New methods for the simulation with finite element of the human elbow

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Abstract**—** In this paper one presents on virtual models of bones the cinematic and dynamic analysis of the human elbow with the analysis of finite elements. The model is made in Solidworks then is imported in Visual Nastran for the analysis. Then we study the cinematic and dynamic simulation of the bio-system elbow articulation for the movement of deflection-extension with the presentation of different graphics of the ulna. It is studied also for the humerus bone the tension and stress between intervals of 0.1 - 0, 2 seconds. The results showed that the virtual bone has a great capability to predict the moments of fracture apparition with application to future researches.

Keywords**—** Bio-system fracture, flexion-extension, human elbow, tension.

I. THE METHOD DESCRIPTION

To obtain the bone cross sections were used a PHILIPS AURA CT tomography installed in the Emergency Hospital from Craiova (Figure 1).

Fig.1 The PHILIPS AURA CT tomography

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Fig.2 The real bone components of the present study.

To obtain the tomography's of the three bone components (humerus, cubitus and radius) were used two scanning schemes presented in Figure 3. First, was made a complete scanning operation for 5 mm distances having the results of 147 images. After that, it had been obtained cross section images at the distance of 1.25 mm from the ends of the bones and the elbow joint area.

Fig.3 Scanning schemes applied to the humerus, cubitus and radius.

To have the possibility to report the next 3D model to a fixed coordinate system and to respect a correct representation scale, the studied bones were scanned with a plastic bar having known dimensions (Figure 4).

Fig.4 Using a known dimensions bar.

For the ends of the bone the scanning operation was made at the distances of 1 mm and for the medial areas at the distances of 3 mm.

To have the possibility to report the next 3D model to a fixed coordinate system and to respect a correct representation scale, the bone component was scanned with a plastic bar with known dimensions [5].

For the preparation of the model for the cinematic analysis the bone components were loaded in the module assembly of program SolidWorks.

This module allows defining the motion constraints (of the type axle-axle, flat-plane, distance, etc.) and the definition of the bio-mechanical system in terms of freedom of movement.

First, it was used the **Mate** command for the correct positioning of the three components [4]. For the study of the cinematic and dynamic analysis the mechanical system has been exported as ACIS (SAT).

The Visual Nastran is the program that allows the study of cinematic and based on forces occurring in the mechanical system allows finite element analysis of the various components [6].

Fig. 5 The initial biomechanical assembly

II. THE INITIAL SETTING OF THE PARAMETERS AND CINEMATIC AND CINETOSTATIC FUNCTION

The study of this bio-mechanical system it was achieved in the condition of the simplifying assumptions [1]:

- it has been considered a complete cycle of flexion-extension with total duration of 1 seconds;
- in the elbow joint it was considered a motor rotation couple having angular variation given by:

$$\alpha = 160 \cdot \sin(2\pi \cdot t) \qquad (1)$$

where:

α is the angle made by the humerus and cubitus and is considered null when the two bones are in extension;

t - time in seconds;

The following step was to divide the solids in finite elements (structure definition "mesh").

Thus, the structure of humerus has the following elements: the finite element size 5 mm, structure factor of 0.000529, resulting in 64,979 nodes and 40,247 elements.

The finite element structure of cubitus has the following characteristics elements: the finite element size 3 mm, structure factor of 0.000285 resulting in 64,281 nodes and 39,895 elements.

The finite element structure of radius has the following characteristics elements: the finite element size 3 mm, structure factor of 0.000285 resulting in 64,281 nodes and 39,895 elements.

Fig. 6 The element finite structure of the humerus, cubitus and radius

III. THE CINEMATIC AND DYNAMIC SIMULATION OF THE BIO-SYSTEM ELBOW ARTICULATION FOR THE MOVEMENT OF DEFLECTION-EXTENSION

The running of the simulation is initiated by the command World / Run, and the first major result is film simulation [2].

In figure 7 are presented nine key frames of cinematic simulation.

Fig.7 Nine key frames of cinematic simulation.

