# A Numerical Study on the Injury Risk of Human Arm in Focal Low-Speed Loading

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# A Numerical Study on the Injury Risk of Human Arm in Focal Low-Speed Loading

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## Background....

- A possible basis for injury assessment of human forearm exposure to dynamic low-speed loading determines the tolerance level of the forearm during impact.
- The injury mechanism in the lower arm
- Finite Element modeling offers a viable approach in predicting the injury to the arm due to impact loading
- THUMS (Total Human body Model for Safety) (AM 50, height 175cm, weight 77kg) used in this study has been developed by the Toyota Central Research and Development Lab [Ref 1,2].
- The forearm of THUMS has been used in this study for deriving the injury criteria during free impact
- Material Modeling, Validation, Comparison of Results with Experimental Data

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## THUMS....

- **THUMS is a computational model to simulate**
  - Gross motions
  - Human body response in impacts
  - Reproduces anatomical geometry data & biomechanical properties
- **Features of THUMS**
  - Modeling of each joint anatomically with the major ligaments and tendons
  - Biofidelity on the human geometry and mechanical properties
  - Reasonable computational time
  - Possibility of detailed investigation on the bones and the joints for impacts
  - Possibility of applications for automotive crash, ergonomics, sport engineering

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## THUMS....

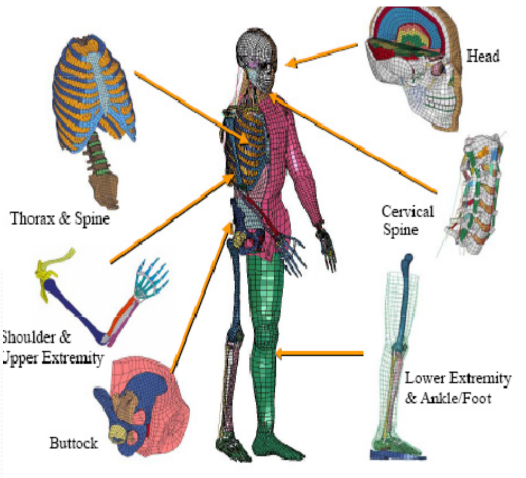


Figure 1. THUMS- Whole Body FE Model, Ref [3]

**Profile of the THUMS**

- **Human: Male**
- **Height: 175 cm**
- **Weight: 77 kg**
- **Age: 30 – 40 yrs**

**Outline of the FE Model**

| | |
|---|---|
| T.N Nodes | 108,000 |
| T.N Materials | 1,550 |
| T.N Elements | 145,000 |
| Solid | 67,800 |
| Shell | 74,000 |
| Beam | 3,200 |

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## Injury Mechanism....

- The increased risk of lower-arm injuries in forensic applications include impacts to the (Ulna, Radius).
- The goal of this study is to determine the risk of lower-arm injury caused by impacts and to elucidate the injury mechanism.

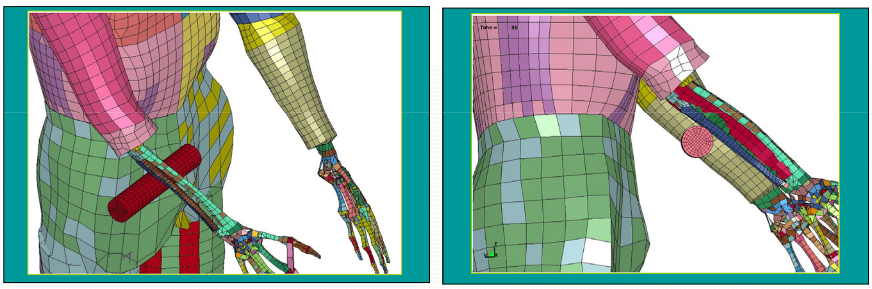

Figure 2. Side View of the Lower Arm- THUMS with Removed Soft Tissue to Expose Ulna-Radius

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## Lower Arm....

- Lower Arm in THUMS consists of

- Ulna
- Radius
- Hand Bone
- Ligaments
- Muscles, Tendons
- Skin, Soft Tissues

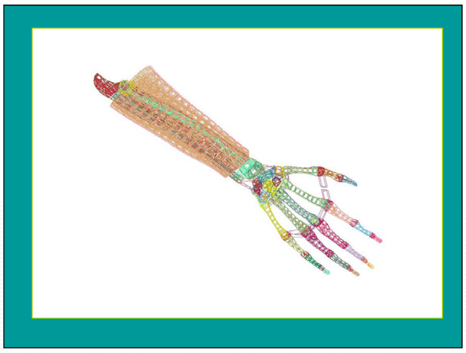

Figure 3. Lower Arm in THUMS

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## Material Modeling Ulna ....

