Numerical Evaluation of Lower Extremity Injury with Variation in the Angle of Impact

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I. INTRODUCTION

Crash analysis has been one of the most challenging areas of research. Crashworthiness assessment is dependent on the injury risks of the occupants and pedestrians, which in turn, is dependent on the deceleration tolerance limits of the human body. Pedestrians belong to one of the most vulnerable group of people during a crash. During a car pedestrian impact, injuries may happen to the head, which may be serious enough to cause death or injuries to the lower extremity which is non-fatal in nature. The region including the lower extremities is the first region in the human body to come in contact with the vehicle. The bumper is the component which results in lower extremity injury during a car pedestrian impact. Injury to the lower extremities can either be a bone fracture or knee ligament injury. The injury possibility varies with the type of impact. Pedestrian Crash Data Study (PCDS) [1] reports reveals the fact that the impact orientation to the pedestrians mostly occurred in the lateral direction (68%), 17% of the impacts occurred from the front and 10% of impacts occurred from the rear indicating that the pedestrians were facing away from the vehicle. The present study is intended to investigate the variation in injury possibilities of the lower extremities with the variation in impact orientation.

II. METHODS

Computational Modelling

The Total Human Model for Safety (THUMS) representing an average size adult male (AM-50%ile) in a standing posture has been used for the investigation of injuries to the lower extremities. The lower extremities of the human model selected for the study has been validated to the experimental study conducted by [2].

The knee ligaments and bone in the lower extremities were modified with failure criteria and were incorporated as ultimate strain values for knee ligaments and ultimate stress values for bones. Failure strain of the knee ligaments have been assumed as 28% for collateral ligaments and 22% for cruciate ligaments [3]. Failure was incorporated as ultimate stress values of 130MPa for cortical bones and 50MPa for cancellous bones [4]. The orientation has been varied from frontal, lateral and rear and also oblique impact, 30deg and 60deg towards the front and rear direction of the lower extremities. Three different impact positions of the impactor have been considered to study the influence of impactor position along with the orientation in injury occurrence in the lower extremity.

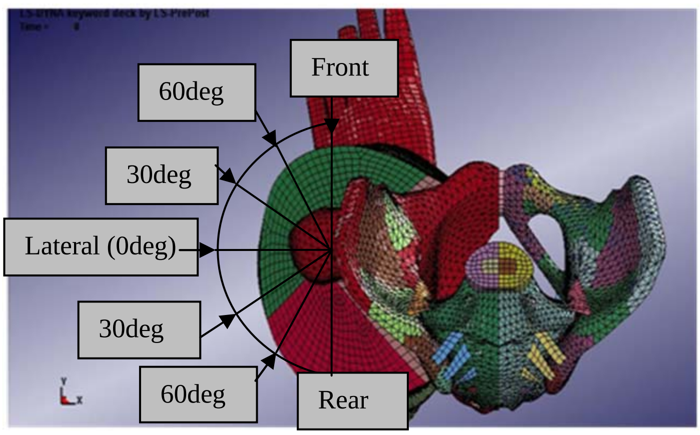

Fig. 1. Orientation of impact

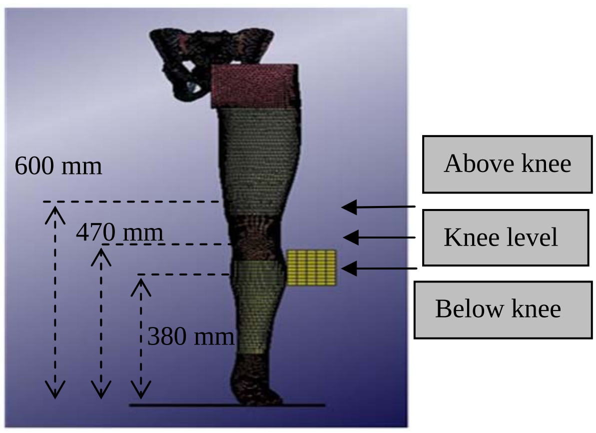

Fig. 2. Position of impact

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III. INITIAL FINDINGS

The lower extremity model has been validated with the experimental study by [2, 3] for the displacement of the specific target points chosen according to the experiments.

