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Finite Element Analysis of Tibia Bone

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Abstract:
The present research in the field of automotive industry incorporates the analysis of lower region of the human body in order to bring more accidental safety to human life.The lower skeleton is composed of thigh, knee, lower limb and foot. The lower limb bone in medical term coined as Tibia bone. The Tibia bone is more prone to damage during accidents; it is the second strongest bone to take major body weight. The bone has the ability to withstand large loads without fracture, but the bone fails during impact loads.Present work considers the analysis of the Tibia bone for impact loads.3D model was generated using Catia software after taking CT scan of a typical Tibia bone. Finite Element Model (FEM) was developed using Hypermesh software. Finite Element Analysis (FEA) was carried out by using Nastran software.

Keywords: CT scan , FEM, Hypermesh, Nastran

I. INTRODUCTION:

There has been lots of research regarding safety of human life in the field of automotive industry. Most of the cases, the research has been done on the upper part of the body and injury has been eliminated to an enormous extent, like by incorporating air bags and strengthening the vehicle body. But the lower part of the body is not considered until now, which is also a major part of the body. The recent Automotive Crash Analysis research has been found that, the driver's tendency is to depress the brake pedal just before the impact and crash. This action deserves the greatest impact in the lower leg. This led to lower leg research, study on composition of human bone, knowing its strength to withstand injury and rethink in the design of cars so as to reduce the impact force on lower bone. Tibia is the second largest and strongest bone in the human body. The Tibia bone is also known as shine bone. The lower leg consists of two types of bone, which in biologic term called as Tibia and fibula. Tibia is classified as a long bone and consists of two epiphyses and a diaphysis. The diaphysis is the middle section of the Tibia, also called the body or shaft. While the epiphysis is the two bone limbs, the upper (also known as superior or proximal) closest to the thigh and the lower (also known as distal or inferior) closest to the foot. In the lower third, the Tibia is most contracted and the distal end is smaller than the proxima. The Tibia bone is a composite material made up of hard and soft, spongy material Called Cortical bone and Cancellousbone or trabecular bone respectively. Bone Cancellous is one of type of human tissue found in the body. Cancellous bone occurs at the extreme ends of large bones and also in columns of pelvic bones.

II. LITERATURE REVIEW:

M. TothTascau et al [1] made an experimental study to evaluate the adult canine bone mechanical properties (Tibia), using mechanical bending test and numerical analysis.The results are correlated using finite element analysis. The geometry of Tibia bone is obtained from Computed tomography (CT) and numerical analysis was performed using ANSYS.The test concludes that, deficiency induced in Tibia proximal area bone doesn't have any significant influence on the mechanical behaviour of Tibia bone considering bending test. The fracture lines tend slightly to defect zone. BAO Chun-yu and MENG Qing-hua [2] made an analysis study on Tibial stress during jumping moment using finite element analysis.The geometry of the bone is obtained from CT. Stress and displacement was simulated using finite element software. The results are used as theoretical basis for sports training, sports injury and treatment.The study concludes that, the stress is concentrated on the mid location of Tibia bone. The stress located on the foreside of Tibia is higher than rear. SaileshRajani and Bhavin V Mehata [4] focused on studying the development of stress on Tibia bone under static loads and studying the effects of different material properties on stresses, used Magnetic Resonance Imaging and solid modelling software to build a 3D model.The behaviour and stress pattern concludes that Cancellous bone act as a damper and distribute maximum stress to compact bone.

III. OBJECTIVES:

1) To find out stress, strain of Tibia bone subjected to static loading using Nastran for loads of 5KN and 10KN to understand impact load.
2) To calculate impact strength and check with Yield strength of bone material.
3) To find out deformation of Tibia bone to understand the type of fracture and displacement of bone.

IV. METHODOLOGY:

The following are the steps followed for analysis of Tibia bone.

- CT Scan
- 3D Slicer
- Catia

- Hypermesh
- Nastran

CT Scan:

Computed Tomography is an imaging technique, used to scan the human body. Special x-ray equipment is used in scanning the body.

3D Slicer:

3D slicer is an open source medical imaging software platform. It is used for image processing and three-dimensional visualization. Using this software, a three- dimensional view of Tibia bone is created using CT data as input.

Catia:

Computer Aided Three- dimensional Interactive Application is abbreviated as CATIA. It is well-known multi-platform modelling software, used to create 2D, 3D geometry.The CAD model is created using the geometry of scanned 3D model.