In the bio-system studied are important the cinematic characteristics of the elbow joints which are presented in the figures below:

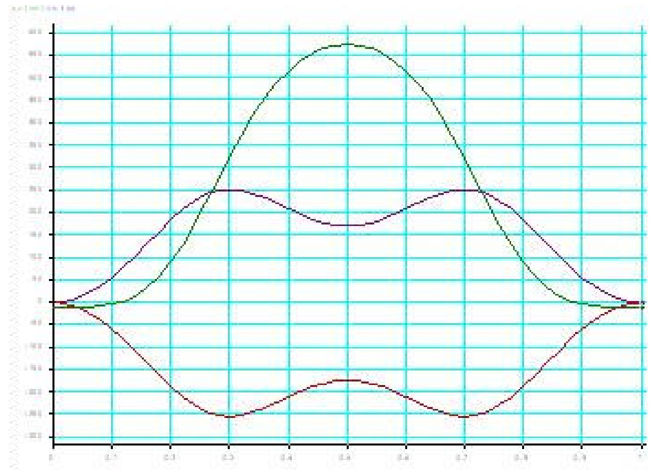

Fig.8 Cubitus position in x,y,z coordonates function of time

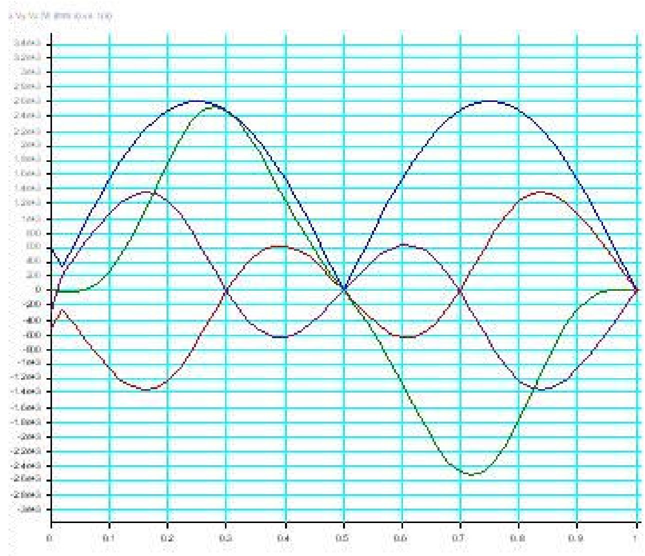

Fig.9 The components of the velocity speed of mass center of the cubitus in mm / s function of time

