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Analysis of stress and displacements of phalanx bone with the finite element method

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Abstract

In this paper analyze of phalanx bone supposed at compression, torsion and bending is made. We know that the bones are one of the most important natural composite materials. The finite element method offers the possibility for the study of the stress and the displacements which appears in different solicitations cases. We realized that the most solicited parts of the bone which will be the next broken parts, so the fracture are the once from the meeting of the bone's body with its hand. The observations made by studying 74 cases of fractures caused by torsion and compression and also made by the testing of 23 phalanx bones confirm these conclusions.

Keywords: *phalanx bone, stress and displacement analysis, finite element method.*

Introduction

The hand is the body segment and with its help man can do many activities. That is why the hand and its skeleton undergo the most diverse stresses. In this paper we study the phalanx bone and its compression and bending and twist solicitations.

We know that the bones are made of one of the most important natural composite material. Phalanx bones contribute to the complexity of the hand skeleton.

The body of the hand bone is made out of a compact bone tissue cylinder pierced by a central channel called the medullar cavity. The bone marrow is in the medullar cavity. The ends of the bones are made of a compact substance thin layer outside and a spongy mass inside.

Figure 1 – ***The skeletal hand***

The authors used the finite element method for the spatial model of the phalanx bone [1].

The geometry's and mechanical properties' natural variability of the bone system from one to the other is a big problem which brings about many difficulties in the biomechanical researches.

The dimensions, form, mechanical properties, elastic constants, physical constants of the bone are different from one to the other. They depend on: age, sex, height, profession etc.

The geometrical aspects of the bone systems modeling are dominated by the necessity of using some spatial models because most of the bone elements have complicated geometrical forms in space.

Material and methods

We used the section method of the bone divided in section parts with the tomography computer for the determination of the phalanx bone's spatial geometry. With these sections' help we determined precisely the spatial coordinates of 12 points set from every section's boundary [2].

Then we built the spatial model of the bone using the finite element EMRCNISA soft. At first, with the lines' method the points were united by interpolation, giving every section's form. Then, with the help of the surfaces' method, there were united close sections two by two and with the hyper-surfaces method, the program realized the spatial model of the whole bone.

The model was generated with the help of hexahedral finite element.

Work hypothesis

For the correct modeling of the phalanx bone with the finite element method, we used two work hypotheses:

a) The bone is made of two kinds of materials, like a composite material.

b) The values considered for the two materials Young's constants are:

- $E_{compact}$ = 25 000 N/mm^2, and
- E_{spongy} = 2 N/mm^2.

In the first case, the bone was submitted to a compression force equal with 2.4 kN distributed on the top hand surface [3]. The bone is leaned in its base.

In the second case the bone was submitted to a bending force equal with 2 kN distributed on the lateral hand surface (I) [4, 5]. The bone is leaned in its base.

In the third case the bone was submitted to a bending force equal with 2 kN which acts on the middle of the bone (II). The phalanx bone is leaned on its ends.

In the fourth case the bone was submitted to a torsion torque which acts on the hand of bone. The bone is leaned in its base.

Results and discussions

Finally, we obtained the compression resultant displacements (Figure 2), the bending resultant stresses diagram (I) (Figure 4), the bending resultant stresses diagram (II) (Figure 3), the bending resultant stresses diagram in his longitudinal section (I) (Figure 5), the torsion resultant stresses diagram (Figure 6), the torsion resultant displacements diagram (Figure 7).

Conclusions

By minutely observing the stresses diagrams and the displacements diagrams obtained with the finite element method, we realized that the most solicited parts are the once from the meeting of the phalanx bone's body with its head. These zones are the potential fracture sections.

The observations made by studying in hospitals 74 cases of real fractures and also the observations made by the testing of 23 bones confirm these conclusions.

The finite element method offers the possibility of studying the stress and displacements, which appear at different bones for different cases of solicitation: traction, bending, twisting and compression [6].

