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Natural Vibration Analysis of Femur Bone Using Hyperworks

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Abstract:- The main objective of the femur bone analysis is to know the natural frequencies and identify the fracture location of the bone through simulation based on the HYPERWORKS. The femur bone analysis is subjected to free-free and fixed-fixed boundary conditions. The mode shape shows that the natural frequency of free-free boundary condition varies from 0 Hz to 57 Hz and for fixed-fixed boundary condition 11 Hz to 171 Hz. On the bases of these two boundary conditions mode shape is determined and fracture location can be easily notified.
Keywords:- Femur Bone; FEA; Vibration Mode; Natural Frequency; Fracture; Boundary Conditions.

I. INTRODUCTION

Human body subjected to any type of vibration is called Human vibration. The main reason of human vibration study is reduce the health risks and increase the level of comfort.

The human vibration can be divided into two types known as Hand-Arm vibration(HAV) and Whole body vibrations Hand-Arm vibrations are included via the hands and this is main cause of circulatory disorder, bone , joint or muscle diseases. Whole-Body vibrations are included via back and the feet of a person and it may cause harm to spinal column. The human body and each organ have its own natural frequencies that can resonate with vibration excitation received at their natural frequencies and this resonance may cause adverse health effects. The bone between the hip and the knee joint is called femur bone. It is the longest and strongest bone of the human body. The upper end of femur fits into a socket in the pelvis to form hip joint. The head is connected to the bone shaft through the neck of the femur and this neck of femur is structural weakness and fracture point. The lower end of the femur is hinges with the shinbone to form the knee joint. Our objective is femur bone vibration analysis. Human body vibration has studied for more than 50 years. Many researchers and authors have contributed a lot.

Researchers have been studying the vibration characteristic of femur bone from 1980 khalil et al. (1981) obtained natural frequencies and mode shapes of femur bone using experimental and analytical methods. The experimental measurements were based upon Fourier analysis of transfer function. The first 20 Experimental natural frequencies vary from 40 Hz to 1300 Hz. In actual condition femur bone is constrained between pelvis and tivia. So in this work we have considered two boundary condition for checking the result. The result for natural frequency of the free-free boundary condition is very low starting from 0 Hz. For fixed -fixed boundary condition the natural frequency varies from 11.349 Hz to 171.609 Hz.

II. THE CAD MODEL

The femur bone model was constructed from CT scan data and reconstructed using software CATIA V5. The shape of the femur is asymmetric and curved in all three planes. Hence, a three-dimensional model is required for a quantitative vibration analysis. The CAD software CATIA V5 is selected to prepare the solid model of the femur bone. The CAD model is shown as figure 1. After the completion of the model the *.IGES file is imported to HYPERWORKS V12.0 software for the analysis. The main step of the FEA based analysis is to divide the bone in small pieces called elements and these elements are connected at nodes. The meshed model of femur bone is shown in figure 2. HYPERWORKS V12.0 is a research version, it provide high quality meshing facility. The meshed model consists of 8741 nodes and 37129 elements. Linear tetrahedral elements are used for meshing.

