



AMPTIAC

ADVANCED MATERIALS AND PROCESSES TECHNOLOGY

The AMPTIAC Newsletter, Spring, 1999

Continuous-Fiber Ceramic Composites – A New Generation of Materials

Guest Editorial

James K. Wessel

Advanced Materials Consultant and

President of Wessel & Associates

The market for ceramics is very large and growing rapidly. Advanced ceramics alone had sales of approximately \$19 billion in 1997, and demand is growing at a rate of 20 percent per year. These materials are prized for their excellent high-temperature properties. They are finding use where temperatures exceed the capability of other materials, especially metals. Even so, they are not selected for many applications because the brittleness of monolithic ceramics makes designers wary. In the search for improvement, material scientists conceived the idea of reinforcing ceramics with continuous strands of high-temperature ceramic fiber. Embedded continuous ceramic fibers reinforce the ceramic matrix by deflecting and bridging fractures.

These continuous fiber ceramic composite (CFCC) materials offer the advantages of ceramics—resistance to heat, erosion, and corrosion—while adding toughness and thermal shock resistance. CFCC materials are evolving to the advanced product development stage thanks to support from U.S. Department of Energy (DOE) Office of Industrial Technology (OIT) through its CFCC Program. Designers are evaluating them in applications in major industries. Thousands of hours of successful tests indicate that they will soon find commercial use.

A 1989 DOE OIT study estimated that CFCC materials would save 1.1 quadrillion BTUs/year of energy, reduce NO_x emissions by more than 0.6 million tons/year, reach a market level of \$10 billion/year and create more than 100,000 industrial jobs.

CFCC Collaborative Program

DOE-OIT initiated the CFCC Program in 1992 as a 10-year collaborative effort among industry, national laboratories, academia, and government. The goals of the program are to advance processing methods, establish an infrastructure of supporting technologies, assess user needs, and achieve suitable properties.

continues, page 2 ➤

Volume 3, Number 1

Spotlight on Technology ...	1
Projection Heating Improves Aircraft Repair...	4
AMPTIAC Bestsellers ...	5
Recent Patents ...	6
NIST's John Rumble Jr., elected President of CODATA ...	6
John W. Lincoln Award Presented to Thomas Swift ...	10
Bone-Shaped Fibers ...	10

Figure 1. Hot-gas filters.

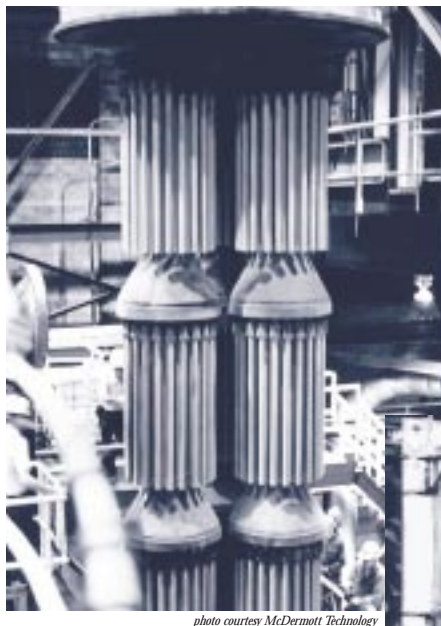


photo courtesy McDermott Technology

The CFCC materials under development support the OIT Industries of the Future Program, including chemical, refining, steel, aluminum, metal-casting, forest-products, glass, agriculture, and mining industries. Together, these industries consume more than 80 percent of the total U.S. manufacturing energy use. Industries that implement CFCC components in their applications will realize substantial energy, economic, and environmental benefits, including lower maintenance, higher efficiency, and decreased operating costs. Additional benefits will accrue from optimization of process operating conditions, reduced

downtime, and increased useful lifetimes. Successful development and commercialization of CFCC materials will enable U.S. industry to remain competitive in the global marketplace.

