Evaluation of Blast Energy Attenuating Floor Mats in Underbody Blast

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I. INTRODUCTION

During an anti-vehicular (AV) landmine event, a large impulse is directed towards the underside of a vehicle, causing rapid deformation of the lower hull and floor. Localized floor accelerations and velocities have been reported to be upwards of 100 g and 12 m/s [1]. These deformations, as well as the global vehicle acceleration, have the potential to cause serious injuries to the vehicle's occupants [2]. As the lower legs are often directly in contact with the floor, they are loaded first and rapidly, and therefore are particularly vulnerable to injury [3]. In response to this injury risk numerous protective systems, such as shaped hulls and energy attenuating (EA) seats, have been implemented to increase occupant protection.

EA floor mats are one technology that offers the potential to reduce the loading applied to the lower legs while being space-efficient. The protective capacity of several EA floor mats has been evaluated in a previous study using the Hybrid III (HIII) lower leg, over speeds of 2–7 m/s [4], however, the HIII considered by many to be too conservative when applied to vehicular landmine protection [3-4]. The aim of the study was to evaluate the EA floor mats using the Military Lower Extremity Leg (MiL-Lx) because it is more biofidelic.

II. METHODS

The Lower Limb Impactor (LLI) [5] was used to conduct a series of tests on the MiL-Lx leg (Fig. 1). The LLI uses a spring-powered plate that impacts the surrogate leg. The peak velocity of the plate is increased by increasing the compression of the spring (Table I). The Anthropomorphic Test Dummy (ATD) with the MiL-Lx leg was positioned in the drop test rig seat. EA floor mat materials were tested using the LLI, all of which are marketed to protect against lower leg injuries in a military environment. These EA floor mat materials were: Firex 50 and Skydex® (Skydex Technologies, Centennial, CO, USA). The Skydex® consists of a double layer of hemispheres made by injection-moulded plastic that, when loaded, reduce the peak force on the lower leg. Each floor mat was affixed on top of the impactor plate. Three tests on each mat for each velocity were conducted.

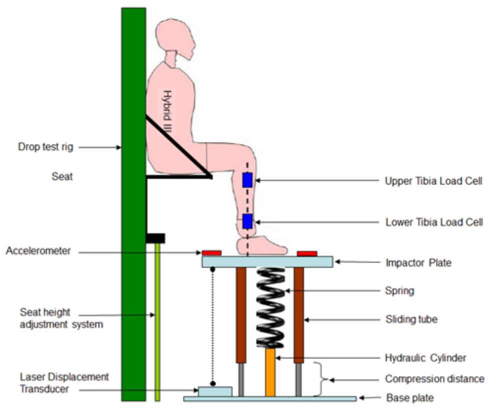

Fig. 1. Experimental setup [5].

TABLE I
THE CHARACTERISTICS OF THE TESTS PERFORMED

Test Condition	Peak velocity [m/s]	Impactor Kinetic Energy [J]
1	2.7	119
2	3.4	179
3	4.7	324
4	5.7	532
5	7.2	851
1	2.7	119

III. INITIAL FINDINGS

Axial upper tibia load data were collected over a range of velocities. The repeatability of the testing setup and material recovery was evaluated using three repeated trials. Standard deviations in force ranged from 1% to 7% of the mean, with the Skydex having the lowest standard deviation and

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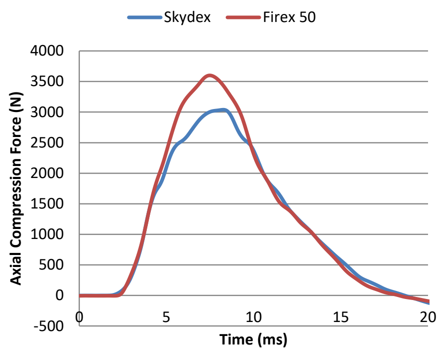
the Firex 50 having the highest. The peak axial forces recorded at the upper tibia load cell for each of the materials (and the baseline condition of no EA material) are presented in Fig. 2 (a) and (b).

(a)



(b)

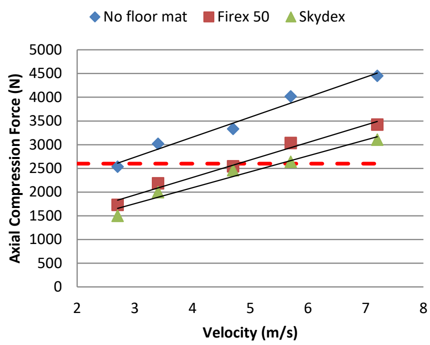


Fig. 2. (a) Axial forces (Fz) recorded in the MiL-Lx Upper tibia load cell during impacts at 7.2 m/s. (b) Axial force values recorded for the baseline condition (No floor mat) and the two floor mat products tested.

Table II shows average peak force values from the UT of MiL-Lx with no floor mat, firex and skydex.

TABLE II
THE CHARACTERISTICS OF THE TESTS PERFORMED

Test Condition	Velocity (m/s)	No Floor Mat		Firex 50		Skydex	
		Average UT Fz (N)	SD UT Fz (N)	Average Peak UT Fz (N)	SD UT Fz (N)	Average UT Fz (N)	SD UT Fz (N)
1	2.7	2 537	38	1 732	23	1 449	13
2	3.4	3 020	24	2 185	28	2 001	18
3	4.4	3 332	94	2 543	62	2 462	57
4	5.7	4 018	44	3 035	77	2 641	65
5	7.2	4 452	137	3 424	235	3 105	98

IV. DISCUSSION

In summary, this study evaluated the protective capabilities of two floor mats under short-duration dynamic axial impact loading using the MiL-Lx leg. At high-impact velocities, Skydex® greatly reduced the loading in the tibia, but all products would be expected to fail to meet the injury threshold (2.6 kN) [6] at the reported floor velocity of 7.2 m/s. The MiL-Lx has limited performance comparisons against PMHS responses outside of those used in its initial development. While these floor mats offer significant protection and ease of integration, the limits of their capabilities should be understood when used in a blast environment. Protection of the lower limbs from impact loading resulting from AV blast loading remains a significant challenge, and further research on and development of floor mats is needed to meet the required injury thresholds.

V. REFERENCES

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