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Natural frequency evaluation of femur bone through modal analysis

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Abstract
Bone density of femur bone is analyzed for evaluation of Natural frequency. Different density 1500 kg/$m^{3,}$ 1200 kg/m^3, 1000 kg/m^3, and 800 kg/m^3 is used and observed natural frequency as 2.4269 Hz, 2.7134 Hz, 2.9724 Hz, and 3.3232 Hz respectively for first mode. Natural frequency of femur bone is decreases with the increase in density of femur bone. Also total deformation of femur bone decreases with the increase in density of femur bone.

Keywords: natural frequency, bone, density, modal analysis

1. Introduction

The femur bone is longest and largest bone in human body. Main function of femur bone is walking and jumping to move from one place to another. Apart from skull bone, femur bone is strongest bone in the body. The femur bone is 0.48 meter in length and 0.0234 meter in diameter of average male adult. It may support up to two times weight of an adult. Bone density is medical term used normally for amount of mineral matter per square meter of bone. This medical bone density is not the true physical density of bone which is mass per volume. Average density is around 1500 kg/$m^{3.}$ The material density of cortical bone is wet weight divided by the specimen volume [1].

Every material has its Natural frequency and their effect on material. Various cut orientation are modeled to test their influence on natural frequency of femur bone. Modal analysis is carried out to determine whether an internal fixated femur is healing. Two type fixations were studied and observed which is sensible to healing [2].

Various studies carried out for strength evaluation i.e. tensile testing, compressive testing, bending testing, torsion testing, and creep testing [3].

In this paper Natural frequencies of femur bone and total deformation of femur bone are studied with different density of bone.

2. Objectives

1. Create three dimensional model of femur bone.
2. Carry out Modal analysis for Natural frequency of femur bone.
3. Evaluate Natural frequency by different bone density.
4. Compare Natural frequency of different bone density.
5. Compare total deformation of different bone density.

3. Method and Material

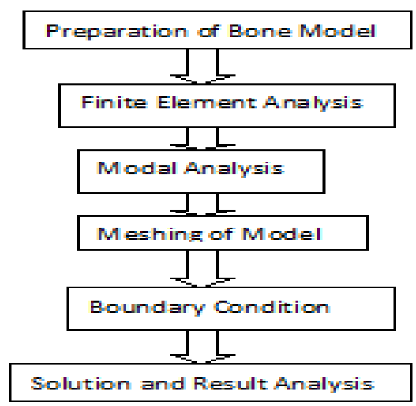

Fig 1

Preparation of bone model

The 3D model of femur bone is created using solid works. This model is then converted into IGS file. So that it is imported in finite element analysis to perform Modal analysis for frequency evaluation.

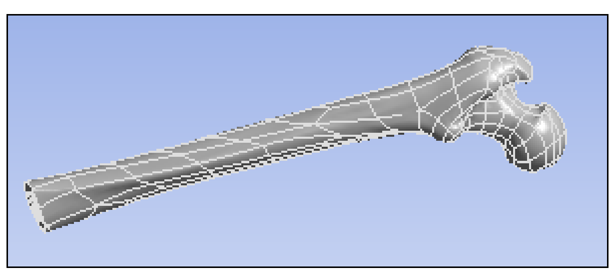

Fig 2: 3D model of Femur Bone

Modal Analysis

Modal analysis we need mechanical properties of femur bone i.e. overall dimensions, Young's Modulus, Poisson's ratio, and Density. Following tabulated mechanical properties are as below

Table 1: Age group and Density [4]

Age Group	Density
43-49	1223.5 kg/m^3
52-60	1162.4 kg/m^3
60-72	1107.5 kg/m^3

Table 2: Overall dimensions of femur bone [4]

Age	Average diameter	Length
45	0.02936 m	0.450 m
46	0.02850 m	0.460 m
47	0.02936 m	0.470 m

Table 3: Material Properties for modal analysis [2]

Material	Young's Modulus	Poisson's ratio	Density
Cortical bone	17 MPa	0.3	1500 kg/m^3

Finite element analysis is performed through Modal analysis by using Ansys software. First step is to import IGS file of femur bone 3D model into Geometry model. Then bring it into Simulation model for further analysis.

Meshing is done automatically by giving initial conditions to geometric model. After meshing, number of nodes are 20058 and number of elements are 10963.