In 1992, after issuing a request for proposals and evaluating them, DOE-OIT made awards to ten teams to conduct a 10-year cost-shared effort. Teams included CFCC manufacturers, end-users, universities, and national laboratories. Manufacturers provide the materials, applications, and testing of materials and components. Universities and national laboratories provide

research and data supporting the areas of composite design, materials characterization, test methods, standards development, and performance-related phenomena. These tasks help build the scientific foundation for the successful design, fabrication, characterization, and utilization of CFCC materials in industrial applications.

Dramatic progress has been made during the years since the start of the CFCC Program. Numerous applications have been identified with high payoff to a broad industry cross section. Six different CFCC materials are suc-

cessfully developed in sizes and shapes scaled to industry requirements. Hot-gas filters and radiant burner screens have survived thousands of hours at operating conditions. Universities and national laboratories have created a CFCC technical support infrastructure that includes



photo courtesy AlliedSignal Composites, Inc.

Figure 2. Radiant burners.

Editor
Barbara K. Severin

Creative Director
Greg McKinney

Information Processing
Judy Tallarino
Patricia McQuinn

Inquiry Services
Barbara K. Severin

Product Sales
Gina Nash

The AMPTIAC Newsletter is published quarterly by the Advanced Materials and Processes Information Analysis Center (AMPTIAC). AMPTIAC is a DoD sponsored Information Analysis Center, administratively managed by the Defense Technical Information Center (DTIC), Defense Information Systems Agency (DISA). The AMPTIAC Newsletter is distributed to over 20,000 materials professionals around the world.

Inquiries about AMPTIAC capabilities, products and services may be addresses to

David H. Rose
Director, AMPTIAC
315-339-7023
E-mail: amptiac@iitri.org
<http://amptiac.iitri.org>

We welcome your input! To submit your related articles, photos, notices, or ideas for future issues, please contact:

AMPTIAC
ATTN: Barbara K. Severin
201 Mill Street
Rome, New York 13440-6916

PHONE: 315.339.7021
FAX: 315.339.7107
EMAIL: amptiac_news@iitri.org



databases, computer design codes, nondestructive inspection techniques, and life-prediction techniques. They are leading the creation of standards, and aiding industry in developing procedures for determining the relationships among fabrication, structure, property, and performance.

CFCC Materials Under Development

Table 1 shows the variety of materials being developed in the CFCC Program. The fibers are silicon carbide, carbon, or metal oxide, such as alumina or mullite. Composite densification is achieved with various techniques described below.

AlliedSignal Composites, Inc., Newark, Delaware, (formerly DuPont Lanxide Composites, Inc.) uses a chemical vapor infiltration (CVI) process. At the start of the process, tooling holds the shape of a preform, which may be made of silicon carbide, carbon, or metal oxide fibers.

The CVI process deposits a carbon interface or a boron nitride interface on the fibers. A silicon carbide precursor gas is then infiltrated between the fibers and a silicon carbide matrix is formed. This is an isobaric, isothermal infiltration process conducted near 1000°C under reduced pressure.

Dow Corning Corporation, Midland, Michigan, produces CFCC materials by polymer infiltration. A fiber preform, usually composed of silicon carbide fibers impregnated with a polymer matrix and cured by conventional methods.

The composite is then pyrolyzed to temperatures greater than 1800°F to convert the pre-ceramic matrix polymer to a ceramic. Subsequent impregnation and pyrolysis steps are carried out to achieve the desired final density. Fiber architecture preforms can include filament windings, braids or two- and three-directional weaves.



photo courtesy Dow Corning

Figure 3. CFCC Shroud.

The melt infiltration technology being developed by General Electric Corporation, Schenectady, New York,

continues, page 7 ➤

Table 1. CFCC Team members, processes, and applications.

