Department of the Navy SBIR/STTR Transition Program

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NAVAIR 2020-832

Topic # N161-010

Novel Method to utilize Multi-scale Physics-based Technique for Crack Path Determination in Fiber-reinforced Composites

Technical Data Analysis, Inc.

WHO

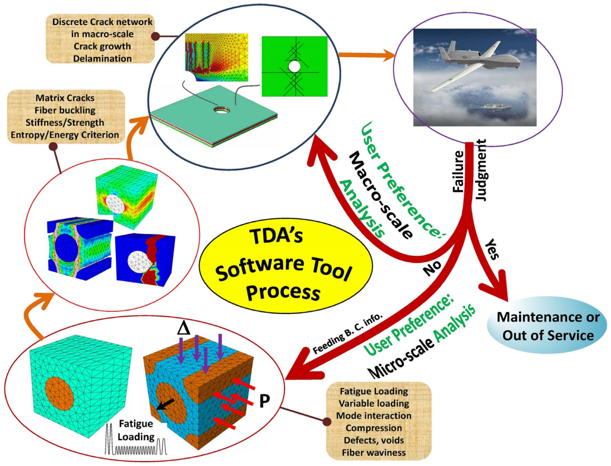
SYSCOM: NAVAIR

Sponsoring Program: PMA 275

Transition Target: V-22 Osprey

TPOC:
(301)904-4124

Other transition opportunities: The envisioned multiscale multiphysics composite analysis toolbox will help composite manufacturers to assess their product, new and old, under expected service loading to qualify their products; and personnel in maintenance and repair organization to assess the efficacy of repair online. This toolbox will be used not only in traditionally composite-heavy industries, but in other sectors including life and medical sciences where complex heterogeneous materials and structures are used.



WHAT

Operational Need and Improvement: Accurate prediction of crack growth behavior is essential in determining inspection intervals and maintenance schedules of aerospace structures where failure could lead to catastrophic consequences and loss of life. The financial costs involved when an in-service component is found to contain a defect is a major factor in the search for numerical methods to predict crack propagation. Damage initiation and subsequent propagation in fiber-reinforced composites are not understood as clearly as metals because of the presence of stiff fibers within soft matrix material causing inhomogeneity. There is a need for a novel physics based method to determine the crack growth and path in fiber-reinforced composite structures. The proposed computational technique underpin the true physical processes, and deal with mechanisms operating at different length scales providing accurate insight into crack initiation, growth in fiber-reinforced composite materials, and enable improved failure prediction and remaining useful life estimation.

Specifications Required: Reliable methods to predict 3-D crack propagation will reduce maintenance inspections and life of in-service components can be extended providing huge monetary savings. The ability to predict crack path progression in fiber-reinforced composite structures is essential in the design of new aircraft and the sustainment of legacy fleet. This effort will provide a pro-active approach in the design of next generation air vehicles as they will be constructed from lighter, stronger materials such as fiber-reinforced composites. Since the first introduction in Navy's F-14 and USAF's F-15, composites have emerged as the materials of choice for military aircraft because of: (1) superior fatigue performance, (2) high specific strengths and stiffnesses, (3) low weight, and (4) excellent resistance to corrosion compared with metals. Approximately 50% of the airframe weight of a V-22 is composites as they are used for the wings, fuselage skins, empennage, side body fairings, doors, and nacelles.

Technology Developed: Accurate estimation of three dimensional (3D) crack path and growth is of paramount importance in determining inspection intervals and maintenance schedules of aerospace structures before catastrophic failure takes place. Especially,in fiber reinforced composites where discrete failure modes are involved, initiation, propagation and tracking crack surface is crucial to reduce the financial cost of maintenance and extend the in-service life of aircraft components.The solution approach involves a true multi-scale analysis to capture realistic cracking process. TDA's product from this effort are tangible components that are fully integrated with commercial finite element analysis software.

WHEN

Contract Number: N68335-18-C-0076 **Ending on:** February 15, 2021

Milestone	Risk Level	Measure of Success	Ending TRL	Date
A novel method for composite materials	Low	Selected benchmark problems are validated against test data. Related published works are available at https://doi.org/10.1016/j.compstruct.2016.10.061 and https://doi.org/10.1177/0021998316681189.	TRL1	June 2016
A novel fatigue analysis of composites	Low	TDA has already developed and showed the essentials of the toolbox for static loading. In addition, we have published a paper describing fatigue analysis using kinetic theory of fracture and entropy principles https://doi.org/10.1016/j.compstruct.2019.01.	TRL3	May 2020
Graphical User Interface GUI) for Toolbox	Low	An initial version of the software and GUI have been established and demonstrated. End-to-End demonstration of selected benchmark problems used in validation are performed. A web-page for software toolkit has already been developed to start advertisement	TRL3	July 2020
Composite multiscale multiphysics tool (CMAT)	Low	TDA will release the initial version of toolbox to the government sponsor.	TRL4	February 2021

HOW

Projected Business Model: The global market size for composite materials application is projected to grow from USD 69.50 Billion in 2015 to USD 105.26 Billion by 2021 at a CAGR of 7.04% between 2016 and 2021. Assuming just 1% of the total is spent in tools for analysis and design of composites, the market for analysis tools is quite impressive. Of course, this will be for various types of tools and needs, and therefore partnering with a major vendor of FE software seems to be the right strategy for us in getting the tool a wide exposure. We will license the tool and contact various FE software vendors and make presentations describing our tools capability and get the attention. We plan to provide our components to identified vendors to test and try it out, and may incorporate their suggestions if within the scope of SBIR effort. This will set a stage for future marketing strategy beyond Phase II, to strategically partner with finite element software vendors to sell our two components: multiscale modeling component and advanced finite element component.

Company Objectives: The final product is a software toolbox capable of being plugged into available commercial software.The final tool will be implemented as a plug-in in a commercial available FE software such as Abaqus and will provide the suggested workflow for setting up and running a composite processing model. Our products from this effort are two tangible components that are fully integrated with commercial finite element analysis software. This integrated package assists engineers to perform degradation evolution in composites under static and fatigue loading. Moreover, the analysis package provides the engineer, whether in the design or service to predict structural response, strength and useful life considering the various types of defects inherent to composites such as voids, wrinkles, and waviness.

Potential Commercial Applications: Our tool will enable engineers in composite industries as well as user community in DoD, FAA and their contractors to better characterize service performance of existing composite components as well as come up with new designs. Therefore, our customers are going to be composite and aerospace industries and DoD and their contractors.

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