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Guest editorial

Special issue on ceramic armour

The development, engineering, and testing of ceramic armour systems and materials has been carried out during the past 50 years and dates back to the pioneering work of M. L. Wilkins and his colleagues.[1] Arguably, the first indications that such armour would be ballistically efficient were seen much earlier than Wilkins when, in 1918 Maj Neville Monroe-Hopkins found that a thin layer of enamel improved the ballistic performance of a thin steel plate.[2] Indeed, many early designs employed a hard ceramic face backed by a relatively ductile material, thereby employing the disruptor (or "disturber") / absorber recipe that is still used in modern armour systems today.

Since the work of Wilkins, as in so many areas of engineering and science, our understanding of the behaviour of ceramic materials under impact loading conditions has been enhanced by analytical models and finite element simulations coupled with laboratory testing techniques that probe the high strain-rate response. However, despite the numerous studies on the impact response of these materials, we still have a lot to learn and there are still rich avenues of study to pursue, ranging from their quasi-static behaviour to the shock response of these materials where strain-rates of $10^5 – 10^6$ s^{-1} are common. Current themes of research include: attempts to understand the flow characteristics of the comminuted material; methods for enhancing interface-defeat; strength behaviour under shock-loading and particularly the processing techniques to enhance their performance. The key to all of this is to understand the mechanisms by which a projectile penetrates (or "interacts") with the ceramic and thereby deduce the important properties that maximise performance. This may appear a trivial task but the time durations during which a penetrator is in contact with a ceramic are typically short and this often makes analysis difficult. Furthermore, ceramic materials are required to cope with diverse threats from bullets to shaped-charge jets where the mechanism of interaction is quite different. Consequently, the properties that are useful in defeating shaped-charge jets (such as the fragmentation and subsequent flow characteristics of the material) differ from those that are best for defeating high-velocity bullets such as hardness, acoustic impedance and particularly, how the armour system is engineered.

Even if we consider one particular threat regime, it has been known for some time that it is not one, isolated material property that defines the behaviour of a ceramic during penetration, which is why it is important to study these materials using a range of different techniques. Consequently, this special issue contains papers written by researchers from a range of different backgrounds, including modellers, material scientists, engineers and physicists.

Contained within this special issue are several papers examining the mechanisms by which projectiles penetrate ceramic targets. In particular, there is an examination of the modes by which penetrators can be defeated via dwell. Importantly, there are contributions that consider the mechanical properties of ceramics including an examination of the strain-rate response of aluminium nitride doped silicon carbide. The properties and ballistic performance of explosively-damaged alumina are also presented and these data are very important for when we design ceramic armour systems to cope with multiple impacts. There is also a comprehensive review on the historical development of ceramic armour that covers the major breakthroughs in our understanding of the properties that govern ballistic performance. This review comes highly recommended for its attention to detail and extensive reference list.

I should point out that ceramic materials do not offer a panacea for ballistic protection – mainly due to their low toughness and tensile strength. Nevertheless, they are very important materials, used for saving lives, where a limited number of impacts are expected. Most importantly, ceramics tend to offer a weight-efficient armour solution – particularly for body armour where the mass of the armour needs to be low. Correspondingly, they are widely used in the design of aircraft armour, and vehicle protection where there is an ever-increasing requirement to reduce the mass of the vehicle for strategic deployment reasons.

Hopefully the papers presented here will stimulate further discussion and ideas for research on how best to produce more cost-effective and weight-efficient ceramic-based armour systems. I am grateful to the authors for their contributions and trust you will find the papers of interest and use.

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[1] M.L. Wilkins, C.A. Honodel, and D. Swale, An Approach to the Study of Light Armour, Lawrence Radiation Laboratory, Livermore, UCRL-50284, June (1967).

[2] S. Dunstan and R. Volstad, Flak Jackets: 20th Century Military Body Armour, Osprey Publishing Ltd., London, ISBN 0-85045-569-3, (1984).