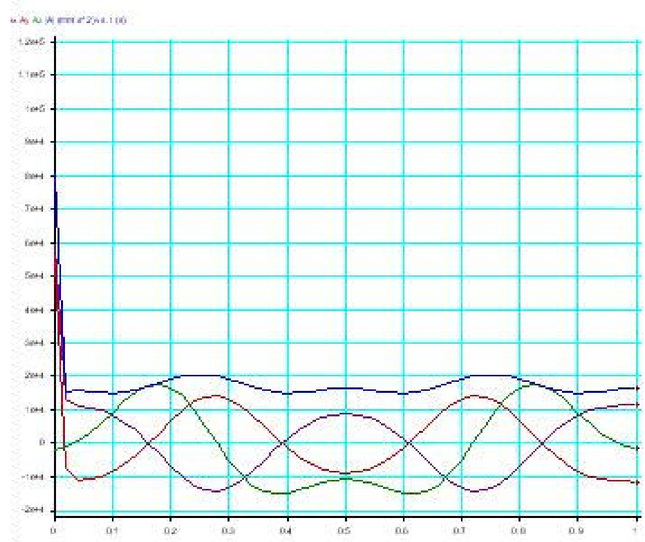

Fig.10 The components of the acceleration center of mass function of time

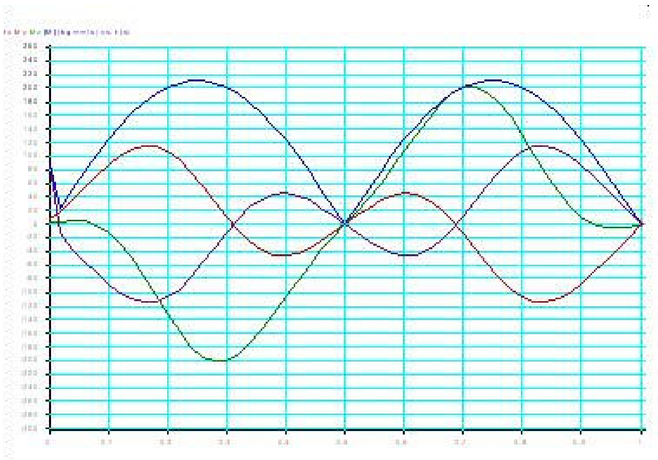

Fig.11 The momentum components of cubitus function of time

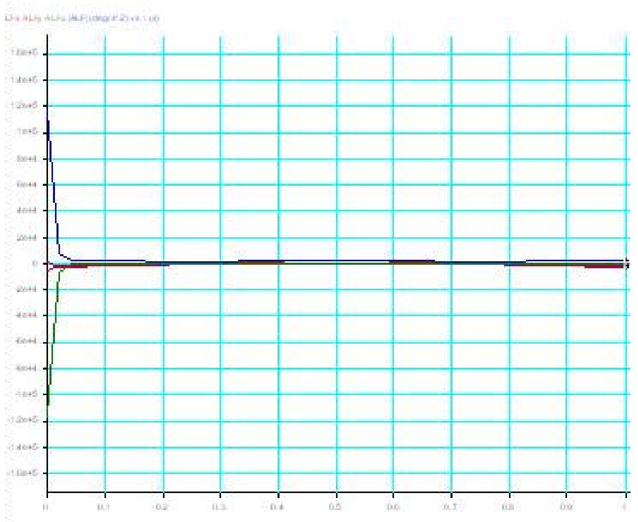

Fig.12 The angular acceleration of cubitus function of time

IV. HUMERUS ANALYSES

A humerus fracture is an injury to the bone of the upper arm. The upper arm bone, the humerus, connects the shoulder to the elbow.

Humerus fractures are generally divided into three types of injuries

- Proximal humerus fractures occur near the shoulder joint. The shoulder joint [8] is a ball-and-socket joint, with the ball being the top of the humerus bone. Fractures of this ball are considered proximal humerus fractures. These fractures may involve the insertion of the important rotator cuff tendons. Because these tendons are important to shoulder motion, treatment may depend on the position of these tendon insertions.
- Mid-shaft humerus fractures occur away from the shoulder and elbow joints. Most humeral shaft fractures will heal without surgery, but there are some situations that require surgical intervention. These injuries are commonly associated with injury to one of the large nerves in the arm, called the radial nerve. Injury to this nerve may cause symptoms in the wrist and hand.
- Distal humerus fractures are uncommon injuries in adults. These fractures occur near the elbow joint. These fractures most often require surgical treatment unless the bones are held in proper position.

Humerus fractures are commonly seen in the acute care setting and make up 5% of all fractures. The most common cause of proximal humeral fractures is a fall from standing, followed by motor vehicle accident and a fall involving stairs.

Additional mechanisms include violent muscle contractions from seizure activity, electrical shock, and athletic-related trauma. Proximal humeral fractures are most often closed.

We analyze the case when we simulate the direct trauma through falling or strong hit [3]. Humerus fractures can occur by many different mechanisms, but are most commonly caused by falls. The simulation scheme is presented in the Figure 13.

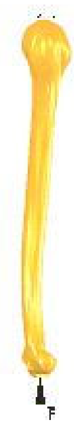

Fig.13 Simulation scheme

where: F- force given by the relation;

$$F = 707 \cdot \sin(7.8525 \cdot t) \quad (2)$$

After the rulation of the application with finite elements for a time interval of 0.1 - 0, 2 seconds we obtained the following results showed in Figure 14.

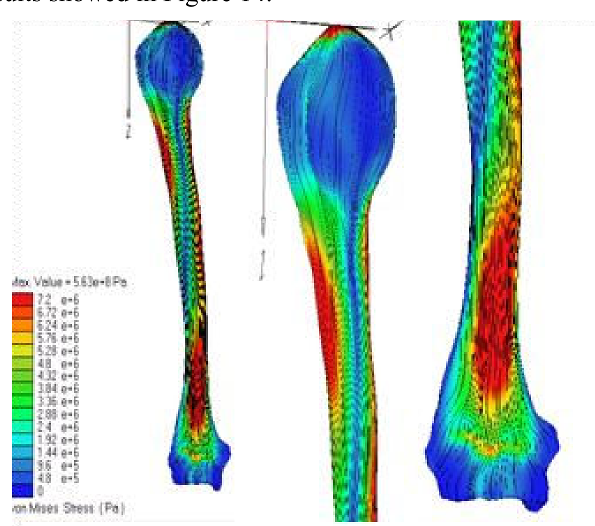

Fig.14 Tension von Mises for t = 0.1 sec.

