Introduction

Novel Materials and Manufacturing in Military Vehicle Design

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The AVT-384 Research Specialist Meeting (RSM), exploring novel materials and manufacturing in military vehicle design, was held in Koblenz, Germany, in October 2024. It brought together experts from NATO countries to address the issues and potential gains of breaking down barriers and tightly integrating component/system design, material development/design, and manufacturing processes for military vehicle development. The goal of the meeting was to identify the state-of-the-art, as well as areas of future research, to enable tighter collaboration between component/system design, materials, and manufacturing, resulting in more effective capability to the warfighter (defined as greater performance/$) at an accelerated rate of delivery.

The meeting brought together over 85 participants from 15 countries and was divided into three primary sessions: novel materials, novel design methods, and novel manufacturing techniques for military vehicles. Each session had a keynote presentation, followed by the exposition of several technical papers, in turn followed by a panel discussion. The keynote presentations and papers provided a good mix of industry research (at a higher technology readiness level/manufacturing readiness level [TRL/MRL]) and academic research (at a lower TRL/MRL). The design methods discussed ranged from the component level to full system level, while much of the materials discussion was focused on moderate to high temperature materials, along with meta-materials. The manufacturing session focused on additive manufacturing and automated composite lay-ups. To advance the development of novel materials and manufacturing techniques, particularly for extreme environments, it is essential to foster tight collaboration between materials scientists, design engineers, and manufacturing experts.

A carefully selected representative set of papers, of exceptional quality and drawn from the AVT-384 RSM, are included in this issue of the *NATO Journal of Science and Technology*. The pursuit of advanced materials and manufacturing techniques for next-generation defense platforms forms a common thread weaving through the presented research. Each article explores a facet of this challenge, from fundamental material science to sophisticated design and manufacturing processes.

The need for advancements in the integration of novel materials, design, and manufacturing, particularly the role of additive manufacturing, is underscored in the examination by De Stefano Fumo et al. of the extreme conditions faced by hypersonic vehicles. The demand for materials capable of withstanding intense heat fluxes and pressures drives the exploration of Ceramic Matrix Composites (CMCs) and ultra-high temperature CMCs (UHTCMCs).

Beblo's research on multiscale materials in topology optimization offers a path forward, demonstrating the potential for designing complex structures, such as thermal protection systems for high-speed vehicles, by optimizing both material properties and structural topology. This links directly to the thermal challenges outlined by De Stefano Fumo et al. and the need for robust materials in extreme environments.

Furthermore, the work by King et al. on automated fiber placement for manufacturing CMC conical structures demonstrates a practical application of advanced manufacturing to produce complex shapes using these high-performance materials. This directly addresses the manufacturing challenges associated with CMCs, as highlighted by De Stefano Fumo et al.

Finally, the investigation by Amsterdam and Chabok into the fatigue life of additively manufactured materials provides a critical link between the material properties, manufacturing process, and structural integrity of components under cyclic loading, essential for ensuring the long-term reliability of structures built using advanced manufacturing techniques.

In essence, these summaries collectively paint a picture of a concerted effort to push the boundaries of materials science and manufacturing technology to meet the demanding requirements of future defense platforms. They highlight the interconnectedness of material development, design methodologies, and manufacturing processes in achieving this goal, emphasizing the need for a holistic approach that considers the entire lifecycle of these advanced systems.

Key recommendations from the RSM include:

1) **Integrated Development**: Continue developing materials and meta-materials with multifunctional properties, leveraging topology optimization and next-generation manufacturing techniques.
2) **Synchronized Timelines**: Address the mismatch between material development and design timelines by creating parametric models of materials that can be used early in the design process and educating design engineers on Material Readiness Levels.
3) **Manufacturing Representation**: Integrate manufacturing constraints and uncertainties into the MADO process from the outset, using mathematical representations of manufacturing processes to inform design decisions and optimize production plans with tolerances and cost considerations.

By implementing these recommendations, organizations can bridge the gaps between material development, design, and manufacturing, ultimately accelerating the creation of innovative materials and products for extreme environments.