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Natural Frequency Analysis of the Human Head in Normal models

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ABSTRACT
Natural frequencies of the human head in the living condition and skull in an experimental condition have been set. Since the behavior of the numerical model under transient loading is similar to the human head, it is necessary that the natural frequency of the numerical model is in the real range. Frequency analysis is an impressive way to determine the frequency and it is well matched in both calculated numerical and experimental frequencies in frequency analysis of brain with calculated frequencies in two-dimensional models of other researchers. To assess the damage and determine the severity of vulnerability points , tension-time chart in different areas of the brain tissue is studied .
Keywords :*Frequency analysis , brain , Frequency response , skull , cerebro-spinal fluid .*

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INTRODUCTION
The human head when exposed to the collision , it becomes one of the most vulnerable parts of the body . Studying the human head under the impact terms may be divided into two parts ; first calculating the deformation of the skull and the contents inside as a results of the impact loading and second to determine the correlation between a change in a particular form of the tissue and damages in that tissue .
Gurdjian [1] measured the natural frequency of alive head and a skull filled with the silicone gel .He found that it's essential that the skull as a rigid body moves under the frequency of 150 Hz ,since the first resonance may be seen in the frequency of 313 Hz .
Fogel ,Stalnaker [2] determined the electrical resistance of the head of the human and monkey bodies in vivo and in vitro . The resonant frequency of 166 Hz has been registered for the human head .
The results showed a special reduction in the frequency in the absence of the membranes [5].Ruan ,Prasad [6] provided the analysis results of the human head's complete model , the analyzes include the model with the brain and skull .

MODEL
Brain, membranes of the brain and cerebro-spinal fluid
Brain may be divided into five parts about the structure and function : cerebrum , cerebellum, midbrain , pons and medulla oblongate.
Average length of the brain is 165 mm and the maximum transverse diameter is about 140 mm . The weight of the adult human head is about 4.5 kg . The average brain weight is about 1.5 kg for men and slightly fewer for women .Its average specific weight is 1040 kg per cubic meter . The detectable structure of the brain may be non-homogeneous and irregular . The Brain and the spinal cord are covered by three layers that play an important protective role (Figure 1) . The outer layer is dura mater and the inner layer is called piamater, arachnoid located between these layers .
Since the frequency analysis based on the linear theory, we should note that we can not use them for large movements and deformations.

Table 1 –The calculated frequencies in the various articles

Analysis type	researcher	Frequency values(Hz)
Experimental :human corpse	Gurdgian [1] Stalnaker and Fogel [2]	313-880 166-820
Experimental : dry scalp	Kalil and Viano [3] Tzeng [4]	(10 mode) 1385-4245 1286-2539 (6 mode)
Experimental : human volunteer	Tzeng [4] Willinger and Cesari (1990)	161 100-200
Numerical : brain model	Ward and Thompson (1975)	23/1-37/8 (with membrane) 19/3-34/5 (without membrane)
Numerical : skull model	Ruan and Parasad [5]	325-2167
Numerical : head model	Ruan [6]	70-118 (with membrane) 48-90 (without membrane)

Frequencies that calculated in this study is in the range of 68-115 Hz in the presence of the membranes and it's in the range of 34-85 Hz in their absence (Figures 2 and 3) .

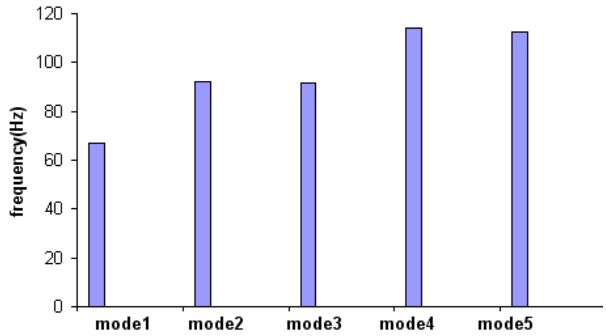


Figure 2 –special frequencies of the brain in the presence of the brain membranes.

