The Dynamic Response of Porcine Fat

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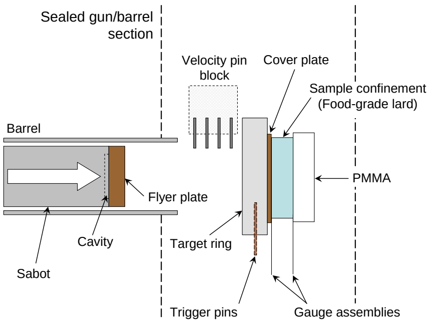
Introduction

In order to protect the human body against ballistic impact, an understanding of the behaviour of its tissues and biological components under high strain-rate loading and exposure to shock is required. Typically, ballistic simulants such as ordnance gelatin and ballistic soap are used to assess impact events however; there is a requirement for simulants to be more representative of the human body. A rendered porcine fat was subjected to flyer-plate impact (76-882ms^{-1}) to interrogate the material response at a strain-rate of c.$10^{6-7}s^{-1}$ and thus gain insight into the dynamic behaviour of the medium.

Experimental Setup

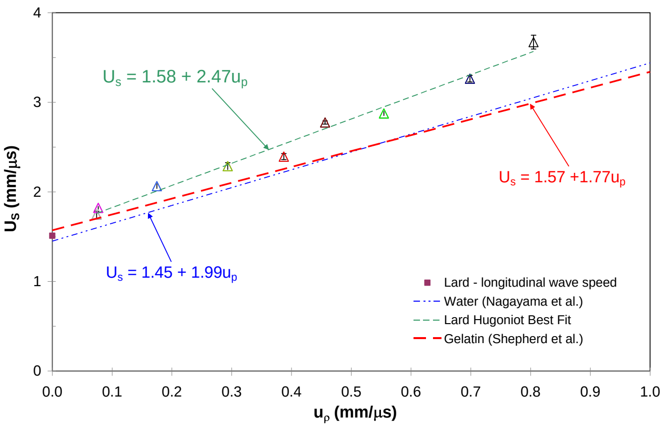


Experimental design provides 1D strain response data for the material

Δt between front and rear gauge shock arrival times gives U_s (shock velocity)

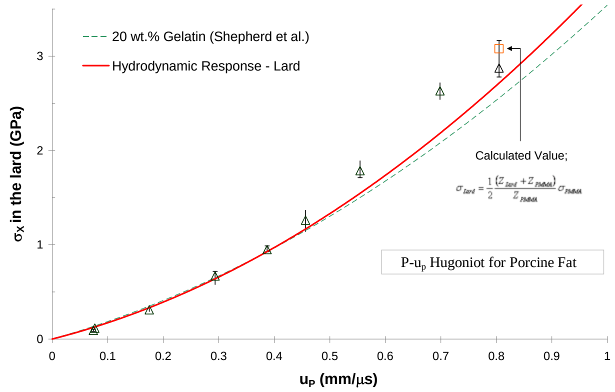
Data interpretation leads to the formation of an equation-of-state that can be used in Hydrocodes such as AUTODYN® to simulate ballistic impact experiments

Results

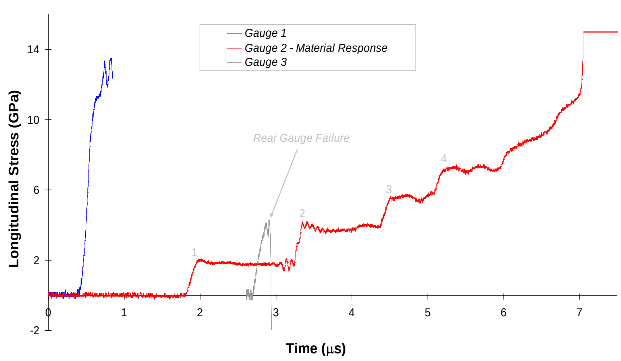


Principal Hugoniot Relationships (U_s-u_p above);

- Similarity between the behaviour of water and 20 wt.% ballistic gelatin
- Contrasting behaviour between the porcine fat and ballistic gelatin



- Lard behaves non-hydrodynamically under shock-loading i.e. it exhibits strength
- Ballistic Gelatin has been shown to behave hydrodynamically under shock, like water (Shepherd et al.)
- Porcine fat responds to shock in likeness with simple polymers. This is in agreement with structural composition of these materials



Experimental data obtained from a ring-up experiment with the porcine fat is shown above. Utilisation of a novel target design in which a manganin pressure gauge was embedded within the porcine fat has proved a successful method for the multiple shock-loading of such bio-materials. It is hoped that the method will yield a value of Grüneisen Gamma for the adipose material.

Conclusions

Initial research has shown that porcine fat - analogous to human fat deposits surrounding the body's vital organs - possesses strength under shock loading. It is hence reasonable to suggest that other soft tissues within the human body may exhibit strength under such loading regimes. Further, this work validates the suggested requirement for tissue simulants to be more representative of the human body.

The Future…

- Research into non-rendered fat – how do the processes involved affect the material's behaviour under dynamic loading?
- Calculation of Gruneisen Gamma for porcine fat
- The dynamic response of skeletal muscle tissue
- Investigation into the specific damage mechanisms of muscular tissues
- High strain-rate strength models that can be used in hydrocodes

K. Nagayama, Y. Mori, Y. Motegi, and M.Nakahara, Shock Hugoniot Compression Data for Several Bio-Related Materials, Shock Compression of Condensed Matter – 2005, pp. 1547-1550

C.J. Shepherd, G.J. Appleby-Thomas, P.J. Hazell, and D.F. Allsop, The Dynamic Behaviour of Ballistic Gelatin, Shock Compression of Condensed Matter - 2010, pp. 1399-1402

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