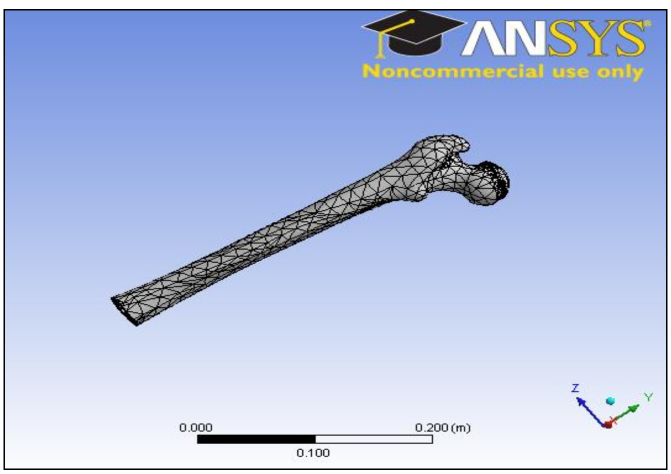

Fig 3: Meshing of femur bone

Femur bone material data used is density 1500 kg/m$^{3.}$ Young's Modulus 17 MPa, and Poisson's ratio 0.3 for evaluating natural frequency of femur bone. Unit system used is metric.Geometry bounding box is 0.049186 m in X length, 0.34999 m in Y length, and 0.1169 m in Z length.Properties of geometry after assigning material is volume 2.7914×10^{-4} m^3 and mass 0.41871 kg.

Initial conditions are applied to femur bone i.e. displacement at one end in X, Y, and Z are zero. Then solved for evaluating natural frequency of femur bone.

The following bar char and table indicates the Natural frequency at each calculated mode.

Table 4: Mode and Frequency after solution

Mode	Frequency Hz
1	2.4269
2	2.5021
3	15.794
4	19.755
5	23.137
6	48.679

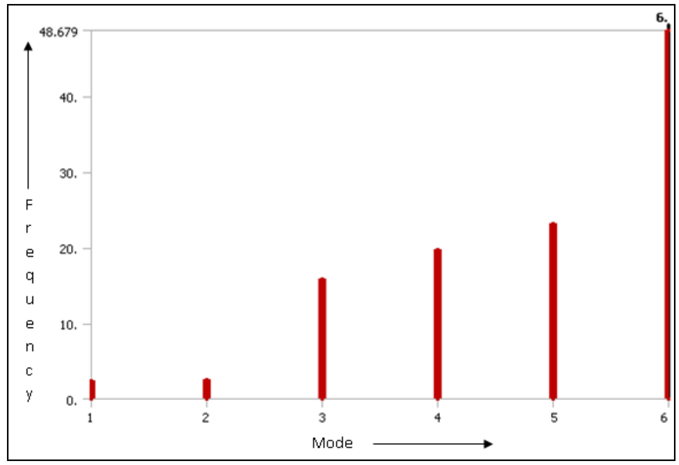

Fig 4: Graphical representation of mode and frequency

Total deformation of femur bone is 2.5411 m.

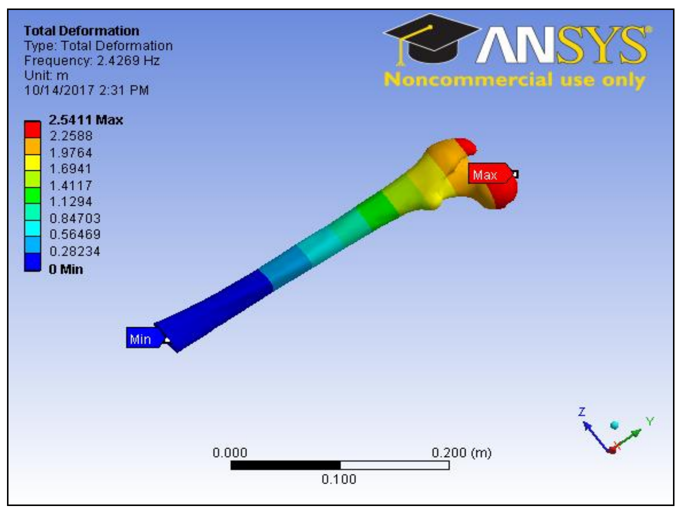

Fig 3: Snap of Total deformation for density 1500 kg/m^3

Results and Discussion

Similarly for different density i.e. 1200 kg/m$^{3.}$ 1000 kg/m^3, and 800 kg/m^3.Modal analysis are performed to evaluate Natural frequency of femur bone. Above values are taken randomly to see variation of natural and total deformation.