Team Member	Fabrication Process	Materials	Applications	Partners
AlliedSignal Composites	Chemical Vapor Infiltration	SiC/SiC	Combustor liners	Solar Turbines
			Reverberatory screens	Alzeta Corp.
			Particle separator	Foster Wheeler
	Direct metal oxidation	SiC/Alumina	Tube shields Recuperator	Foster Wheeler Teledyne Continental Motors & AlliedSignal
Dow Corning	Polymer Impregnation and Pyrolysis (PIP)	SiC/SiC	Turbine tip shoe	Solar Turbines
			Pipe hangers	Chevron Corp.
			Heat treating furnace fan	Surface Combustion
General Electric	Melt Infiltration (MI)	SiC/SiC + Si	Turbine shrouds	General Electric Power Systems
Textron Systems	Nitride bonding	SiC/SiC	Immersion tubes	Representative of the Aluminum Casting Industry
McDermott Technology	Powder slurry/sol-gel	Oxide/oxide	Hot gas filters	Siemens Westinghouse Electric Corp.
			Natural gas burner elements	Institute of Paper Science and Technology

Projection Heating Improves Aircraft Repair

There is growing concern in the Department of Defense as well as in the commercial sector regarding the repairability of aging aircraft fleets. In general, when a repair is required, a composite doubler is adhesively bonded to the structure. Most adhesives used in this application require heat to properly cure. Because the aluminum aircraft structure acts as a heat sink, drawing heat away from the bonded area, controlling the process is sometimes difficult and often the adhesive bond does not cure properly and re-work is required.

Zimac Laboratories Inc., Chateauguay, Quebec has developed a new heat and control process for the purpose of curing bonded doublers on aluminum aircraft structure. This process is referred to as "projection heating." The concept is based on low surface area thermal injection devices called heater cells. A heater cell is essentially an electrically heated milled copper block containing an embedded thermocouple. Control software interfaces with a data acquisition module acquiring data every second. The data from multiple thermocouples and sensors is analyzed and within a second, adjustments are made to the watt density of the heater cells. These adjustments are based on thermal load under and around the heater cell. This aspect of the technology facilitates the installation of aluminum or composite doublers over repair areas with embedded heat sinks. Also, ambient air temperature fluctuations are a non-issue due to the quick response of the system.

A heater cell can be any shape allowing it to fit into tight locations such as those found on airframe sections. Heater cells achieve close thermal contact with the aircraft structure either through vacuum adhesion using an integral vacuum port which adheres them to the surface or by more conventional means such as positive pressure, clamping or vacuum bagging. In many cases, heater cells can be deployed directly over fasteners with excellent results.

Heater cells are independently controlled and can operate at different watt densities. For example, as a heat sink under or near a heater cell equalizes in temperature with

the program target temperature, the watt densities of the heater cell are automatically lowered without any operator intervention. Another advantage of projection heating is the eradication of heat lamps, heat guns or quartz heaters to cure the requisite coatings. This is because these pre-treatments can be cured with heat produced by the heater cells after their placement is determined by a thermal survey. Significant timesaving can be realized by avoiding a make and break of a set-up several times during processing. Also, from a safety standpoint, elimination of heat lamps and other incandescent heat sources is a positive development.

During the heating process temperatures from selected thermocouples are displayed on the computer screen and updated every second. There is provision for changing specific values while the system is operating. Although data is acquired every second for control purposes, the data file generated by the software saves every tenth second. Also included in the system is a remote humidity sensor used to log relative humidity data in the general area of the repair for quality control purposes.

Once the set-up is deemed successful, pictures or digital images can be taken of the set-up so that the set-up can be reproduced at a later date on another aircraft by another technician. The previously captured images can be viewed from the set-up screen within the control software. The data file generated by the control software saves all settings including alarm, heater cell groups and digital images associated with the file. This file can also be used at a later date on another aircraft with the assurance that it is a reproducible event. All saved data can be displayed in spreadsheet format allowing graphing and plotting of any or all thermocouples.

Several aircraft have had thermal surveys completed on prospective repair areas for evaluation purposes. Other aircraft, the F16, B52 and CF18, have had bonded doublers installed.