Our conclusions are very important as they can be successfully used in the design of phalanx prosthesis.

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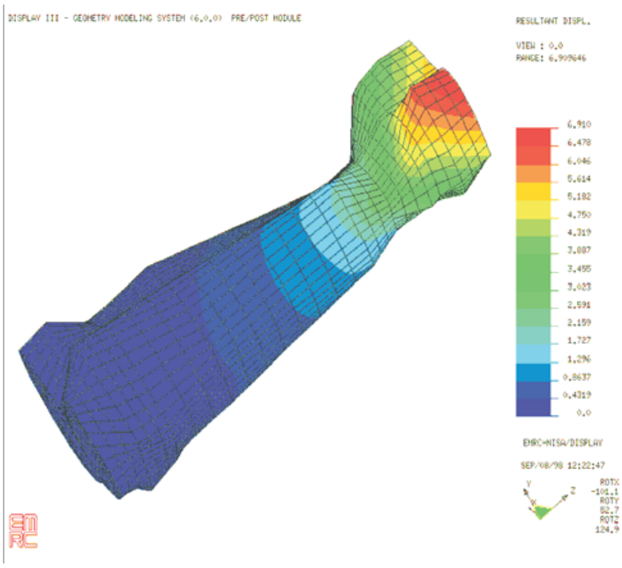