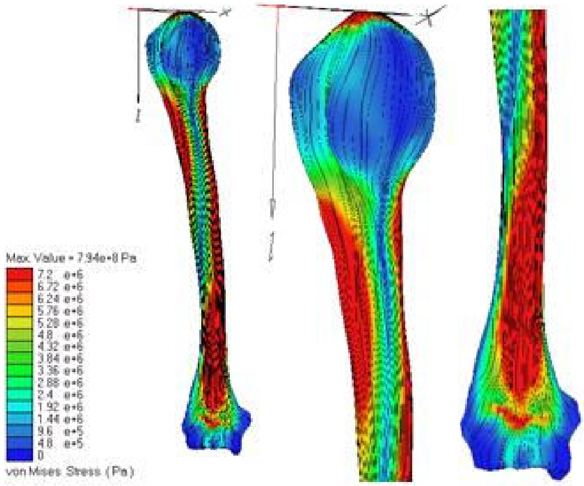

Fig.15 Tension von Mises for t = 0.2 sec.

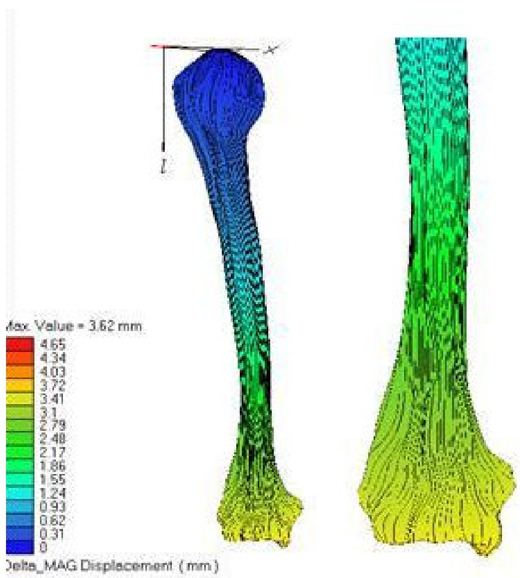

Fig.16 Resulting stress at t=0.1 sec.

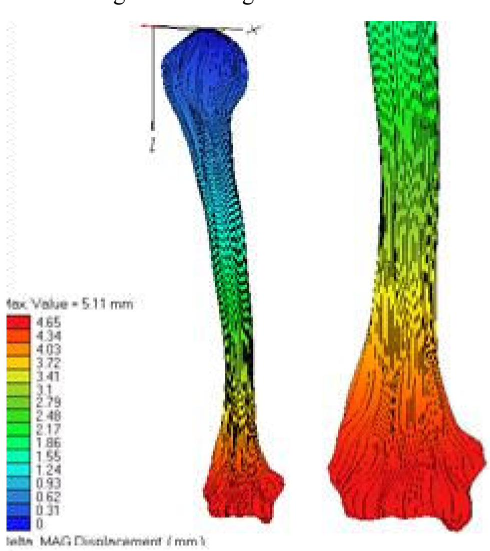

Fig.17 Resulting stress at t=0.2 sec.

V. CONCLUSIONS

The research theme, presented in this paper, is a part of a large subject of study, which attracts the knowledge from different fields [9] (anatomy, surgical techniques, orthopedics, mechanics, bio-mechanisms, computer science, technical graphics, and computer aided design).

The subject of this paper permits the cooperation between many researchers which activate in different fields and which have the capacity to develop informational methods and technologies to solve difficult problems given by the complexity of the scientifically target [2].

The elbow is an important joint from the human skeleton and it is composed of bones, ligaments, tendons and cartilages.

From such reason, scientifically studies are very difficult to realize because the elbow is one of the most complex joint in the human body and they are studied in a statically system [3].

First, to understand the problems, which appear in this joint, it is very important to know the anatomy of the elbow and the way in which the components are working together to realize a normal functionality.

The behavior of the virtual elbow [7] can give the important informations which can be used in the fields of robotics, medicine sciences and medical robotics. Also, on the virtual elbow joint can be attached virtual prosthetic elements for virtual post-surgery simulations. At the analyses of the graphics and tension for this case of solicitation we notice the fallowing results:

- the maximum tension are located in medium zone of the cubitus and has a value between 6.89 Mpa and 794 MPa;
- the resulting stress have a value between 0.042 and 5.11 mm, so the virtual bone is possible to be fractured at the end of the studied case.

In conclusion the virtual bone that we studied can be used as prototype model for the studies regarding humerus fracture with application in medical researches.

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