For the F16, two different locations have had doublers installed using projection heating. The first one is on a Belgian Air Force F16 aft bulkhead supporting the verti-

AMPTIAC Wants Your Contributions

We hope you find this issue of the AMPTIAC Newsletter useful and interesting. You can help us to better serve you by your contributions, such as:

- Your comments on what you liked and disliked about the Newsletter
- Your suggestions for AMPTIAC data products and services
- Technical articles, opinion pieces, tutorials, news releases or letters to the Editor for publication in the Newsletter

To contact AMPTIAC, use any of the ways listed on the back cover, or use the feedback form on the AMPTIAC webpage.

Your contributions are always welcome.

cal stabilizer. The second doubler is on a US Air Force ANG F16 lower wing skin fuel vent hole. In that repair, a heater blanket was also used on the top side of the wing with all 24 heater cells on the lower side. All heat sources were controlled by the Zimac system. Images of this repair are available for viewing at <http://www.x-cd.com/zimac>.

On the B52, three thermal surveys have been carried out. Of special interest is one area where it is possible to cure multiple graphite doublers, in this case two, simultaneously. Previously, this repair was considered possible using a three-zone heater blanket. Also required were heat lamps, special controllers and heat guns. With the projection heating process it is possible to perform this cure in approximately half the time and with less equipment. In the case of the CF18, doublers are being bonded on the lower side of a wing attachment bulkhead. Sixteen heater cells are used for this repair.

With projection heating, the aluminum structure surrounding the repair area is heated to the desired cure temperature using heater cell technology and control system. In effect, the adhesive and composite patch are cured from

the bond line outwards as opposed to the conventional method, which injects heat from the patch face into the adhesive. With this one set-up the silane, epoxy primer and doubler are cured. This set-up does not need to be dismantled for each step of the process. Projection heating eliminates the need for heat lamps or other types of heating apparatus that would normally be required for bonded doubler installation.

The curing of bonded doublers with projection heating is such that it offers highly predictable and repeatable results. Further enhancements obtained from the use of projection heating are less operator dependency and reduced set-up time. It also builds on the current industry objectives related to improving the documentation aspects of bonded doubler installation through data acquisition and storage of all transpired events.

For more information on projection heating contact Zimac Laboratories Inc., 1241 Cascades Street, Chateauguay, Quebec Canada J6J 4Z2 Tel: 1-800-363-9120 Fax: (450) 699-9279 E-mail: zimac.labs@sympatico.ca ■

Bestsellers from AMPTIAC

Oxidation and Corrosion of Intermetallic Alloys (1996)

Provides an overview of intermetallic processing, structural and mechanical properties and applications; covers the behavior and endurance of intermetallics at high temperature and under oxidizing conditions; describes corrosion and oxidation phenomena at intermediate temperatures; focuses on one of the "Achilles' heels" of many intermetallics, "pecking," and corrosion and corrosion embrittlement that can occur at ambient temperatures; and covers ambient temperature aqueous corrosion and corrosion sensitive embrittlement properties. (416 pages)

Order Code: AMPT-1 Price \$136 U.S., \$204 Non-U.S. ■

Properties of Intermetallic Alloys, Volume I, Aluminides (1994)

This volume contains evaluated and analyzed data on the thermophysical and mechanical properties of cobalt, iron, nickel, ruthenium, scandium, titanium, and zirconium aluminides. (601 pages)

Order Code: AMP267 Price \$400 U.S., \$600 Non-U.S.

Properties of Intermetallic Alloys, Volume II, Silicides (1994)

This volume contains evaluated and analyzed data on the thermophysical and mechanical properties of silicides of cobalt, iron, molybdenum, niobium, nickel, rhenium, tantalum, titanium and zirconium. (570 pages)

Order Code: AMP268 Price \$150 U.S., \$225 Non-U.S.

NASP Bibliographic Database (1998)

This searchable database contains bibliographic records for nearly 600 technical reports written by contractors and government personnel supporting the National Aerospace Plane (NASP) program. These reports address various materials development efforts and technologies including high temperature intermetallics, ceramic matrix composites, and carbon-carbon. Also included are references to oxidation-resistant coatings for these high temperature materials. Access to the database is Windows-based and user friendly.

Order Code: AMPT-9 Price \$200 U.S., \$300 Non-U.S. ■