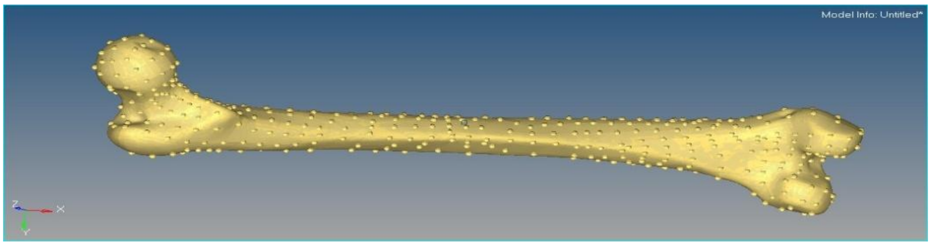


Fig. 1. Cad Solid model of Femur bone

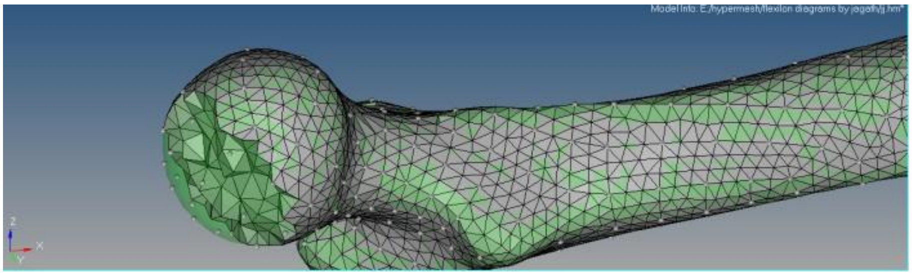


Fig.2. Meshed Model of Femur bone in HYPERMESH V12.0

III. BOUNDARY CONDITIONS AND MATERIAL PROPERTIES

During the analysis geometrical model is subjected to two different boundary conditions. The first boundary condition applied on the femur bone is free-free boundary conditions and the various results have been taken. For free-free condition the femur neck is free. The second boundary condition is fixed-fixed condition.

The complex geometry of Human body is not easily described in terms of simple geometrical shapes. Biomaterials selected for study shows non-linear viscoelastic behaviour so that’s why linear vibration theory fails to succeed in the description of such a complex behaviour. Therefore and as a first step, this study will be limited to a single isolated element, i.e. the femur bone. Mechanical properties (Young’s modulus, Poisson ratio and bone mass density) are required to analyse the femur bone. These are very important parameters for the vibration analysis of the femur bone. The material properties selected for the study of the femur bone are Young’s modulus – 7.400 GPa, Poisson ratio- 0.35, Bone density- 2000 kg/m3. HYPERWORKS V12.0 workbench is selected for modal analysis and the load is selected by program automatically.

To determine the modal response, modal analysis using FE is performed using implicit FE code- HYPERWORKS V12.0. The governing dynamic response equation is given by:

$$[M]\{\ddot{x}(t)\} + [C]\{\dot{x}(t)\}+[K]\{x(t)\}= \{F(t)\} \qquad (1)$$

Where-[M], [C], [K] are the global mass, Damping and Stiffness Matrix of the model; $\{\ddot{x}(t)\}$- Acceleration Vector, $\{\dot{x}(t)\}$-Velocity Vector, {x (t)}-Displacement vector.

For undamped free vibration analysis the damping and external excitation force is zero ([c]=0, [F]=0). So the equation (2) can be represented as undamped free vibration

$$[M]\{\ddot{x}(t)\} +[K]\{x(t)\}= 0 \qquad (2)$$

the solution of the above equation can be written as

$$\{x\}=\{X\}\ e^{i\omega t} \qquad (3)$$

where {X} represents the amplitudes of vibration of all the masses (mode shape or eigenvector's), ω eigen frequency ($rads^{-1}$), so the equation (2) reduces in-

$$([K]- \omega^2[M])\{X\}= 0 \qquad (4)$$

If we replace ω^2 by λ the equation (4) become a linear problem in matrix algebra. $\{X^i\}$ has nonzero solution, then coefficient matrix must be equal zero. Each eigenvector{X} and corresponding eigenvalues $\{\omega_i^2\}$ is solved using HYPERWORKS V12.0.

IV. RESULTS AND DISCUSSION

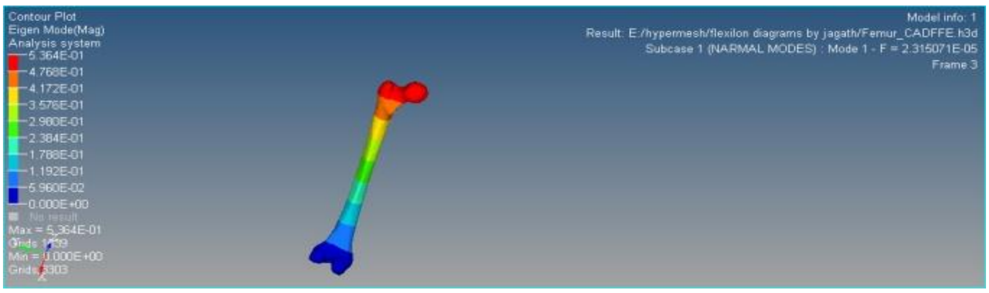
There are two motion supported boundary conditions for which simulations are performed. In free-free boundary conditions all DOF of boundaries are subjected to variations. In the displacements of boundaries are set to automatic under the materials conditions fixed-fixed boundary conditions guarantee that all degrees of freedom are constrained in boundaries. The FEM based software HYPERWORKS V12.0 version solved the hip bone modal analysis and we find the natural frequency and mode shape. In orthopedic problems modeling of boundary conditions and joints are very challenging problems and they might have no unique results.