- The material properties chosen for the Ulna model stem from an extensive literature study.
- Approach previously proven on tibia impacts (Asgharpour et al., ESB 2010)
- An isotropic elastic-plastic material where unique yield stress versus plastic strain curve can be defined for compression and tension is considered for cortical bone of diaphysis of ulna.

Table 1. Material Properties of FE Model of Ulna [Ref 4]

| Bone | Tension | | | Compression | | |
|---|---|---|---|---|---|---|
| | Yield Stress | UTS | E | Yield Stress | UCS | E |
| Ulna (Cortical) | 50 MPa | 60 MPa | 15 GPa | 60 MPa | 180 MPa | 15 GPa |

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## Validation- the First Step ....

- Validation ensures that the model meets its intended requirements in terms of the methods applied and the results obtained.
- In this contest, validation is performed using the experimental data from Quasi-Static three point bending tests of (ulna).

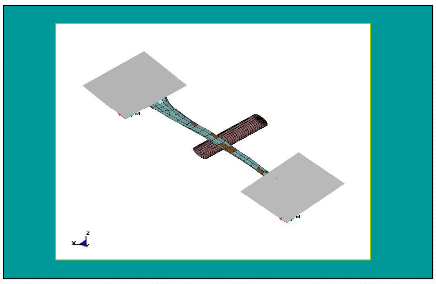

Figure 4. Test Setup for 3-Point Bending of Ulna

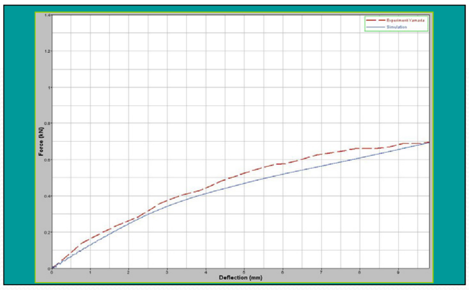

Figure 5. Load-Deflection Curve for Simulation and Experiment [Ref 5]

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## Free Impacts to the Lower Arm ....

- Free Impact to the Ulna at Various Impact Velocities (1,1.5,2 m/s)
- Employment a Validated Skin Model According to the Experimental Data
- Injury Criteria- Worst Case Scenario

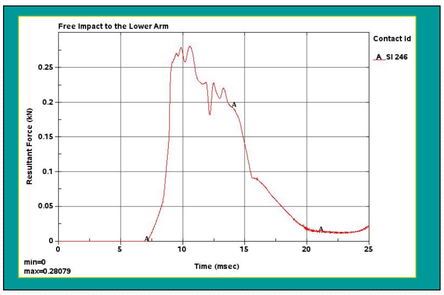


Figure 6. Impact Force Response of Model at Impact Velocity 1 m/s

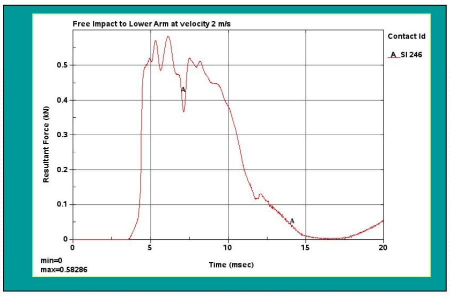


Figure 7. Impact Force Response of Model at Impact Velocity 2 m/s

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## Injury Risk Analysis- A Comparison to the Experimental Results....

Table 2. Resulrs of Dynamic Impact Simulation and Comparison to the Corresponding Critical Values derived from Experiments [Ref 4]

| Impact Velocity | Max- Principal Stress (MPa) | Critical Stress (MPa) (literature) | Max-Principal Strain | Critical Strain (literature) | Max- Force (kN) | Breaking Load from Literature (3p-bending) |
|---|---|---|---|---|---|---|
| 1 m/s | 25.864 | 60 | 0.00304 | 0.01 | 0.28079 | 0.62784 |
| 2 m/s | 60 | 60 | 0.00597 | 0.01 | 0.58286 | 0.62784 |

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## Conclusion / Discussion ....

- This study investigated injury mechanism to the lower arm during impact at various velocities
- A material model for ulna is defined and applied based on extensive literature study
- The validation test has been performed. The bone parameters were in good agreement with the experimental results of the three point bending test.
- The comparison between the peak load during simulation and breaking load of ulna from experiments gives an insight about possible injury risk due to the impact.

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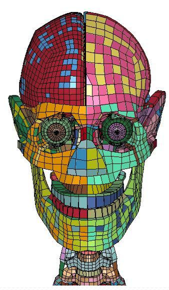
*Thank you For Your Attention !*



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