MATERIALS AND COOLING TECHNIQUES FOR HIGH-TEMPERATURE SUPERCONDUCTOR SYSTEMS SUBJECTED TO BLAST AND IMPULSE LOADING

Jonathan C. Knott[1], Shawn Nielsen[2], Stephen Van Duin[1, 3], Richard Taylor[2]

[1]*University of Wollongong, Wollongong NSW, Australia*
[2]*Queensland University of Technology, Brisbane QLD, Australia*
[3]*DMTC Ltd., Kew VIC, Australia*

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ABSTRACT

Superconductors are materials that exhibit unique properties below a material-specific critical temperature – including the complete absence of resistance at DC, and the capacity to carry large currents at very high current densities. These characteristics make superconductors attractive options for high-power applications including in compact motors/generators, power delivery, and magnetic field generation – among many others. High-Temperature Superconductors (HTS) are materials that can provide these characteristics at liquid nitrogen temperatures (77 K / -196 °C) – substantially higher than traditional superconductors, which require liquid helium temperatures (4.2 K / -268 °C) to operate.

Here we provide a brief discussion on blast and shock considerations for superconducting systems – particularly contrasting with the rapid advance of HTS material and cooling system technology development. We highlight the unique combination of cryogenic temperature and shock considerations on materials and cooling systems. Two novel technological solutions to address specific blast and shock issues are presented, with the utility and applicability of these solutions to be investigated through experiment and simulation in future work.

INTRODUCTION

Superconductors are materials that exhibit unique properties below a material-specific critical temperature – including the complete absence of resistance at DC, and the capacity to carry large currents at very high current densities. These characteristics make superconductors attractive options for high-power applications including in compact motors/generators, power delivery, and magnetic field generation – among many others [1]–[3]. Superconductors can be engineered to have specified sensitivity to external magnetic field – from being impervious to magnetic fields above 100 T [4] to being able to detect single magnetic flux quanta [5] – which opens opportunities for their use in sensors and quantum communications and computing applications [6], [7].

Superconductivity was first discovered in 1911 in the element mercury, which exhibits a complete absence of electrical resistance below 4.2 K (-268 °C). Since that discovery, substantial scientific and engineering effort has gone into discovering and developing materials with higher 'critical transition' temperatures – the temperature below which the material superconducts. Superconducting materials are define by three key parameters: the critical transition temperature, the critical magnetic field, and the critical current density The 'critical magnetic field' is the threshold magnetic field below which the material superconducts, and the critical current density is the threshold current density the material can sustain while remaining in the superconducting state. The key parameters for mercury behaving as a superconductor are a critical temperature of ~4.15 K, and a critical magnetic field of ~0.05 T (for comparison, a refrigerator magnet has a magnetic field of ~0.01 T). A superconductor operating within these parameters will superconduct, however if any of these parameters is exceeded – for example, if the temperature of any portion of the superconductor rises above