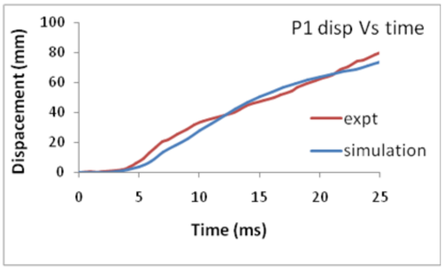

Fig. 3. P1 displacement vs time in shearing loading

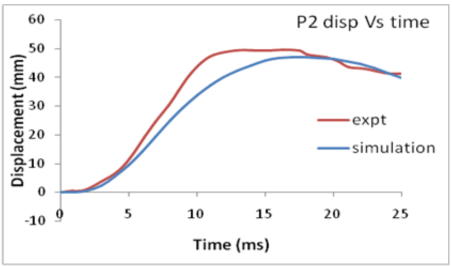

Fig. 4. P2 displacement vs time in shearing loading

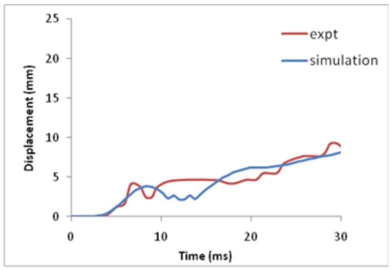

Fig. 5. Upper tibia displacement vs time in bending loading

The variation in the impact orientations resulted in variation in the lower extremity injuries. During lateral below-knee impact relative shearing between the femur and tibia resulted in rupture of the Anterior Cruciate Ligament (ACL). Direct impact on the fibula resulted in fibula fracture. During frontal below-knee impact, anterior rotation of the femur resulted in rupture of the Posterior Cruciate Ligament (PCL) followed by the rupture of the ACL. Rupture of the ACL occurred in the rear below-knee impact during the initial shearing phase.

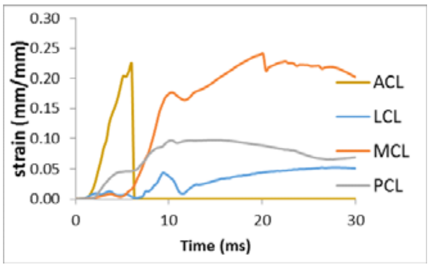

Fig. 6. Strain vs time of lateral below-knee impact

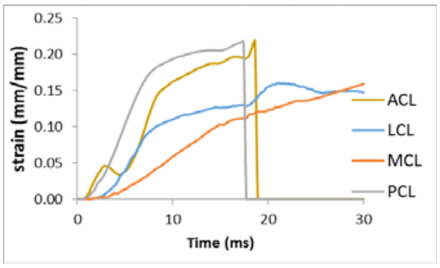

Fig. 7. Strain vs time of frontal below-knee impact

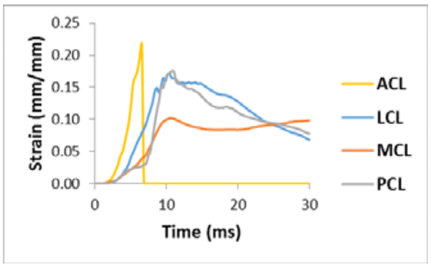

Fig. 8. Strain vs time of rear below-knee impact

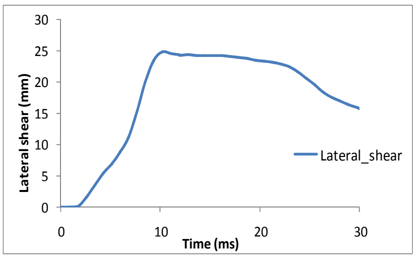

Fig. 9. Lateral shear vs time of lateral below-knee impact

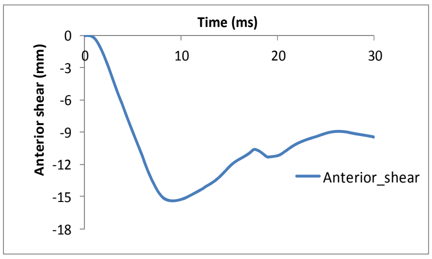

Fig.10. Anterior shear vs time of frontal below-knee impact

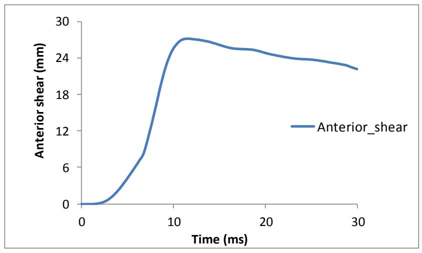

Fig.11. Anterior shear vs time of rear below-knee impact

IV. DISCUSSION

The failure of the ligaments are related to the relative shearing phase between the femur and tibia and also the bending angle at the knee joint. Shearing displacement and bending angle has been observed to assess the failure ligaments obtained in the study.

V. REFERENCES

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[5] Arnoux P J, et al., Int J Crash, 2008.
[6] Schreiber P, et al., Int J Crash, 1998.
[7] Chawla A, et al., IRCOBI, 2004.