Topic: N161-046

Materials Research & Design

Ceramic-Metal Joining for Hypersonic Vehicle and Missile Components
Hypersonic missiles, projectiles, and vehicles traveling at increased Mach speeds (e.g., Navy Hyper Velocity Projectile) utilize leading edges which experience temperatures that exceed the capabilities of most refractory metals. At the same time, the dynamic launch forces are too extreme for high temperature ceramics. Such competing needs call for a hybrid design which utilizes a combination of materials. However, joining metals and ceramics is complex, especially at elevated temperatures. MR&D provides design/analysis service for these advanced materials and for the community of interest - providing the necessary experience to develop a novel metal/ceramic joint. The design will be developed through finite element modeling coupled with fabrication and testing of full-scale test articles subjected to representative flight loads.

Technology Category Alignment:

High-Speed/Hypersonics
Collaborative Analysis and Decision-making
Integrating Architecture and Capability Demonstrations
Corrosion
Propulsion and Extreme Environments

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SYSCOM: NAVSEA
Contract: N00178-17-C-7006
Corporate Brochure: https://navystp.com/vtm/open_file?type=brochure&id=N00178-17-C-7006

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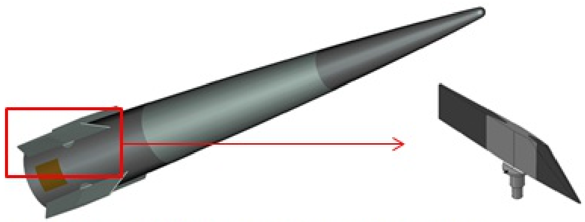
WHO

SYSCOM: NAVSEA

Sponsoring Program: IWS 3.0 Weapons

Transition Target: Navy Hypervelocity Projectile

TPOC:
(301)227-4501



http://www.baesystems.com/en-us/product/hyper-velocity-projectile-hvp

Hybrid Control Fins under Development for Hypervelocity Projectiles

Other transition opportunities: In addition to control surfaces, hypersonic vehicle leading edges, radomes and antennae all benefit with the use of high temperature ceramics. As an example, high temperature, monolithic ceramics are currently being evaluated for radomes and antennae due to their desirable durability and dielectric properties. Robust joints are required to join these components to the surrounding metallic airframe. Outside of hypersonic projectile applications, ceramic-metal joining technology would be desirable in a variety of commercial industries including gas-turbine engines, medical CAT scan equipment, chemical processing, cutting tools and high temperature furnaces.

WHAT

Operational Need and Improvement: When traveling at hypervelocity speeds, the sharp leading edges of advance high speed missile and projectile control surfaces, such as those used on the Navy Hyper Velocity Projectile, experience severe heating that exceed the capabilities of most refractory metals. At the same time, dynamic launch forces may be too extreme for high temperature ceramics. Such competing needs call for a hybrid design which utilizes both materials.

Specifications Required: The design of an appropriate metal-ceramic joint is critical for the successful design of an optimized hybrid control fin to meet the expanding performance requirements of future high speed missiles and projectiles with more demanding operational needs. Careful consideration must also be given relative to cost, thermal shock performance and integration with an existing munition system.

Technology Developed: MR&D has successfully demonstrated the feasibility of ceramic-metal joints for hypersonic vehicles through a combined analytical and experimental program. Finite element simulations were performed using representative design loads (structural, thermal and inertial) for a HVP projectile control surface. The design was successively modified and improved until a robust design was generated. Using this final hybrid fin, a subelement test article was designed which incorporated the main features of the metal to ceramic joint for flexure testing to demonstrate it's ability to carry the required loads. Continued research has resulted in a higher strength joint which is being demonstrated under both arc jet and high speed gun testing to demonstrate thermal shock and high dynamic load performance, respectively.

Warfighter Value: The successful development of a robust metal-ceramic joint is required to design a hybrid control fin for future hypersonic projectiles with increasing performance, speed and range requirements.

WHEN

Contract Number: N00178-17-C-7006 **Ending on:** September 1, 2020

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Survive peak bending moment	Med	Experimental validation of brazed and mechanically attached joint options	5	September 2018
Survive thermal shock conditions comparable to those experienced by 32MJ EMRG	Med	Demonstration of joint performance under representative thermal shock conditions	6	December 2018
Survive high dynamic load conditions comparable to those experienced by 32MJ EMRG	Med	Demonstration of joint performance under representative dynamic loading conditions	6	June 2019

HOW

Projected Business Model: As a service-based company, MR&D does not retain ownership of the resulting designs. Ultimately, the final design will be owned by the hypervelocity projectile Prime contractor. In order to facilitate this transition, MR&D will require a close working relationship with such companies to ensure that the final design blends with current operational requirements. Under the current effort, MR&D is working with a current HVP Prime contractor and their current design. At the conclusion of the effort, MR&D will deliver four control fins to the contractor for consideration in a future launch test.

Company Objectives: MR&D seeks to discuss current needs relative to metal-ceramic joints for hypersonic applications with ceramic and metal fabricators along with other prime contractors. The experienced gained on this program will directly benefit future programs which seek a similar design solution.

Potential Commercial Applications: Commercial space companies, such as SpaceX, Generation Orbit and Virgin Galactic are gradually developing vehicles capable of hypersonic flight. As operational needs for this vehicles increase, there will be a need to develop robust metal-ceramic joints in order to leverage the performance benefits offered by each material.

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