A Computational Model for Prediction of Lower-Limb Injury in Under-Vehicle Explosions

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I. INTRODUCTION

The single most prevalent threat to Coalition Troops in recent conflicts has been the improvised explosive device (IED) [1]. The IED is capable of causing multiple casualties in a single incident. The occupant's lower extremities have been shown to be particularly susceptible to injury [2], and therefore a number of mitigation systems have been developed in attempts to reduce the severity of these injuries. Experimentally, these systems have been shown to reduce the force transmitted to the lower extremity [3], but experimental analysis is often expensive and time-consuming. The MIL-Lx anthropometric test device was developed in 2009 to mimic, to some extent, the behaviour of the human leg during an under-vehicle explosion and it presents the most biofidelic surrogate for under-vehicle explosion research to date [4]. The aim of this study is to develop a validated finite element (FE) model of the MIL-Lx fitted with a combat boot, which can be used as a tool to assess and develop new mitigation systems quickly and inexpensively.

II. METHODS

Axisymmetric, finite element models of the MIL-Lx and combat boot (Meindl Desert Fox Combat Boot) were developed using MSC Marc (MSC Software, USA) and validated separately against experimental data obtained from two different traumatic injury simulators.

Combat boot geometry was obtained through analysis of the dimensions of the individual layers, as captured on microscopic computed tomography (micro-CT) scans (HMX ST 225, Nikon Metrology Ltd, Tring, UK); the MIL-Lx geometry was reverse engineered. The properties of the materials of both combat boot and MIL-Lx were obtained experimentally by harvesting material samples, which were then tested in compression both quasi-statically and dynamically.

III. INITIAL FINDINGS

The model of the combat boot was validated against drop-tower tests [5] and then combined with the MIL-Lx model, which was then compared with traces of upper tibia axial force and compliant element compression obtained through experiments conducted on AnUBIS (a traumatic injury simulator housed at Imperial College London) at a range of severities [6] (Fig. 1).

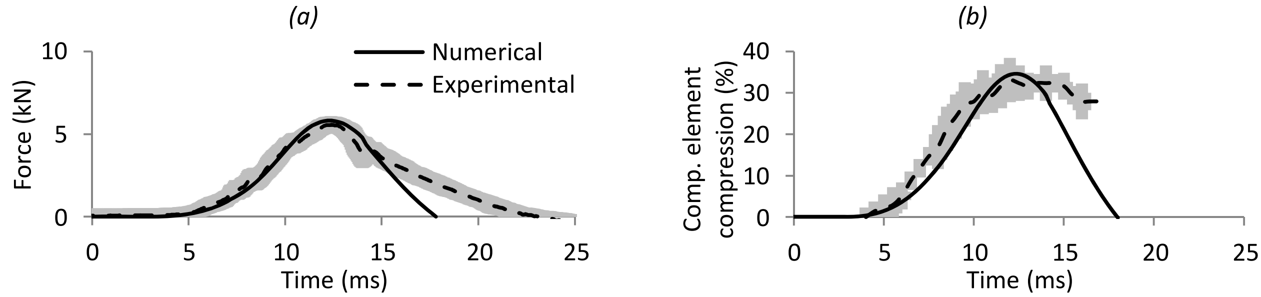

Fig. 1. A comparison of (a) the force-time traces and (b) the compliant element compression traces obtained numerically and experimentally at the upper tibia load cell during a simulated under-vehicle explosion using a traumatic injury simulator (Imperial College London's AnUBIS rig). The grey shading represents ±1 S.D. for the experimental results. Further details of the experimental set-up can be found in Newell et al. [6].

To gain further confidence in the numerical model, five MIL-Lx experiments, conducted independently on University of Virginia's ODYSSEY rig [7], were simulated. The difference in peak axial force in lower and upper tibia load cells of the MIL-Lx were 9% (range 1–17%) and 13% (range 9–19%), respectively (Fig. 2).