Hypermesh:

Hypermesh is an multi-disciplinary finite element pre-processor and post- processor software. It is one of the most effective tool for meshing largest and most complex models. The Tibia bone mode is imported from Catia for mesh generation.Tetrahedral elements are used for mesh generation of 3D models.

Nastran:

Nastran is finite element analysis software, used for analysing the given data. Nastran is one of the most used software in field of aerospace and other field.

Material Properties of Tibia Bone:

For the stress and displacement analysis, the bone is assumed to be isotropic material. The properties of the bone are shown in Table I.

Table.1. Material properties of Tibia bone

SI. no	Materia l	E in GPA	δ in g/cm3	μ	σy in MPa
1	Tibia bone	14	2	0. 3	177

Analysis of Tibia bone:

The bone is created and meshed using tetrahedral mesh elements. The boundary conditions are fixed –free. A compressive load of 5KN and 10KN are applied at the proximal end of Tibia bone individually. The Tibia bone with mesh and constraints are shown in fig I.

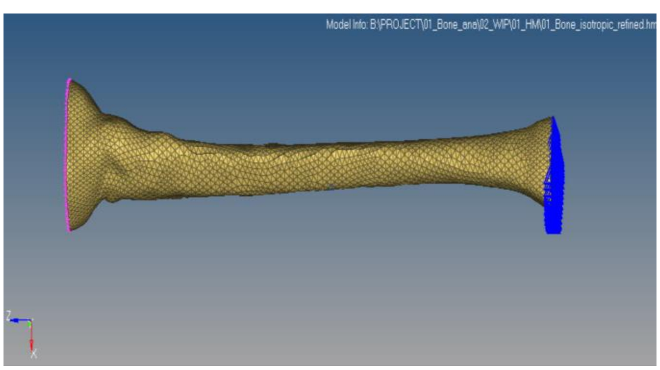

Figure.I. The loading and boundary condition

Constraints:

The Tibia bone is considered as single bone without considering the joints at distal and proximal end; hence the distal end is completely fixed.

The stresses and deformation for 5KN and 10KN are shown in Fig II to V.