Table 5: Natural frequency for different density values

Density	1500 kg/m^3	1200 kg/m^3	1000 kg/m^3	800 kg/m^3
1 mode	2.4269	2.7134	2.9724	3.3232
2 mode	2.5021	2.7975	3.0645	3.4262
3 mode	15.794	17.658	19.344	21.627
4 mode	19.755	22.086	24.194	27.05
5 mode	23.137	25.868	28.337	31.682
6 mode	48.679	54.425	59.62	66.657

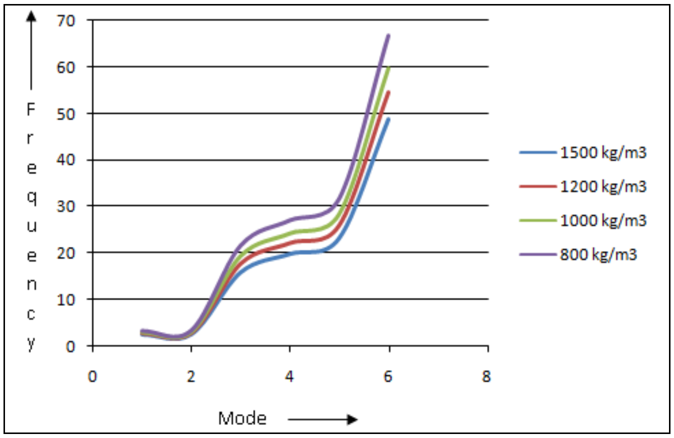

Fig 4: Variation of Frequency with different Density

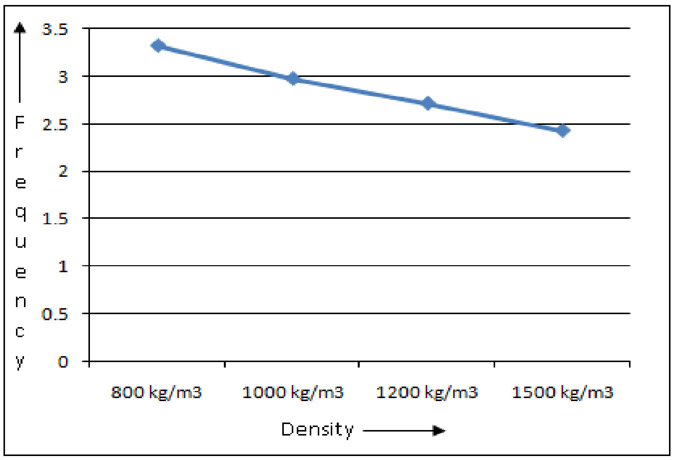

Fig 5: Frequency decrease with increase in density

Table 6: Density and total deformation for first mode

Density	1500 kg/m^3	1200 kg/m^3	1000 kg/m^3	800 kg/m^3
Minimum deformation	0 m	0 m	0 m	0 m
Maximum deformation	2.5411 m	2.841 m	3.1122 m	3.4795 m

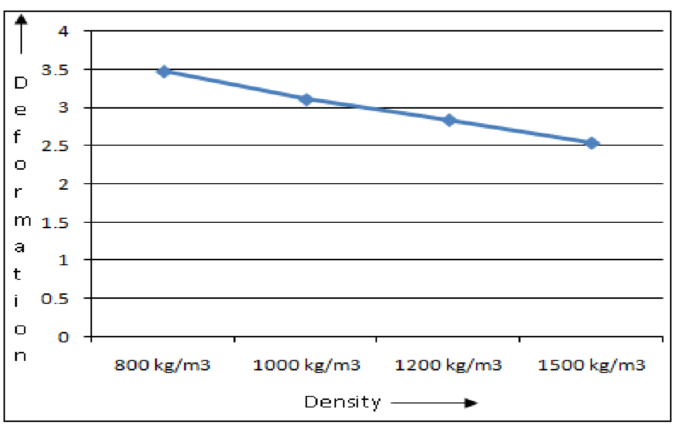

Fig 6: Total deformation decrease with increase in density

From above table 5 we observed that for different modes i.e. 1 to 6, the Natural frequency varies from 2.4269 Hz to 48.679 Hz for density 1500 kg/m^3.We observed that this variation is also seen for different density i.e. 1200 kg/m$^{3.}$ 1000 kg/m^3, and 800 kg/m^3.

We also observed that the Natural frequency for first mode is 2.4269 Hz, 2.7134 Hz, 2.9724 Hz, and 3.3232 Hz for 1500 kg/m^3, 1200 kg/m$^{3.}$ 1000 kg/m^3, and 800 kg/m^3 respectively.

From graph 3 we observed that frequency decreases with increase in density value.

Total deformation for different value of density i.e. 1500 kg/m^3, 1200 kg/m$^{3.}$ 1000 kg/m^3, and 800 kg/m^3 are 2.5411 m, 2.841 m,3.1122m,34795 m respectively. From graph 4 we observed that deformation decreases with increase in density value of femur bone.

4. Conclusion

- Model is created successfully using Solid Works
- Finite element analysis is performed for Modal analysis to evaluate Natural frequency of femur bone for different density values i.e. 1500 kg/m^3, 1200 kg/m$^{3.}$ 1000 kg/m^3, and 800 kg/m^3.
- Natural frequencies evaluated are having different values for different density value.
- Total deformations evaluated are having different values for different density value.

5. References

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