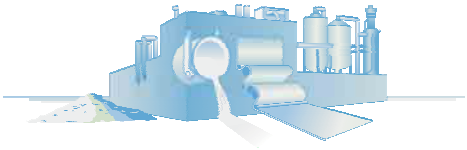
Development of Functionally Graded Materials for Manufacturing Tools and Dies and Industrial Processing Equipment

New Functionally Graded Tools and Dies Will Enable Better Thermal Management, Possess Better Wear Resistance, Reduce Scrap, and Improve Process Productivity

Tools, dies, and process equipment currently used in the metal casting, forging, and glass manufacturing industries are generally composed of thick-sectioned monolithic H13 or other tool steels. Although the starting materials are relatively inexpensive, the conventional tool manufacturing process results in low material yields, significant machining time, long lead times, and high overall cost. When the dies are in contact with either hot/molten metals or glass as appropriate, significant degradation of the surfaces occurs due to soldering, heat checking, and/or physical erosion. Damaged dies lead to part-surface imperfections, dimensional tolerance issues, high part-reject rate, and die repair downtime. Better tool and die materials are needed for use in tools, dies, and industrial process equipment used in the metal casting, forging, and glass industries. It is desirable to engineer these materials so that the properties of a tool can be customized to the particular needs of the application and the right area of the tool or die to possess the correct property.

Functionally graded materials (FGMs) and structures made from ferrous or nickel-based materials and composites are candidate materials for this application. Laser powder deposition (LPD) and solid-state dynamic powder consolidation (SSDPC) are two energy-efficient and unique near-net manufacturing processes that will be utilized in the development and fabrication of the FGMs.

Properties of functionally graded tools can be customized for the application.



Benefits for Our Industry and Our Nation

Functionally graded tools and dies will possess superior elevated temperature properties, improved thermal management, dimensional stability, wear resistance, and resistance to die surface degradation. The enhanced attributes will lead to reduced scrap and waste in parts manufacturing, reduced cycle times, and increased tooling life.

Applications in Our Nation's Industry

Improved tools and dies fabricated from functionally graded materials will be used in the aluminum, forging, glass, metal casting, and steel industries.

Project Description

The goal of this project is to develop new powder-metallurgy-based near-net-shape fabrication technologies that will result in the creation of specialized, functionally graded tools, dies. The focus of the project is to develop and apply two unique processing technologies—LPD and SSDPC—to construct engineered FGMs.

Barriers

Major barriers to be overcome include:

- Lack of data to guide the selection and predict the performance of the powder metallurgy tools and dies;
- Lack of demonstrated processes to reliably and efficiently produce functionally graded materials; and
- Lack of database of experimental data on the performance of FGM tools.

Pathways

The objectives of this project will be achieved through (1) identifying appropriate needs for FGM metallurgical systems applicable to the metal casting, glass, and forging industries; (2) thermal modeling of glass manufacturing and design of FGM glass-forming dies; (3) optimization of laser powder deposition and fabrication of FGM prototype materials; (4) optimization of solid-state dynamic powder consolidation and fabrication of FGM prototype materials; (5) metallurgical and mechanical evaluation of materials; and (6) prototype trials in each of the industries.

Milestones

- Define appropriate FGM materials systems for each industrial application
- Using thermal modeling, define material property requirements for prototype tools used in die and glass press molds
- Develop initial tooling concept for metal die-casting and glass-press-forming tools using LPD process
- Develop initial tooling concept for conventional forging tool using SSDPC
- Complete prototype glass press mold trials using LPD-fabricated FGM structures
- Complete initial forging trials of powder metal tooling performance
- Develop scale-up equipment and processes
- Complete industrial forging trial of powder metallurgy prototype tooling

Commercialization

The project includes collaboration between a leading supplier of specialty allow metal powders and two of the largest suppliers of forged components in the world. The availability of manufacturing facilities, manufacturing process development engineers, and an immediate market for the tools will facilitate commercialization.

Project Partners

Carpenter Powder Products Inc.
Bridgeville, PA
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GKN Sinter Metals R&D
Romulus, MI

Metaldyne, Hatebur Operations
Royal Oak, MI

South Dakota School of Mines and Technology
Rapid City, SD

Gremada Industries Inc.
West Fargo, ND

OPTOMEC
Albuquerque, NM

Pacific Northwest National Laboratory
Richland, WA

RPM and Associates Inc.
Rapid City, SD

Techneglas Inc.
Columbus, OH

THT Presses Inc.
Dayton, OH

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CPS #16941.
June 2004