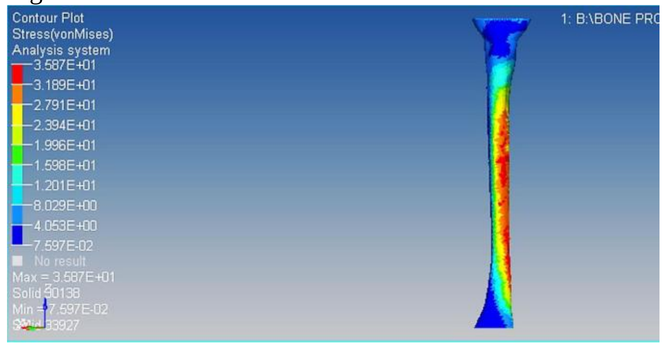

Figure.II. Stress for 5KN

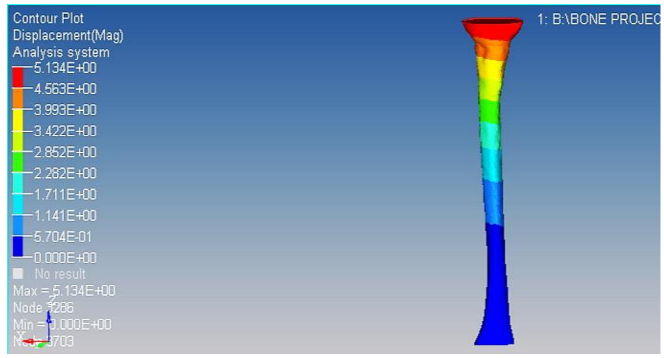

Figure.III. Displacement for 5KN

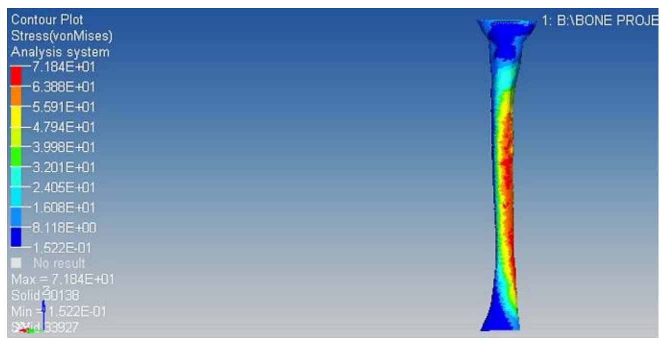

Figure.IV. Stress for 10KN

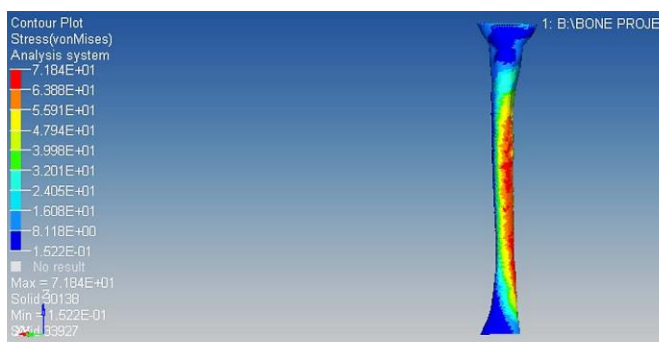

Figure.V. Displacement for 10 KN

The impact stress for the given loads, is determined from the formula.

$\sigma i = \sigma[1+[\sqrt{1+2h\ \delta}]]$

Where σi = impact stress; h= height; δ = static deflection;

σ = static stress.

1) **σi for 5KN**

δ = 2.4 mm; h = 100mm; σ = 35.8 MPa

σi = 363.4 MPa

2) **σi for 10KN**

δ = 4.8 mm; h = 100mm; σ = 71.8 MPa

σi = 536 MPa

The moment of inertia of the bone is determined from the formula.

$\delta = wl348EI$

Where δ = static deflection; l = length of the bone; w = weight on the bone; E = young's modulus; I = moment of inertia.

for δ = 4.8 mm; l = 360mm;

I = $1.44*10^5$ mm^4

A graph of Tibia bone on variation of polar moment of inertia with the area is shown in Fig VI.

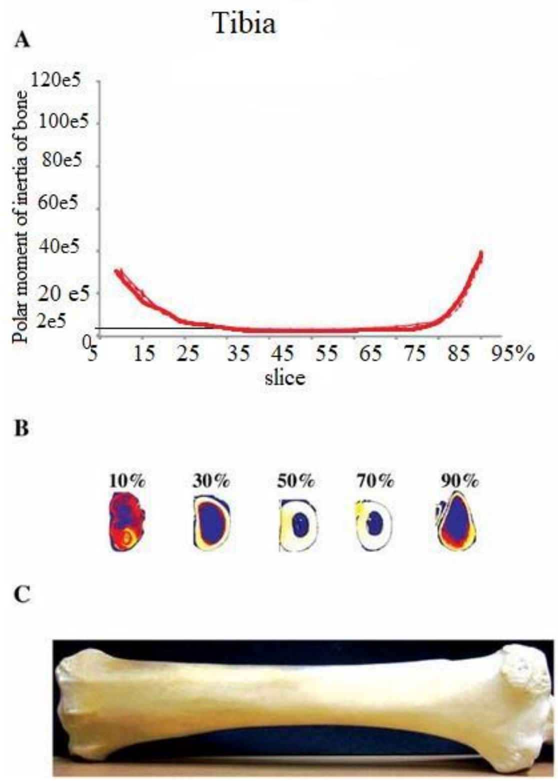

Figure.VI. variation of polar moment of inertia with area of the bone.

Results of Tibia bone subjected to static and impact load

Stress and displacement results are shown in Table II.

Table.II. Displacement and stresses in Tibia bone

SI. no	Load in N	Displacement in mm	Stress in MPa
1	5000	5.3	35.8
2	10000	10.2	71.8
3	5000 (impact)	-	363.4
4	10000(impact)	-	536

From the results of the analysis it is found that, the bone can withstand static load and stress induced is well within the Yield point, but the bone fractured at impact loads, because of high stresses which are higher than the Yield strength of the bone. Hence fracture of the bone takes place.

V. CONCLUSIONS:

The analysis was carried out to study the behaviour of Tibia bone during static loading and during impact loading. The loads (5KN and 10 KN) were applied on the Tibia bone in static condition. The Yield strength of Tibia bone is 177 MPa. The analysis results showed that, the maximum stress induced in Tibia bone was 35.8 MPa and 71.8 MPa respectively at above said loads. The bone fractures during impact loading condition. This is due to high value of induced impact stresses. The impact stresses were calculated analytically and are found to be 363 MPa and 536 MPa respectively at aforesaid loads. Since, impact stresses were more than Yield strength of the bone, the bone would fracture under impact loading during crash.

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