U.S. Department of Energy
Energy Efficiency and Renewable Energy
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INDUSTRIAL TECHNOLOGIES PROGRAM

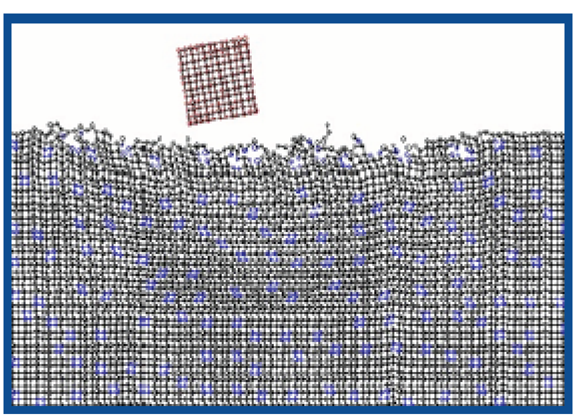
Advanced Nano-Composites for Increased Energy Efficiency

Degradation-Resistant Materials Will Extend Usable Life of Industrial Tools and Components

Degradation of materials not only reduces energy efficiency of industrial processes, but also lowers our nation's overall industrial competitiveness. All materials wear or degrade to some extent during normal usein industrial environments, this degradation results in an increase in the energy needed to continue operation of the component or system. In some cases as materials enter into a "severe wear" mode, the decrease in energy efficiency can be dramatic. The development of advanced wear-resistant materials offers an opportunity to realize meaningful energy and cost savings across a broad range of manufacturing environments.

The pathway to new materials with improved resistance to wear involves finding the optimum combination of hardness and toughness. Hard but brittle materials can degrade rapidly due to fracture, whereas highly malleable or ductile metals exhibit high wear rates due to plastic deformation. Initial studies on AlMgB14-based composites demonstrate the potential for achieving a highly wear-resistant and lightweight material through laboratory-scale powder processing and hot pressing.

One of the major objectives of this project is to develop a cost-effective, industrial-scale processing and synthesis approach capable of producing bulk materials possessing comparable or even improved wear resistance compared to the research-scale specimens. Optimization of composition and processing on the laboratory scale will serve as an initial milestone, providing industrial processing partners with a "template" for developing their procedures. Emphasis will be placed on examining alternate powder processing techniques and densification routes to eliminate porosity and achieve the maximum combination of hardness and toughness.



Computational model of degradation by erosive wear.

Erosion testing of advanced materials

Benefits for Our Nation and Our Industry

The implementation of advanced, degradation-resistant materials in industry will result in greatly improved usable tool life, faster and more efficient pumping speeds, higher reliability in severe service valves, and sustenance of optimal efficient performance for longer periods while decreasing replacement costs and downtime. The reduced energy budget will result in a decrease in both cost and detrimental air emissions. Preliminary analyses show savings of 30 trillion Btu per year by 2030 with an associated annual savings of $187 million and a reduction of harmful emissions on the order of thousands of metric tons.

Applications in Our Nation's Industry

Industry consumes approximately one-third of the total annual energy output in the United States. Improved degradation-resistant materials offer the potential to increase energy efficiency across a wide range of industrial applications, such as material conveyor systems, hydraulic drive components, abrasive fluid transport and handling systems, and pump seals. New materials will also enable advances in adaptive manufacturing, rapid prototyping, and nanomanufacturing, where tribology issues become even more pronounced.

Project Description

The goal of this project is to increase energy efficiency and operating lifetime of wear-intensive industrial components and systems by developing and commercializing a family of ceramic-based monolithic composites that have shown remarkable resistance to wear laboratory tests.

Barriers

Major barriers to be overcome include:

- Lack of detailed understanding of microstructural and compositional influence on ultimate performance and reliability;
- Lack of a sufficiently complex and robust computational model for predicting long term wear behavior; and
- Limited number of pathways for powder processing and consolidation techniques that retain laboratory-scale properties on industrial scale.

Pathways

The objectives of this project will be achieved through: (1) optimizing composition ratios of AlMgB14, TiB2, and binder phase; (2) investigating promising new powder synthesis and densification techniques; (3) developing a robust computational model to extend understanding of long term wear behavior; (4) expanding laboratory scale processes to the industrial scale; and (5) evaluating full-scale materials in various industrial settings to verify properties for commercial viability.

Progress and Milestones

- Determine the optimum $AlMgB_{14}$-TiB_2 ratio corresponding to the maximum microhardness, wear resistance, and toughness. (Complete)
- Determine the microhardness, erosive wear rates, abrasive wear rates, and fracture toughness of composite–Co(Mn) binder cermets. (Complete)
- Develop a commercially cost-effective scale-up of powder production/handling methods to achieve production of hundreds of grams of powder per batch.
- Fabricate and field test prototype severe-service valve components and abrasive jet nozzles from composite material.
- Develop a robust predictive mathematical model of the wear resistance of ceramic-based composites.

Commercialization

The partnership of industry, academia, and national labs provides a great deal of commercialization specialty and opportunity. CPP and IMI Vision are well positioned to introduce the wear-resistant materials into their industrial spheres, as well as further develop computational techniques developed in this project. The academic and laboratory partners will also play a crucial role in developing commercially viable materials, processes, and tools.

Project Partners

Ames Laboratory, Iowa State University
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Carpenter Powder Product, Inc.
Bridgeville, PA

IMI Vision/CCI Valve
Rancho Santo Margarita, CA

Oak Ridge National Laboratory
Oak Ridge, TN

The University of Alberta Edmonton,
Alberta, Canada

The University of Missouri
Rolla, MO

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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