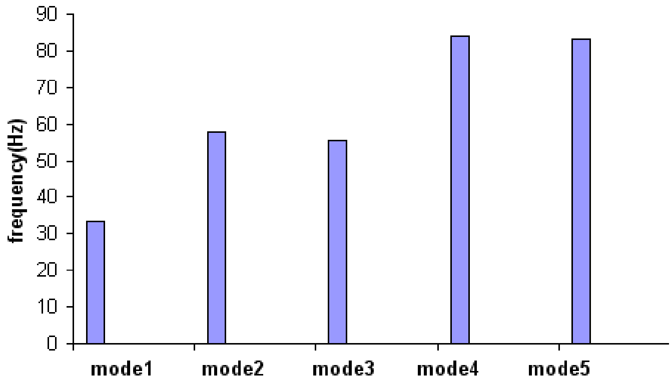


Figure 3 – Special frequencies of the brain in the absence of the brain membranes.

Material properties

The skull as a homogeneous isotropic structure come models with linear behavior . External and internal layers of the skull has the characteristics of the compact bone and middle layer has the properties of the cancellous bone .

In this model the components within the skull with linear material properties have been included . The properties of all head tissues are in the Table 2 .

Table 2 – The characteristics of the head tissue materials .

Head Tissue	E (Pa)	$\rho\,(kg/m^3)$	ν
Outer Table	*10⁹12/2	3000	0/22
Diploe	5/66*10⁹	1750	0/22
Inner Table	12/2*10⁹	3000	0/22
CSF	1/48*10⁶	1040	0/4887
Membrane	9/45*10⁶	1113	0/45
Brain	66/7*10⁶	1040	0/48

Simulation and comparison of the impact :

A time period of 10 milliseconds in given to simulate .When considering the relationship between the frequency of the system , time step is calculated . Simulations were done with ANSYS code .
The finite element code may be used in this regard because it may be modeled the contact between the brain and skull . The calculated tension and tension-time chart are shown in Figures 4 and 5 .

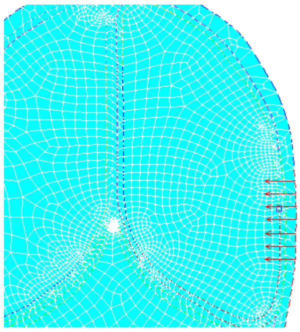


Figure 4 – The defined node in the impact area to see results .

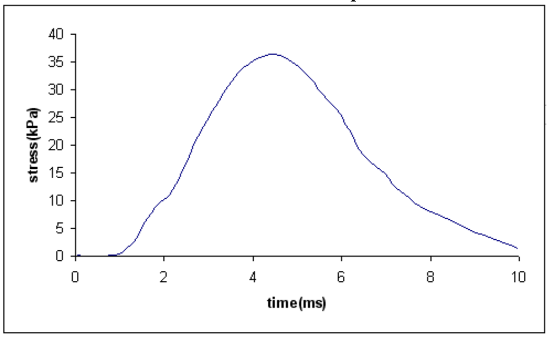
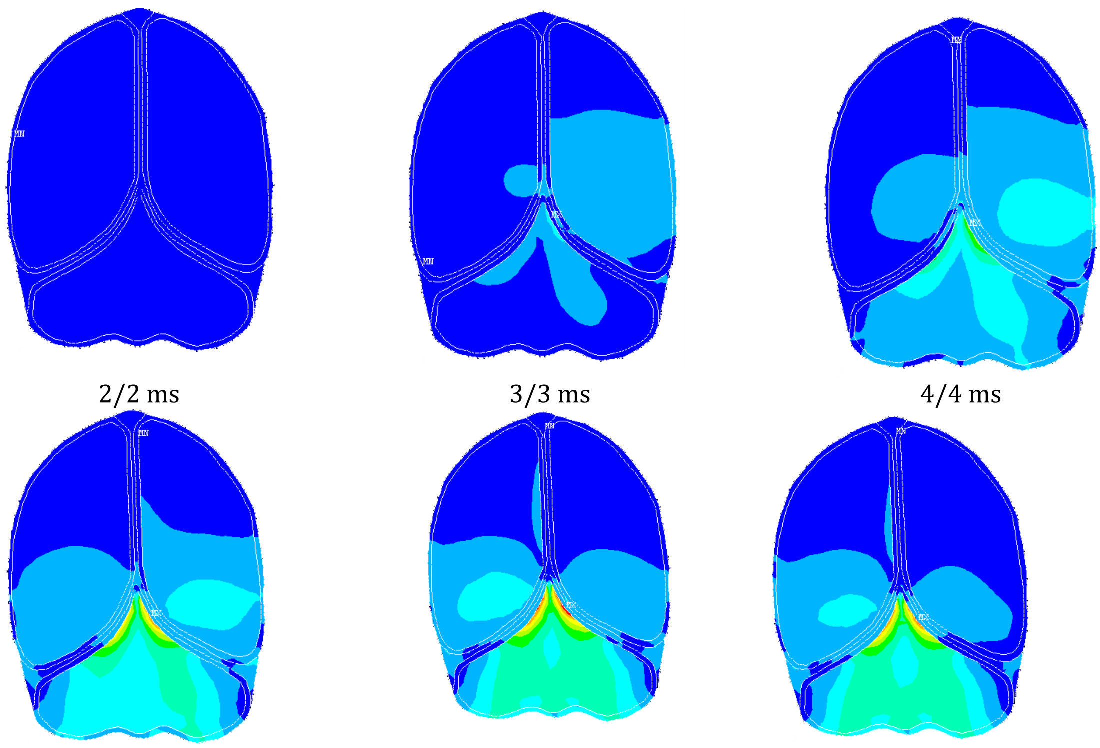


