CHARACTERIZATION OF LONG BONES BENDING UNDER IMPACT

By

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To my wife ***Priscilla***

for her unconditional love, compassion and sacrifice.

CERTIFICATE

This is to certify that the thesis entitled **Characterization of Long Bones Bending Under Impact** being submitted by Mr. Mike Winifred Jimbry Arun to the Indian Institute of Technology Delhi for the award of Doctor of Philosophy in Department of Mechanical Engineering is a record of bona fide research work carried out by him. He has worked under my guidance and has fulfilled the requirements for the submission of thesis, which, in my opinion, has reached the requisite standard.

The results contained in this thesis have not been submitted in part or full, to any University or Institute for the award of degree or diploma.

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ABSTRACT

Human body kinematics is influenced by long bones during impact. The objective of this thesis is to derive a single finite element material model for long bones, which can predict both mechanical response as well as the different fracture types over a wide range of loading conditions.

On reviewing the literature, the unavailability of a single material property that can capture both structural and failure characteristics for a wide range of strain rates was identified. Cadaveric human humerus (right and left) from people in the age group of 40 - 60 years have been tested in three-point bending with impact speeds up to 20 kmph. Long bones are seen to exhibit strain rate dependency in stiffness as well as in failure. Oblique fractures were observed in all experiments. Therefore it was concluded that the rate-dependency effect has to be included for an accurate structural and failure characterization.

Subject specific finite element model of human humerus was developed. An inverse FE characterization method to identify the bone dynamic material parameters was developed. Genetic algorithm (GA) was used as an optimization tool during this characterization process. A user subroutine (VUSDFLD) was developed to model the rate dependency of elastic modulus, yielding and failure. A Drucker-Prager (D-P) model was used to capture yielding and a damage model was used employed to capture failure.

By using the proposed method, fracture types observed in the field were reproduced in most of the cases, including those, which were not predicted by earlier models.

In addition to the fracture types, the mechanical responses were also predicted with a correlation greater than 0.8.

The outcome of this work would contribute significantly in evolving biofidelic FE human models, to protect both occupants and vulnerable road users (VRU).

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