Topic: N13A-T008

Alpha STAR

Interlaminar Mode I and Mode II Fracture Toughnesses in Ceramic Matrix Composites (CMCs)
Ceramic matrix composites (CMCs) are used for critical components that operate in high temperature environments enabling one to increase the power, performance and efficiency of turbine engines and other aerospace applications; however, existing test methods for CMCs are expensive, unreliable and often fail to capture critical behavior. Alpha STAR, a global provider of physics based simulation technologies and services has developed, with the University of Akron, reliable, repeatable test protocols, specimen designs, and multi-scale material modeling and simulation tools to measure and predict the behavior of CMCs in order to produce more reliable, more efficient parts in a timelier and cost-effective manner. Alpha STAR seeks to transition this to interested program offices for CMC propulsion applications for validation and certification testing, enabling the U.S. Navy and commercial OEMs to reduce life cycle costs.

Technology Category Alignment:

Aircraft Propulsion, Power and Thermal
Engineered Resilient Systems (ERS)
Materials & Manufacturing Processes
Air Platforms
Modeling, Simulation & Test Infrastructure

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Department of the Navy SBIR/STTR Transition Program

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WHO

SYSCOM: NAVAIR

Sponsoring Program: Metals & Ceramics Branch AIR-4.3.4.1; Aerospace Materials Engineering

Transition Target: This technology will serve high temperature applications on rocket engines and gas turbines associated with fixed and rotary wing aircraft, UAVs, and critical weapon platforms.

TPOC:
(301)342-8075

Other transition opportunities: CMCs are applicable to propulsion, exhaust, thermal protection, and structural applications. Their unique properties make them a logical fit for aerospace design with a primary goal to improve power, performance and efficiency.

Courtesy of US Navy 160814-N-XW558-274 AUG 2016, http://www.navy.mil/management/photodb/photos/160814 N-XW558-274.JPG

Notes: For over two decades AlphaSTAR has been singularly focused on developing GENOA, an accurate and physics based analytical methodology for virtual testing of advanced materials. GENOA tools and methodology have been continually validated by FAA, NIAR, NASA, as well as major aerospace companies.

WHAT

Operational Need and Improvement: Concerns exist regarding the reliability and durability of CMCs due to their complex architectures and orthotropic properties. A thorough understanding of CMCs is critical to their exploitation and use. Laminated construction ensures mechanical properties are different in interlaminar and in-plane directions. Further, CMCs are highly susceptible to delayed failure (stress rupture or fatigue) even under interlaminar shear at elevated temperatures. Currently, there are recognized standards for testing CMCs at both ambient and elevated temperatures, including interlaminar tension and shear strength. However, a secure method for determination of interlaminar fracture toughness does not exist. Previous efforts related to measurement of interlaminar Mode I and Mode II fracture toughness for various types of CMCs have shown definite limitations. A reliable methodology is needed to capture this data and make it available to engineers.

Specifications Required: An urgent need exists to develop innovative test methods to determine interlaminar Mode I and Mode II fracture toughnesses (KI and KII) or crack growth resistances (GI and GII) unique to CMC material systems. Reliable methods would provide mechanisms to fabricate CMCs with a desired level of damage tolerance. New methods would support establishment of material databases for design, reliability and life-prediction analyses of CMC structural components at room and elevated temperatures, up to 2400F (1316C).

Technology Developed: Alpha STAR and the University of Akron will establish standard (ASTM) test protocols to determine relevant CMC delamination crack growth resistance (CGR) material properties (Mode I & Mode II) under service load temperature conditions. The protocol will provide reliable test data and validate virtual tools to predict behavior. Improved capability will provide companies with tools to produce better aerospace engines in a timelier and more affordable manner.

Warfighter Value: Technology will enable accelerated integration of CMCs in aerospace applications increasing the power and performance of fixed and rotary wing aircraft, UAVs, and ship and aircraft weapons, thus helping the Warfighter fight and win.

WHEN

Contract Number: N68335-15-C-0080 **Ending on:** June 30, 2016

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Plan for Test Development and Virtual Validation	Med	Peer Acceptance	4	March 2014
High Temperature Prediction of Toughness Modes and Interaction	Med	Experimental Validation	4	December 2014
Predictive Modeling and Statistical and Probabilistic Analysis of Data	High	Experimental Validation	5	December 2015
Test Demonstration with Acoustic Emission and Electrical Resitivity	High	Repeatable Results	5	February 2016
Hi Nicalon Wedge Double Cantilever Beam Specimen Design (protocol, size and initial crack determined) with ASTM C28 Standards Mode I and Round Robin Program	High	Community Acceptance	5	June 2016

HOW

Projected Business Model: Experimental methods used to characterize material properties/behavior of CMCs are expensive and time consuming. New test protocols have been established to reliably capture complex behavior needed for design. Virtual modeling and simulation tools have been established to predict behavior and support experimental evaluations. Manufacturers may use updated test methodology in coordination with virtual tools to expedite design of materials, components, and complete structures. Large scale parametric/trade studies may be undertaken to virtually examine variations in design and application. Utilization of virtual tools will dramatically reduce size and scope of physical testing and therefore dramatically reduce costs and development schedules. Successful utilization of virtual tools will accelerate integration of CMCs into new product development, improving component performance and efficiency. Virtual modeling and simulation tools, training and application support will be monetized. Manufacturers will recognize savings.

Company Objectives: Complete Round Robin Verification of test methodology and virtual predictive tools by leading aerospace manufacturers of gas turbine, rocket engines and other power plants. Secure recognition and acceptance of test protocol (specimen design and experimental method) by ASTM, MIL STD, and other peer accepted standards organizations. Present justification of methodology to community through peer reviewed journal literature, technical presentations, joint research and other outreach. Establish test methodology and predictive virtual analysis as standard practice in CMC component design and product development.

Potential Commercial Applications: A proven virtual and experimental tool set to assess the behavior of CMCs would be of great value to engineers, scientists and manufacturers. It will support the complete evaluation of CMC interlaminar properties, ensuring more reliable designs based on accurate life prediction. It will accelerate the integration of CMCs into high temperature applications in both civilian and military applications, providing improved performance and greater value.

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