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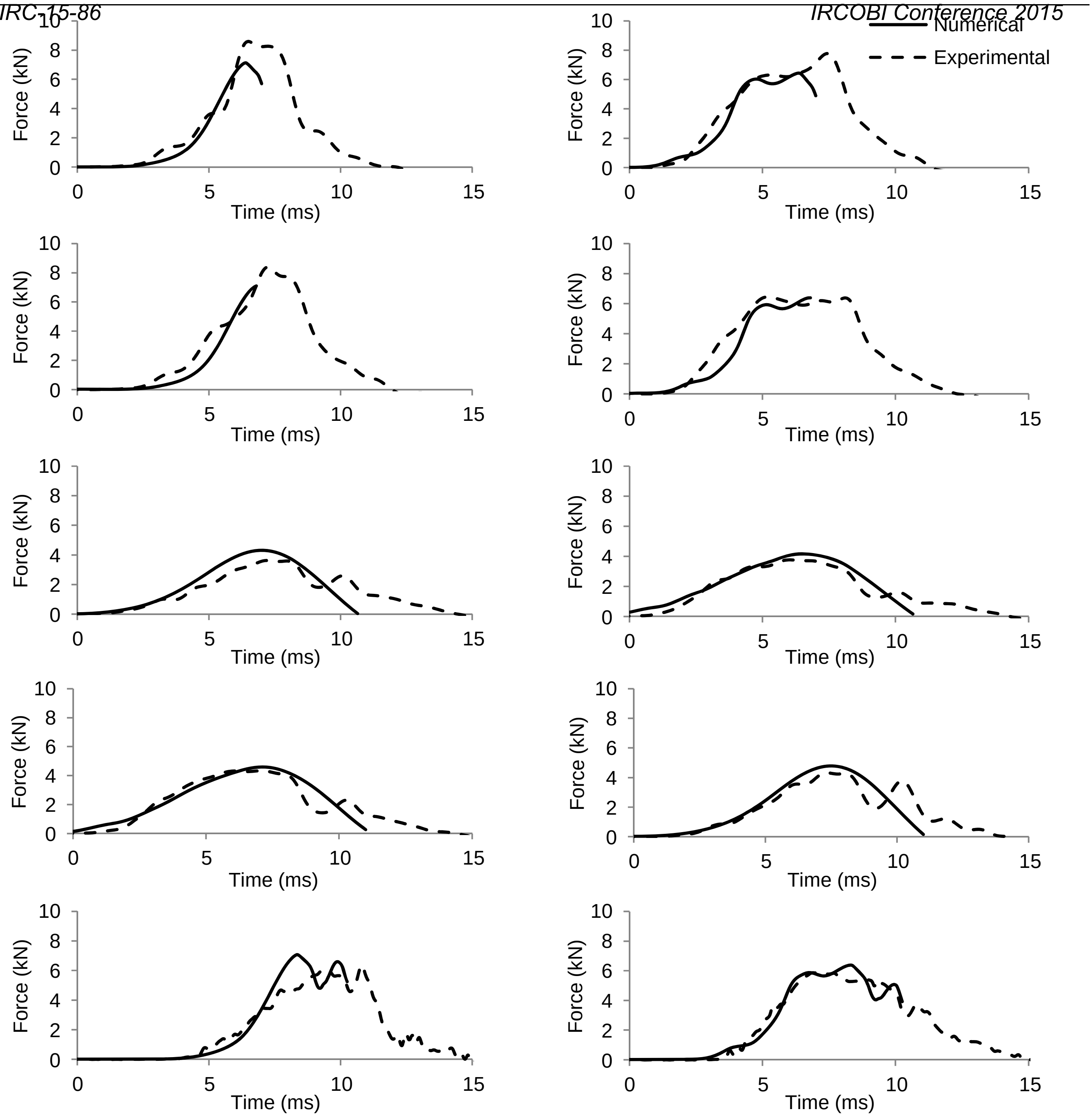

Fig. 2. A comparison of the force-time traces obtained numerically and experimentally at the upper (*left column*) and lower (*right column*) tibia load cell using the University of Virginia's ODYSSEY rig. Each row represents tests labelled 2.1–2.5 in Bailey et al. [7].

IV. DISCUSSION

A validated numerical model of the MIL-Lx with combat boot has been developed and can now be used to examine the effect of protective systems on injury severity to the lower extremity in underbody blast.

V. REFERENCES

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