 2.5mm step. 3D geometry and then mesh of each organ was then obtained with a computation of digitized slices (Serre 1999, Chabert 1998). This model was made of around 25000 elements, and includes the description of all compact and trabecular bones, ligaments, tendons, skin, muscles, organs (livers, stomach, ...) and intracranial organs (fig. 1). Material properties of the model were based on literature data and specific experiments performed for the project. The spongious and compact bones were considered as elastoplastic materials for which damage was introduced through plasticity behaviour in the model. The soft tissues such as ligaments, tendons, muscles, internal organs (livers, stomach, kidney...) were considered as viscoelastic material. At last, skin and cartilage were assumed to be elastic materials. According to the available literature data specific sets of parameters were defined on each anatomical entity. The muscle modelling was performed using volumic elements to model damping properties of passive muscles during shocks and using springs to model muscles line of action. Interaction between segments was performed using tied interface (to ensure flesh attachment to bones), and self contact interface (to ensure contacts between moving parts). Validation was obtained on isolated segments and then on the whole model. The upper and lower limbs were tested on their physiological movements, on dynamic eversion, inversion, dorsiflexion, compression of the foot ankle complex and also with frontal impacts and antero-posterior dynamic loading on the knee. The head and Neck segment was submitted to frontal, oblique and lateral impacts, in which acceleration and pressure levels were compared. Dynamic frontal loading were applied on the thorax, pelvis and abdomen parts in order to check relative
kinematics of organs and global force and deflexion response of the thorax during the experiments. Validation of the whole model was possible with 4 sled tests experiments performed by the Laboratory of Biomechanics and Mechanics of chocks (INRETS-Bron). The Human subject was seated and belted and instrumented with force and accelerometers sensors on the head, arms, lower limbs, spines, thorax and belt. On the all testing, results obtained with the HUMOS model were in good agreement with the experimental one. All data used for model design and validation are listed in HUMOS guideline (Arnoux & Thollon 2001)

PART 2. HUMOS MODEL INJURY EVALUATION

HUMOS model validation was obtained on isolated segments and then on the whole model as well in frontal impact situations as for lateral tests. Validation concerns mainly the comparison with recorded acceleration, force, moment and deflexion level during experiment. One major interest in HUMAN model (HUMOS in this paper) deals in the possibility to record numerically specific parameters (strain, stress, pressures, kinematics) on all anatomical component, to show the tissues kinematics and interaction during crash situation and then potential injuries with a medical point of view. Some example of interpretation of these parameters are summarised below

- The kinematics interpretation. Model kinematics is recorded in order to check global behaviour of the model and to study interaction with car environment. In the HUMOS model this kinematics can also be shown on each joint in order to check joint mobility by comparison of healthy joint mobility described in literatures and the correct relative movements between the corresponding bones. In case of the frontal impacts and more particularly head-neck deceleration, relative movements between HUMOS vertebrae C1 and C2 show that this relative displacement can lead to an luxation of interspinal ligaments with a deformation closed to 75% (cf. fig. 3).

- The force and stress level. The force level could be used to show potential injuries of bone materials. Therefore, the Von Mises stress distribution in bones and evolution during several stage can be used to show localisation and chronology of injury (cf. figure 3). Damage is assumed to start when stress reach yield stress level defined on each component. The element failure is introduced through ultimate deformation level defined in each material property. For example, in thorax impact test, it is possible to follow potential rib injury process during tests using stress distribution (Von Mises curve).

Fig. 2 - Three stage of the frontal impact

Fig. 3 - Three stage of the Bouquet thoracic impact
- Deformation measurements. The deformation and deflection measurements can be mainly attributed to soft tissues injury evaluation. Damage properties of soft tissue can be mainly described in term of deformation level in soft tissue structures (damage is assumed to start with deformation level upper than 20% (Arnoux 2000)). In case of abdominal impacts tests, abdominal organs deformation is very high (more than 40% deformation) and can be the cause in real accident situations of spleen, kidney and liver injuries by haemorrhage leading to human death (cf. figure 5).

![Fig. 4 – Two stage during Cavanaugh Abdomen impact test](image)

DISCUSSION - CONCLUSION

This work shows that the HUMOS model can provide an accurate description and understanding on human injuries. These results obtained with validation procedure of the numerical model show a strong reliability with experimental results but also with identified trauma during hospitalisation. This Humos model is a first step in the design of an European database of the finite element model of Human. Improvement in the capability of the model to describe injuries have to be included. These improvements deals with failure properties of biological tissues, blood pressure effects morphological differences (…) and will be studied during the HUMOS2 project. Therefore a next step will deal with the integration of the HUMOS model in a car crash environment in order to identify injury mechanisms reported in epidemiological studies.

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REFERENCES


