A NEW HEAD PHYSICAL MODEL

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KEYWORDS : Biomechanics, cadavers, finite element method, head physical model, stereolithography.

INTRODUCTION

ONE PART OF the current research project is the identification of the bone biomechanical behaviour of the human skull. This project deals with the development of finite element and physical models of the human head. In order to identify skull bone behaviour, the inverse method is used. It consists in solving a group of equations deduced from the direct problem in order to determine the behaviour of the system, unknown of our problem. The solution is obtained using an optimisation process: minimization of the difference between the experimental answer considered as reference and the numerical response of the finite element model.

The aim of the research described in this paper is to determine an equivalent resin in mechanical characteristics to the human bone. This work is included in a program of head injury research which investigates the mechanical properties of all tissues of the head. The final aim of this program is to precisely determine the characteristics of these materials. So appropriate physical and finite elements models of the head can be built.

QUASI-STATIC BENDING TESTING OF SPECIMENS FROM EMBALMED HUMAN SKULL

Quasi-static axial bending loads (figure 1) are applied to skull bones taken from cadavers in order to quantify the mechanical response of the bone structure. A reference system is used to identify the location of test specimens from the human skull (Delille, 2002).

The load-displacement characteristics of the skull bones are established and the analytic Young's modulus is determined. A finite element model of specimen (the "sandwich model") is used. Inner and outer tables and diploë are represented by only one layer (elastic plastic solids) and average mechanical properties. Young's modulus E, tangent modulus E_t, yield stress σ_y, and maximum plastic strain ε_l are the parameters we want to identify. The inverse method is also used. Average bone characteristics are identified (table 1).

Figure 1 - Impact conditions for the quasi-static tests

	Average	Standard deviation
Experimental E	3780 MPa	837 MPa
Identified E	2965 MPa	1040 MPa
E_t	1518 MPa	795 MPa
σ_y	28 MPa	11,1 MPa
ε_l	3 %	1,5 %

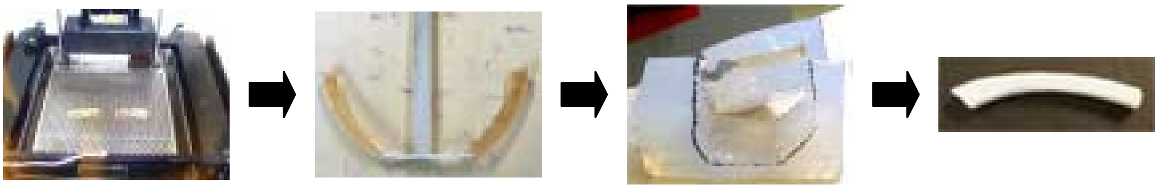
Table 1 – Results of identified parameters

Differences are noted between the experimental Young's modulus and the identified modulus. The experimental Young's modulus is obtained using a mechanical analytic calculation. A beam in simple bending is considered for calculations. The geometry of specimens is not taken into account. An elastic law is only considered when failure occurs. Numerical simulations allow to identify an elastic-plastic material law (four parameters are identified).

THE HEAD PHYSICAL MODEL

CREATION OF THE RESIN SPECIMENS BY STEREOLITHOGRAPHY

A bone specimen geometry is reproduced in stereolithography in order to carry out the model master of the silicone mould (figure 1).



Stéréolithography Model master Silicone mould Resin test sample

Figure 2 – Creation of the resin specimen by stereolithography

In the same way, quasi-static bending tests are applied to this specimen. Different resins were tested. Others resins are under development.

CREATION OF THE HEAD PHYSICAL MODEL

Initially, a skull finite element model was carried out by the University of Valenciennes. It is composed of 5000 elements and 6800 nodes. The external and internal geometry of this skull define the geometry reference of the physical model. Then the head physical model will be created according to the same method used with resin test sample. The resin is the same that the one who was identified with bending tests. The head will be validated with compressive quasi-static skull test (Delille, 2001). Quasi-static axial loads were applied to skull taken from cadavers (figure 3) in order to quantify the mechanical response of the global structure. A flat rigid impactor delivered loads to the temporo-parietal region of fixed skulls. The loading surface was a 150 cm^2 rectangular plate. The skull's degrees of freedom were fixed by rigid foam.
A head model in stereolithography is initially carried out. It will be used as a master model in order to make the silicone mould (figure 4).

Figure 3 – Initial conditions for the skull tests

Figure 4 – Master model for the physical skull

CONCLUSION AND DISCUSSION

The aim of this work is to obtain a resin which has the same mechanical properties than the skull bone. This resin will be used for the creation of a head physical model in order to have a new head dummy design. This model will be deformable.

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