C/ORNL97-0488

ornl

OAK RIDGE NATIONAL LABORATORY

LOCKHEED MARTIN

Metals and Ceramics Division

CRADA Final Report
for CRADA Number ORNL97-0488

RAPID PROTOTYPING OF CERAMICS

S. D. Nunn
Oak Ridge National Laboratory

B. Conway
Performance Research

Date Published – January 2000

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
LOCKHEED MARTIN ENERGY
RESEARCH
CORPORATION
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-96OR22464

APPROVED FOR PUBLIC RELEASE
UNLIMITED DISTRIBUTION

MANAGED AND OPERATED BY
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL-27 (3-96)

C/ORNL97-0488

Metals and Ceramics Division

CRADA Final Report
for CRADA Number ORNL97-0488

RAPID PROTOTYPING OF CERAMICS*

S. D. Nunn
Oak Ridge National Laboratory

B. Conway
Performance Research

Date Published – January 2000

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
LOCKHEED MARTIN ENERGY RESEARCH
CORPORATION
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-96OR22464

* This work was supported through a CRADA with Performance Research, Denver, North Carolina, sponsored by the Laboratory Technology Research Program, Office of Science, U. S. Department of Energy, under contract DE-AC05-96OR22464 with Oak Ridge National Laboratory, managed by Lockheed Martin Energy Research Corporation.

Abstract

This Cooperative Research and Development Agreement (CRADA) between Lockheed Martin Energy Research Corporation (Contractor) and Performance Research (Participant) was initiated to fabricate high performance automotive components of ceramic materials. A further purpose of the CRADA was to investigate the use of solid free-form fabrication methods (rapid prototyping) to produce these components. There was excellent cooperation between the partners and good progress was being made, however, cancellation of half of the project funds at ORNL ended work on the CRADA before all of the planned tasks could be completed.

CRADA Objectives

The technical objective of the CRADA was to fabricate a high performance automotive component of ceramic material for property measurement and engine testing. As a baseline for comparison, components were to be gelcast in aluminum molds. Advanced forming methods using solid free-form fabrication (rapid prototyping) were to be evaluated for production of this component. Two rapid prototyping approaches were to be evaluated. The first was to use a stereolithography apparatus (SLA) to produce a resin casting mold directly from component drawings. The mold would then be used to gelcast the ceramic components. The second approach was to use a UV-curable gelcasting slurry in the SLA to directly form a ceramic green body.

Meeting Objectives

The CRADA statement of work included six technical tasks. The first three tasks were completed and the fourth task was partially completed. Cancellation of half of the project funds at ORNL made it impossible to complete the remaining CRADA tasks.

CRADA Benefit to DOE

Conduct of research under this agreement served to establish initial capabilities for fabricating ceramic components using UV-cured, gelcasting-type slurries.

Technical Discussion

Introduction

The gelcasting process has been used successfully to form ceramic green bodies from numerous ceramic materials including: silicon nitride, silicon carbide, alumina, zirconia, etc. In addition, numerous component configurations have been fabricated for use in various industries. The ability to produce reliable ceramic components at a competitive price depends upon developing more economical methods of fabrication. Solid free-form fabrication is one method which can greatly speed the development cycle and, when combined with gelcasting technology, has the potential to reduce the cost of component fabrication. The desired result of this CRADA was the development of rapid prototyping fabrication methods and the successful fabrication and testing of ceramic components in an automotive engine.

Baseline Component Fabrication

Component drawings were received from Performance Research and the corresponding mold drawings for fabricating the component by gelcasting were prepared by ORNL and sent to the Participant. Aluminum molds were machined and anodized by the Participant and shipped to the Contractor. These molds were used to cast the baseline components, which were made of silicon nitride, a high-performance ceramic material. Some defects were present in the castings and attempts to eliminate the defects were unsuccessful. The molds were redesigned and a new set of molds was made. These molds eliminated the defect problem, but loss of CRADA funding did not allow fabrication of finished components for material property testing at ORNL or engine testing at Performance Research.

Resin Mold Fabrication

Resin molds were fabricated using a 3-D Systems SLA-250 stereolithography machine. Two different resin materials were evaluated for compatibility with the gelcasting chemical systems. File conversion from a CAD drawing file to computer control code for building a component on the SLA-250 was accomplished successfully. A cured resin mold for gelcasting the automotive component was fabricated on the SLA-250 directly from the converted drawings. This mold was then used in casting trials. It was found that the stepped surface of the build architecture was too rough for easy release of the part from the mold.

UV-Cured Gelcasting Process Development

As the first step in developing the capability to fabricate ceramic components directly on the SLA-250 machine, ultraviolet (UV) curing agents compatible with the gelcasting chemicals were identified and tested. Two curing agents were shown to form solid gelled ceramic green bodies from standard gelcasting slurries. These were Irgacure 2959 and Darocur 4265, both manufactured by Ciba-Geigy Corp. Initial trials were begun to evaluate the UV-curable gelcasting systems in the SLA-250, however loss of program funding halted the investigation before meaningful progress could be made.

Conclusions

This Cooperative Research and Development Agreement (CRADA) was initiated to fabricate high performance automotive components of ceramic materials. A further purpose of the CRADA was to investigate the use of solid free-form fabrication methods (rapid prototyping) to produce these components. There was excellent cooperation between the partners and good progress was being made, however, cancellation of half of the project funds at ORNL ended work on the CRADA before all of the planned tasks could be completed.

Report of Inventions

There were no inventions developed under this agreement.

Commercialization Possibilities

The gelcasting process variations that were developed under this agreement may be commercialized at some time in the future; however, there are no such plans currently in place.

Plans for Future Collaboration

No plans have been made for future collaboration.

Conclusions

Some of the technical objectives of this CRADA were met in a timely manner with good interaction between ORNL and Performance Research; however, loss of funding support at ORNL resulted in the project ending before all of the tasks could be completed.

Internal Distribution

1. S. D. Nunn, 4508, MS 6087
2. R. J. Lauf, 4508, MS 6085
3. R. A. Bradley, 4500S, MS 6161
4. T. M. Rosseel, 4500S, MS 6158
5. R. Hamrin, 4500N. MS 6285
6. L. L. Horton, 4500S, MS 6132
7. J. Luffman, 5002, MS 6416
8. T. L. Payne, 5002, MS 6416
9. C.A. Valentine, 111 UNV, MS6499
10-11. Laboratory Records (2) 4500N, MS 6285

External Distribution

12. B. Conway, 3684 Delling Downs Rd., Denver, NC 28037
13. DOE-WFO, MS G0209
14. S. J. Barish, DOE-HQ, Energy Research Laboratory Technology Research Program, SC-32, 1990 Germantown Rd., Germantown, MD 20874-1290
15. P. L. Gorman, 4500N, MS 6269
16. W. M. Polansky, DOE, SC-32, 1990 Germantown Rd., Germantown, MD 20874-1290
17-18 Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831