Figure 5 –The tension –time response in the impact area for the reference model .

The shear response:

To imagine the shape of the brain in the coronal plane , figure 6 shows the Von-Mises tension distribution at different times . The brain is exposed to higher levels of Von_Mises tension in 2-6 milliseconds time , especially outside of the brain is affected by the highest tensions .



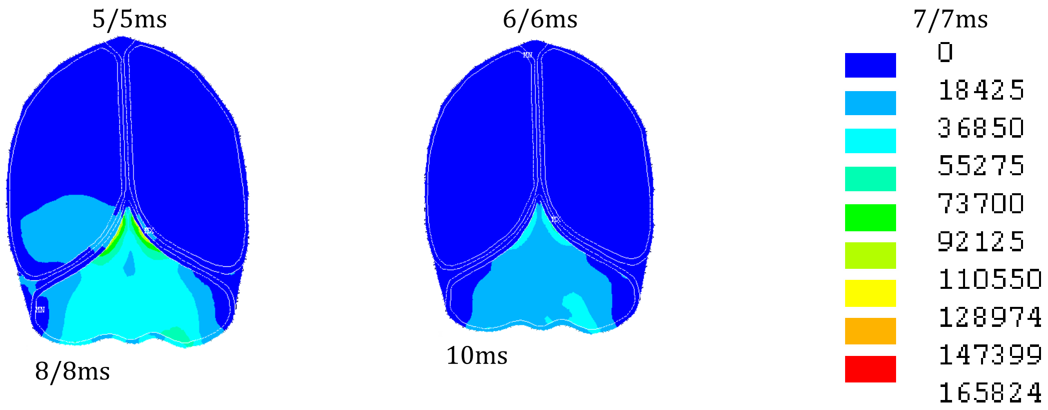


Figure 6 –Von-Mises tension distribution in the reference model in the impact area .

Expansional response :
Expansional response is offered by the major maximum strain .The results indicate that the maximum strains occur in the range of 3-6 milliseconds (figure 7) .