Table. 1 Mode number and corresponding natural frequency (Free-Free Boundary Condition)

Mode Number	**Natural Frequency(Hz)**
1	2.32E-05
2	4.36E-01
3	1.65E+00
4	2.78E+00
5	3.49E+00
6	5.59E+00
7	7.336
8	9.649
9	1.16E+01
10	1.33E+01

Table. 2 Mode number and corresponding natural frequency (Fixed-Fixed Boundary Condition).

Mode Number	**Natural Frequency(Hz)**
1	11.349
2	24.822
3	38.477
4	64.611
5	72.377
6	102.187
7	116.759
8	147.961
9	159.981
10	171.694



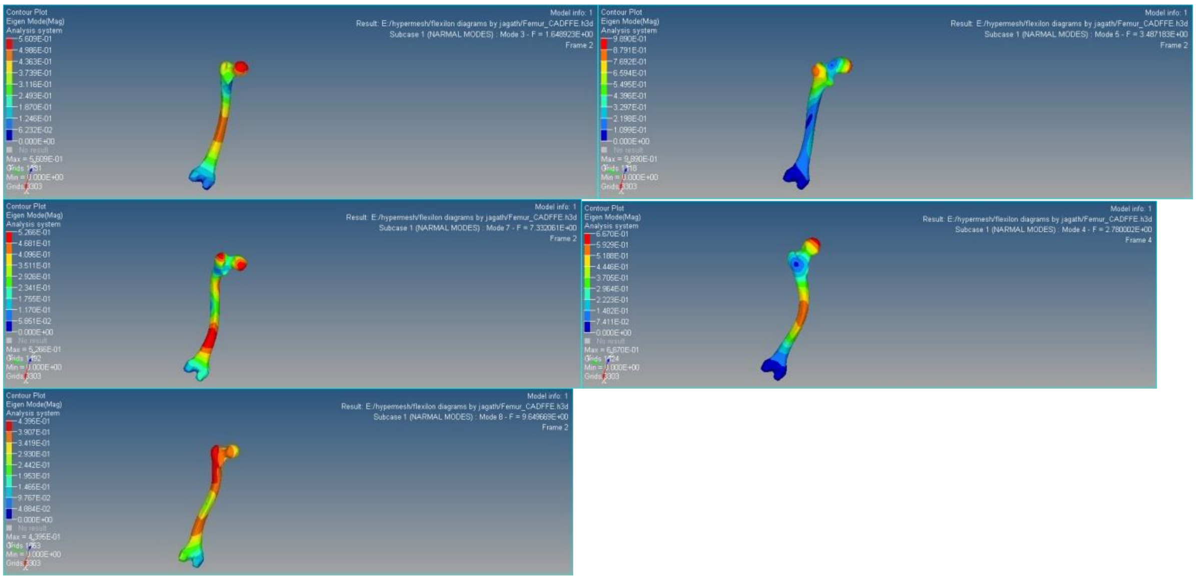


Figure 3. Different mode (1,3,5,7,4&8) shapes of the femur bone Model (Fixed-Free boundary condition).