Figure 2 – ***The compression resultant displacements***

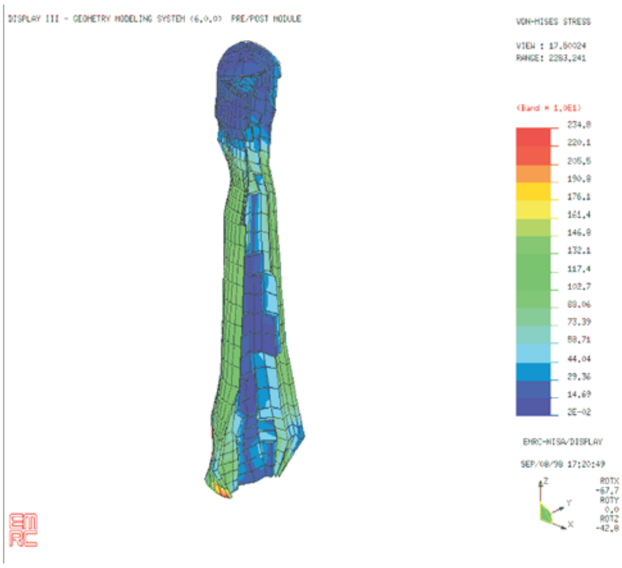

Figure 3 – ***The bending resultant stresses diagram (I)***

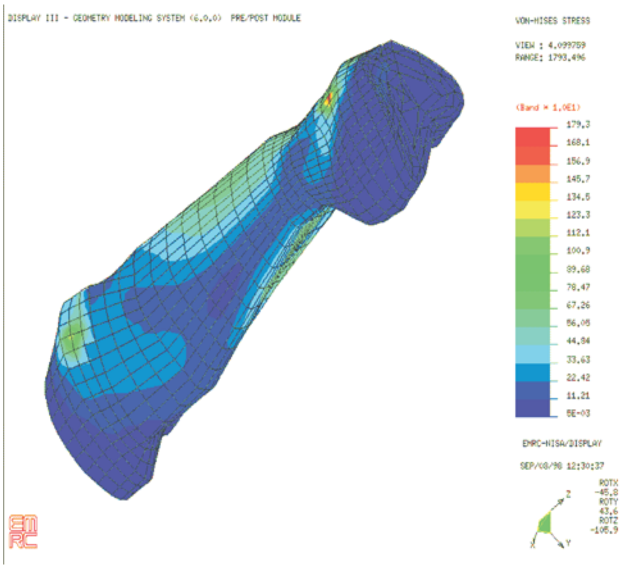

Figure 4 – ***The bending resultant stresses diagram (II)***

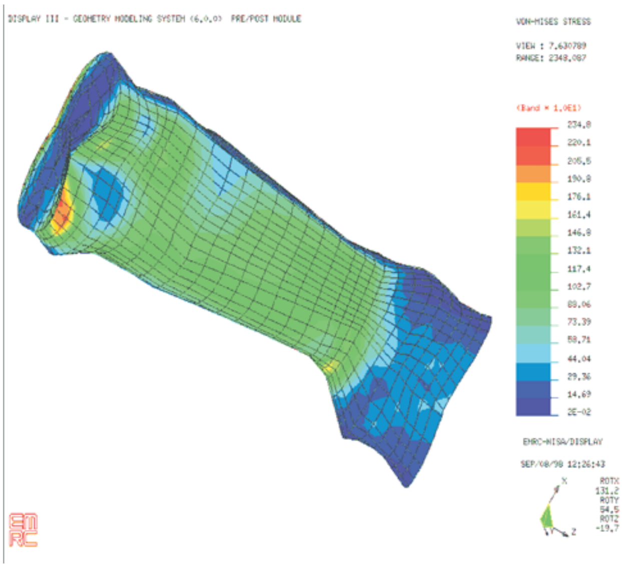

Figure 5 – ***The bending resultant stresses diagram in his longitudinal section (I)***

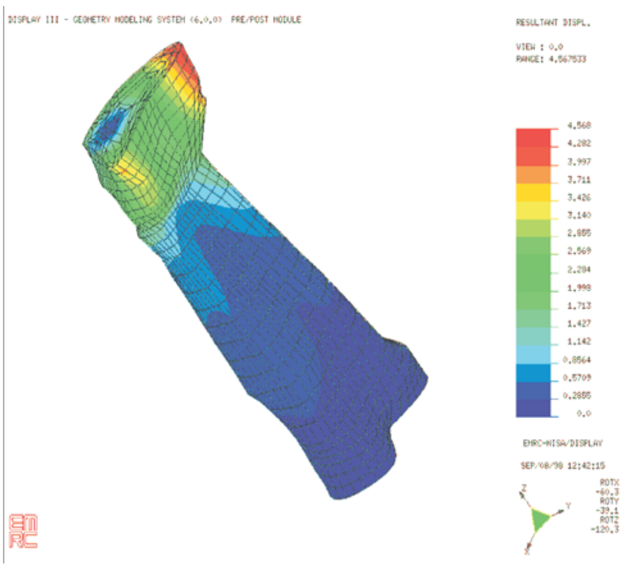

Figure 6 – ***The torsion resultant stresses diagram***

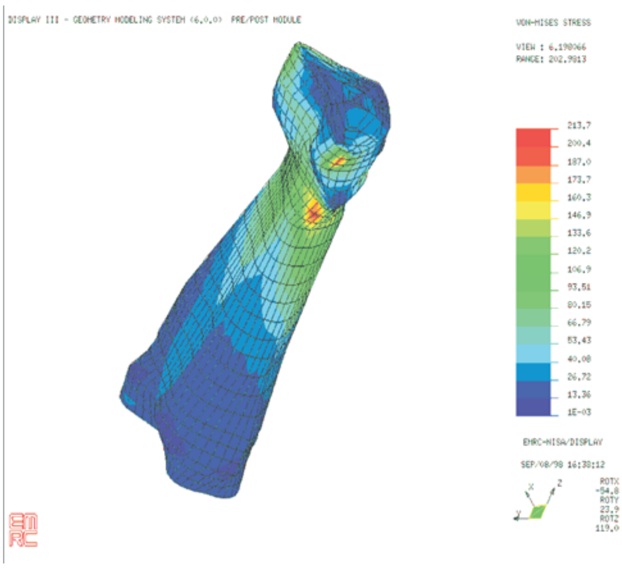

Figure 7 – ***The torsion resultant displacements diagram***