TOPIC NAME: CRACK NUCLEATION PREDICTION THROUGH SURFACE ROUGHNESS MEASUREMENT

TOPIC NUMBER: SB072-003 • CONTRACT NUMBER: W31P4Q09C0217 • DARPA OFFICE: DSO

Improvement in Predicting Material Failure Using Component Simulations

Value Proposition

Simulations of the structure and behavior of material under stress at the microscopic grain level allow better failure forecasts and produce significant savings by reducing or eliminating physical stress tests otherwise required before manufacturing.

About the Company

Year founded: 2000
Loren Nasser, President and CEO
VEXTEC's Virtual Twin™ product simulators predict the life of manufactured components and systems by simulating the behavior of the component material.

VEXTEC using new simulation technology to analyze repair worthiness and product readiness for the Army, Navy, and Air Force.

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Technical Description

VEXTEC's DARPA SBIR work in crack nucleation through surface roughness measurement extends a decade of prior work developing successful grain-level simulation models to predict fatigue and failure in components and fleets. Because cracks often initiate at the surface, surface roughness parameters were generated and calibrated, and models were developed to predict the durability or life of a component. The durability models drew on VEXTEC's Virtual Twin product simulators and Virtual Life Management™ (VLM) technology, which use state awareness to predict durability.

VEXTEC's VLM is an enabling technology that has the potential to significantly improve product design, testing, quality, manufacturing, warranty, maintenance, and lifecycle management disciplines globally. Utilizing VLM to create a Virtual Twin product simulator—a digital copy of a component, product line, or fleet—manufacturers can explore "what if" scenarios that would have been impossible to physically test due to budget and time limitations. The Virtual Twin simulates the degradation of every component grain—even for components comprised of millions of grains—and then digitizes and aggregates that information into a 3-D product representation. VEXTEC can simulate 10 years of use for a thousand-unit component fleet—requiring billions of individual simulations—in just minutes. By conducting fleet simulations for hundreds of possible usage conditions, the Virtual Twin can identify and isolate the factors that contribute to performance, durability, failure, and lifetime costs in time to affect their financial consequences. VEXTEC is the first company offering this technology, which is supported by three granted and four pending patents.

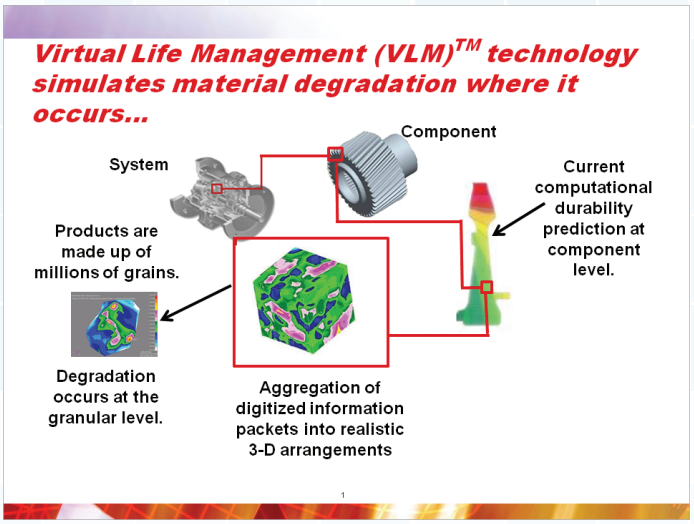

Fig. 1 VLM simulates damage where it occurs, at the material microstructure.

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Technical Challenge Addressed

Prior methods to predict fatigue and failure of military systems or components (e.g., airframes, engine blocks, gears) required lengthy and costly processes, reconstruction of large empirical databases and models for each component's unique structure and stress application. The goal is to make better and faster failure predictions by simulating the behavior of material at the micro structural level where cracks originate, form nuclei transitions (nucleation), and propagate. This requires reusable models that extend beyond finite element analysis to depict and correlate the intrinsic particle density properties for millions of grains in a material with surface roughness metrics and applied stress, and predict the number of micro-cracks that will propagate through the microstructure. Such reliable models can more cheaply and accurately forecast fatigue and failure in components, fleets, or large batches of products.

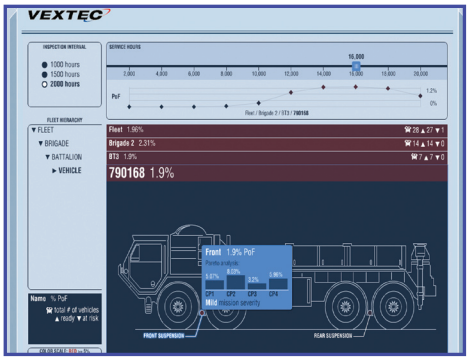

Fig 2. Example of VLM predictive maintenance system.

Lessons Learned and Best Practices

- Involve customers early so they are supportive of your technology, comfortable with your approach and understand risks.
- Build 3rd party support—nothing speaks louder than validation from satisfied customers and respected analysts, or industry insiders.
- Winning awards from respected 3rd parties is invaluable. (In October of 2009, VEXTEC was named the "Most Promising Company in America" by *Forbes*, which raised the company's profile immeasurably. (http://www.forbes.com/entrepreneurs/promising-companies/)

Applications

VEXTEC's simulation technology is being used to analyze military applications for the Army, Navy, and Air Force such as repair worthiness of turbine blades and disks, truck fleet readiness based upon maintenance intervals, and helicopter repair processes and failure prediction. Planned applications include aircraft and ground fleet failure and readiness forecasting.

Commercial simulation applications include medical implant devices, industrial equipment, automotive failure analysis and aerospace maintenance forecasting. Additional planned commercial applications include gear design and development for aerospace, automotive and energy.

Partnering and Collaboration

The Virtual Twin capability was developed in conjunction with several other DoD efforts, and significant research collaboration continues with the Air Force and Navy. The underlying computational materials simulation methods were developed with the help of the Air Force SBIR, "Probabilistic Micromechanical Fatigue Model for Intermetallics." The simulations were verified on titanium and nickel gas turbine engine components for low and high cycle fatigue with the Air Force SBIR, "Probabilistic Micromechanical Fatigue Modeling of Propulsion Structures," and extended to transmission systems with the Navy SBIR, "Physics-Based Gear Health Prognosis." The technology was applied to airframe structures under the DARPA SIPS program in collaboration with Northrop Grumman and applied to electronic solder joints under various Navy programs.

Economic Impact

- VEXTEC has received nearly $20 million in SBIR/STTR funding, which initially spawned over $3.4 million in commercial projects and military extensions.
- The company employs 27 people in three locations.
- Cash flow has been positive since its founding.
- Commercialization of Virtual Twin simulation technology for failure prediction began in late 2009, and VEXTEC is now seeking its first capital funding.
- SBIR/STTR funding has made the company viable and attractive by providing opportunities and resources for its technology to be developed and vetted before marketing.

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