VALIDATION OF A FINITE ELEMENT MODEL OF A SHOULDER SURROGATE FOR ACCESSING PADDINGS IN RUGBY UNION

Syed Imam [1,2], Heather Driscoll[3], Keith Winwood[1], Prabhuraj Venkatraman[1] and Tom Allen[1]

[1] Manchester Metropolitan University, Manchester M1 5GD, UK
[2] Canterbury Christ Church University, Canterbury, CT1 1QU, UK
[3]Advanced Manufacturing Research Centre (AMRC), Sheffield S60 5BL, UK

To govern the padded clothing used in rugby union, World Rugby™ have defined a set of specifications and directives in their Handbook, specifically Regulation-12 Schedule 1: *Specifications relating to Players' Dress* [1]. Regulation-12 concentrates on player clothing, providing, i) design and construction regulations; ii) material specifications, and iii) performance requirements and test methods. One of these tests is a drop tower style impact test with a flat-faced steel drop hammer, where the padding is placed over a cylindrical steel anvil. World Rugby™ intends for padding clothing to reduce the risk of injuries to the skin tissue only, and not for preventing more severe injuries like fractures or dislocations. A steel anvil is clearly not ideal for assessing the risk of damage to soft tissue. As such, a shoulder surrogate consisting of a steel core covered with a layer of silicone and chamois leather [2] was made for the purpose of testing rugby padding, specifically for assessing the risk of injuries to skin tissue.

A finite element model of the shoulder surrogate was developed in Ansys© LS-DYNA®. The material properties of the silicone and chamois leather were obtained with quasi-static compression testing (curve fit with hyperelastic models) and compressive stress relaxation testing (curve fit with a Prony series). The finite element models were compared against experimental data from impact tests on the shoulder surrogate at energies of 4.9, 9.8 and 14.7 J (14.7 J is the value defined in Regulation-12). The accuracy of the finite element model was assessed using four parameters, peak impact force, maximum deformation, impact duration and impulse. A 5-parameter Mooney-Rivlin material model combined with a 2-term Prony series was determined to be suitable for modelling the soft tissue simulant of the shoulder surrogate, with under 10% overall mean deviation from the experimental values for the four assessment parameters across the three impact energies (Table 1, Figure 1). The difference in the shape of the experimental and FE- loading curves (Figure 1-A) was due to artificial damping (frequency independent with a value of 140 MPa), which was added to the model to improve peak force agreement with the experimental data. Future work will apply the finite element model to predict how well various padding designs reduce the risk of soft

Corresponding author email: adil.imam@canterbury.ac.uk

tissue injuries. Such work will determine whether the 10% overall mean deviation between the model and experiment presented here is sufficiently small to be able to predict differences in injury risk between padding designs.

Table 1: Difference percentages between outputs from the finite element model and the experiment for key parameters for impacts at 14.7, 9.8 and 4.9 J.

Energy	Peak Force	Deformation	Impact Duration	Impulse	Mean Error
14.7	+1	-7	-7	-14	7
9.8	-1	+9	-16	-12	10
4.9	+3	-7	+11	-18	9
				Overall Difference Mean	**8.6**

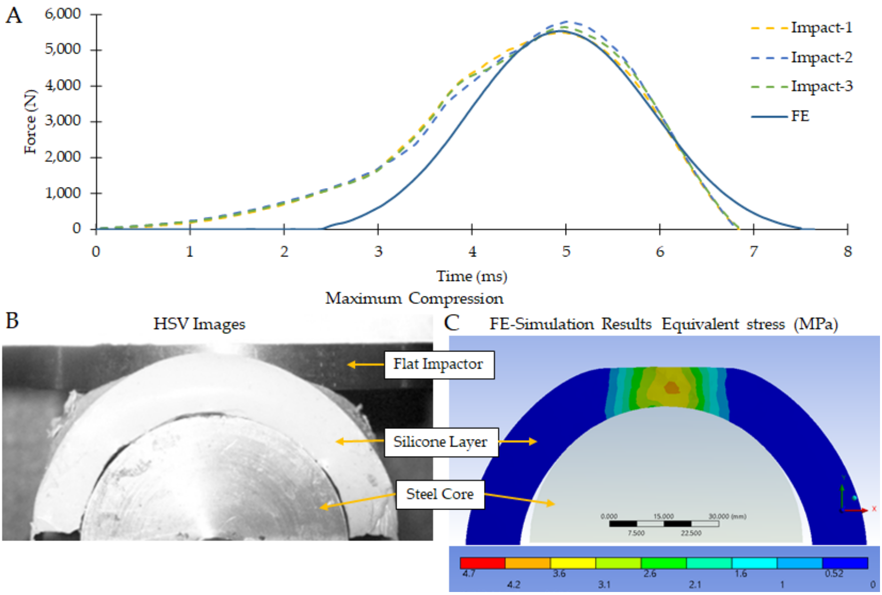

Figure 1: (A) Force time plot for 14.7 J impacts for the finite element model and the experiment, along with maximum compression images from (B) the high-speed camera and (C) model with contours of equivalent stress (MPa).

1. Regulation 12: Provisions Relating to Players Dress, World Rugby Handbook, 2015, pp. 191-222.
2. Hughes, A., Driscoll, H. and Carré, M., 2020. Development of Silicone Elastomer for Use in the Assessment of Padded Clothing in Rugby Union. In *Multidisciplinary Digital Publishing Institute Proceedings* (Vol. 49, No. 1, p. 77).

Corresponding author email: adil.imam@canterbury.ac.uk