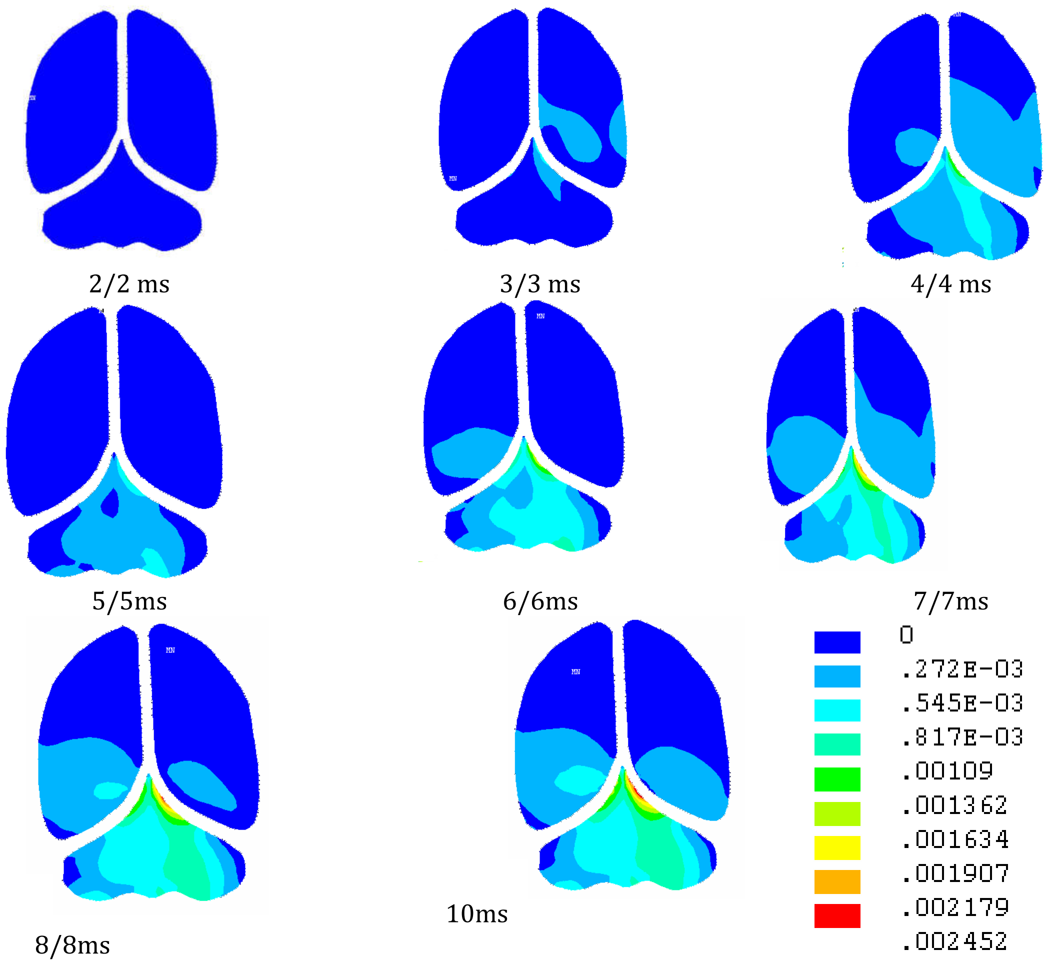


Figure 7 –The maximum tension distribution in the impact area .

RESULTS AND DISCUSSION
The structure of the human head is three-dimensional , however with two-dimensional appropriate assumptions , the plane strain model is so useful for calculating the head deformation under the impact circumstances .

Although their computing value is fewer than the three-imensional model , but each provide a quick understanding of problems . Although the two-dimensional models have problems , the first is the nature of numerical formulation , the plane strain model can offer the unrealistic results under the large deformations . But by all these accounts, each hold the characteristics of the plane strain distribution, so that they are in fact similar to the three-dimensional .
Secondly although the Young's, odulus are similar two and three-dimensional models , two-dimensional model suffered of the loss of geometric stiffness. Since two-dimensional model describes the skull similar to a cross-section of the cylinder ,but its stiffness is significantly lower than the dome structure . Finally for each loading we require the model suitable for that loading. The comparisons made in this section is between calculated numerical results and articles, that does not mean it offers the complete credit of these models but it shall be looking for good agreement with the results of other articles.
The frequency analysis results obtained from this model well latched with the values provided by Ruan [5] .
The calculated frequencies in the frequency analysis of the brain are well matched with the calculated frequency in two-dimensional model of the researchers .

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