Advanced Nano-Composites for Increased Energy Efficiency

Degradation-Resistant Materials 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 use. In industrial environments, this degradation can result in an increase in the energy needed to continue the 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 development of new materials with improved resistance to wear involves finding the optimum combination of hardness and toughness. Hard but brittle materials can degrade rapidly because of fracture, whereas highly malleable or ductile metals exhibit high wear rates from plastic deformation. Initial studies on aluminum magnesium boride ($AlMgB_{14}$)-based composites demonstrated 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 was to develop a cost-effective, industrial-scale processing and synthesis approach capable of producing bulk materials with improved wear resistance compared to the research-scale specimens. Optimization of composition and processing at the laboratory scale served as an initial milestone, providing industrial processing partners with a "template" for developing their procedures. Emphasis was placed on examining alternate powder processing techniques and densification routes to eliminate porosity and achieve the maximum combination of hardness and toughness.

Benefits for Our Industry and Our Nation

The implementation of advanced, degradation-resistant materials in industry can result in greatly improved, usable tool life; faster and more efficient pumping speeds; higher reliability in severe service valves; and decreased replacement costs and downtime. The reduced energy needs minimize both costs and detrimental air emissions.

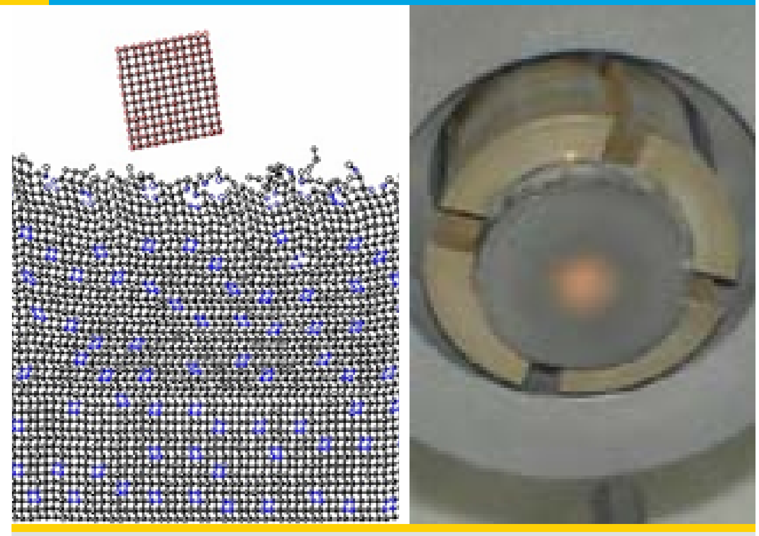

Image 1. Computational model of degradation by erosive wear.
Image 2. Erosion testing of advanced materials.

Image 1. Courtesy of Professor Dongyang Li, The University of Alberta.
Image 2. Courtesy of Ames Laboratory.

Applications in Our Nation's Industry

Improved degradation-resistant materials offer the potential to improve 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 also enable advances in adaptive manufacturing, rapid prototyping, and nanomanufacturing.

Project Description

The goal of this project was 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 had shown remarkable resistance to wear in laboratory tests.

Barriers

Major barriers included:

- 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
- Limited number of pathways for powder processing and consolidation techniques that retain laboratory-scale properties on industrial scale

Pathways

The objectives of this project were achieved through the following efforts: (1) optimization of composition ratios of $AlMgB_{14}$, titanium diboride (TiB_2), and binder phase; (2) investigation of promising new powder synthesis and densification techniques; (3) development of a robust computational model to extend understanding of long term wear behavior; (4) expansion of laboratory scale processes to the industrial scale; and (5) evaluation of full-scale materials in various industrial settings to verify properties for commercial viability.

Milestones

- Determination of the optimum $AlMgB_{14}$-TiB_2 ratio corresponding to the maximum microhardness, wear resistance, and toughness (Completed)
- Determination of the microhardness, erosive wear rates, abrasive wear rates, and fracture toughness of composite–cobalt-manganese binder cermets (Completed)
- Development of commercially cost-effective scale-up technology to achieve kilogram of powder and consolidated materials (Completed)
- Development of a robust predictive computational model of the wear resistance of ceramic-based composites (Completed)

Commercialization

During early commercialization efforts, the research team provided support to NewTech Ceramics in the form of analysis and characterization of their production material, and by providing recommendations for improvements in processing developed during the course of this project. Carpenter's consolidation technology was useful in transferring net-shape processing methods to commercial production. $AlMgB_{14}$ - TiB_2 (also known as BAM) targets are available for purchase through NewTech Ceramics, the current licensee of the technology.

Project Partners

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