U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

INDUSTRIAL TECHNOLOGIES PROGRAM

Wear-Resistant, Nano-Composite Steel Coatings

Laser Processing Techniques Used for the Production of Wear-Resistant Steel Coatings from Iron-Based Glassy Powders

Left: Laser fusing of amorphous powders to steel component.
Right: Nanocomposite coatings will be used in a range of high-wear, industrial applications including rock attrition.

Photos courtesy of Oak Ridge National Laboratory.

Introduction

Steel is widely used in a broad range of engineering, mining, and construction applications due to its mechanical properties, availability, and relatively low cost, but is not optimized for wear resistance. Wear of steel components leads to both direct and indirect costs and energy losses, including losses due to plant inefficiencies and down-time for repairs. The project team aims to address the limitation of wear in steel components by developing a high-yield, low-cost, and scalable manufacturing processes to optimize wear resistant nano-composite coatings and components for a wide range of applications. In this project, complex metal boron-carbide (CMBC) in a metal matrix will be developed from the laser fusing and consolidation of amorphous powders.

The proposed coatings are iron based and can thus be easily applied to a wide range of steel components. Laser fusing of the coatings provides a metallurgical bond between the coating and substrate, preventing the spalling and debonding that is frequently encountered with other coating methodologies. The quantities of powder required to process the relatively thin (0.2 mm to 0.4 mm) nanocomposite coatings is very small and would only add a modest cost to finished components.

Benefits for Our Industry and Our Nation

The application of CMBC nano-composite coatings can extend the life of any steel based substrate that can benefit from improved wear resistance, resulting in reduced maintenance and material replacement costs. The resulting cost savings in the form of increased productivity will be significant, as will the energy savings and reduced carbon emissions.

Applications in Our Nation's Industry

The coatings are designed to be used on most steel substrate and could thus be applied to components from a wide range of markets. These markets include mining (ore processing, surface and underground mining, and drilling), utilities (seals, accessories, and bearings), defense, manufacturing (machining tools, dies, blades), agriculture (equipment for tillage and planting), construction (drill bits, grinder hammer tips, and other hardware), and transportation (brakes, valve trains, bearings, and gears).

Project Description

The goal of the project is to develop laser processing of amorphous and nanocrystalline powders as a nano-manufacturing process for the incorporation of nano-sized CMBCs as a wear resistant coating for steel substrates. A secondary goal is to consolidate the powders via powder metallurgy practices to form bulk nanocomposite components.

Both goals are being addressed through the development of manufacturing technology for production of iron-based amorphous and nanocrystalline powders with high carbon and boron contents, and control of the precipitation of nano-sized CMBCs into a fine grained metal matrix.

Barriers

Ensuring a scalable and commercial-scale friendly manufacturing process, while still maintaining required improvements in wear resistance of the nanostructured coatings

Pathways

The project is using applied research to translate cutting-edge nanoscience into a practical nanomanufacturing method. In particular, the ability to control the insertion of CMBCs in metal matrices at nanometer scales is the novel method that is being utilized to create unique and attractive engineering coatings and bulk components. Metals have been shown to get harder and stronger as the matrix and precipitate grain sizes move into the nanoscale regime.

Three major tasks are being combined as part of the research effort. These tasks include the optimization and fabrication of amorphous and nanocrystalline metal powders, the development of reliable laser fusing of the powders to steel substrates, and finally the subsequent characterization of the nanocomposite coatings, including field tests.

Milestones

This project started in September 2008.

- Use two powder consolidation processes to make nanocomposites. Using one process, develop nano-composites via hot isostatic pressing of powder that can demonstrate a 20% improvement in tensile or compressive testing compared to the ductility baseline of 1.5% (Completed)
- Using a different process, optimize the coating via modification of laser power, scan rate, and powder deposition to produce a coating with a Vicker's surface hardness over 1000 for each component (Completed)
- Produce 2-3 commercial size batches of 800-2,000 lbs. for large scale manufacturing of nano-coatings and composites
- Field validate coated components alongside uncoated components at the site of an industrial end user partner. The targeted wear factor is 7.5x10-4 (a 25% improvement over baseline). The result of this milestone will be a wear factor and estimated lifetime duration improvement

Commercialization

The project partners are well-equipped for product commercialization. From powder producers to original equipment manufacturers (OEMs), all aspects of production and commercialization will be involved in the project. Project partner Carpenter Powder Products is one of the world's most versatile companies for specialty alloys in the form of loose powders and consolidated powder metallurgy products. After initial success with powder production, the project will proceed with laser fusing of full size industrial components and will then implement the coated components on commercial equipment. To ensure successful commercialization, the laser fusing of the coatings will be performed in a manner that allows a commercial entity to replicate equipment and setup.

Project Partners

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