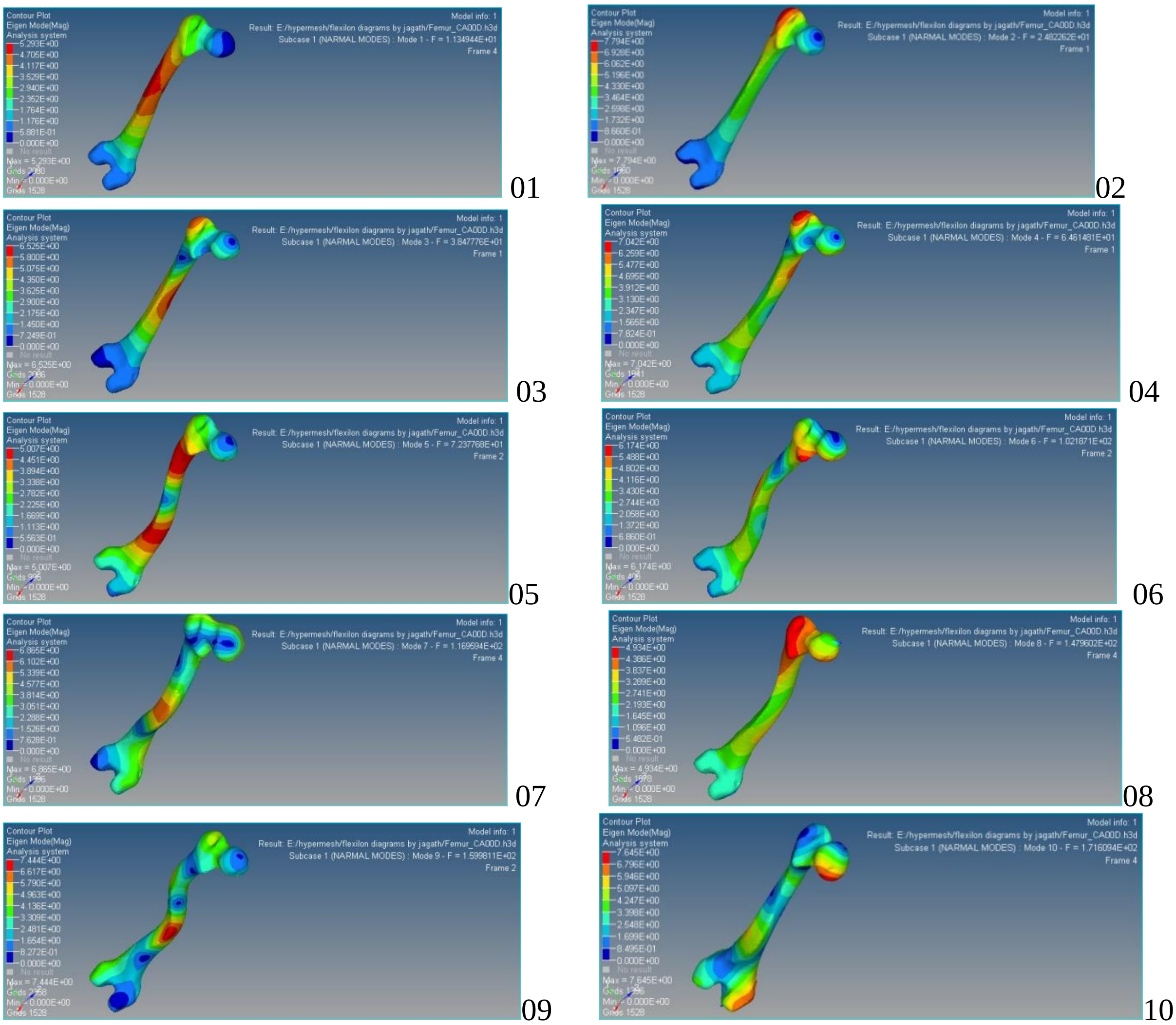


Fig. 4. Ten different mode shapes of the femur bone Model (Fixed-fixed boundary condition

V. CONCLUSION

It is observed that sudden accident and continuous vibration excitation is the main reason for femur bone failure. The results of this study show that the maximum chance of bone cracking is through bone shaft and neck region. The natural frequency and first ten mode shape of femur bone was determined using fixed-fixed boundary condition. The results of this study are verified by the experimental results available in literature. HYPERWORKS V12.0 software has powerful analysis capabilities and CATIA V5 software has a powerful function of solid modeling. They are suited for Finite Element Analysis of complex shapes. The3D solid model is prepared by applying SOLIDEDGE software and is transferred to HYPERWORKS V12.0. In this work we have considered the vibration problem of the femur bone using FEA method. Finite Element Analysis offers satisfactory results with additional ability to calculate regional mode and natural frequency with fracture locations during external loading condition.

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