Four for Foam

Small businesses cooperate on innovative microwave kiln technology commercialization

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(Photo) A load of CFOAM is prepared for firing in a microwave-assist kiln.

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The Bulletin of the American Ceramic Society
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Although competition in materials innovation can be a cutthroat affair, cooperation among small innovators can be the best road to success. Here is a case in point.

Touchstone Research Laboratory, a small materials-based company, developed a new carbon foam material, known as CFOAM, which shows promise in several applications of interest to the Department of Defense.

Promising applications include composite tooling, blast energy absorbing panels and thermal protection systems. Touchstone produces CFOAM tools for the composites industry, using its carbon foam as the substrate, and applying a carbon

CFOAM composite tool for missile body application.

fiber/resin surface coating. Composite tooling is used for the manufacture of carbon and glass-fiber resin composite shapes. The tools must be made of a material that closely matches the coefficient of thermal expansion of the part being produced using the tool. This usually limits the choices to high-nickel alloys, such as Invar, and various forms of carbon. The alloys are significantly more costly to manufacture than CFOAM because of high nickel pricing and difficulty in machining. Comparable CFOAM tools may be one-half the cost. The weight of alloy tools also becomes severely limiting as composite parts become larger, such as those in next-generation aircraft. A weight reduction of approximately 30 percent is achieved using CFOAM tooling instead of alloys.

Because of its unique cellular structure, Touchstone's carbon foam is also effective an energy absorber. This means it can protect equipment and personnel from explosively-formed projectiles, and significantly reduce the weight of armor steel required for threat defeat. A stress-displacement curve demonstrates CFOAM's large capacity for energy absorption in tests where energy is absorbed in the structure of the foam as the cells collapse.

However, CFOAM's success may ultimately be attributed to saavy business practices as much as to cutting-edge research and development. Touchstone created the new material, in part, with funding from the United States Small Business Innovation Research program. Since 1982, SBIR has been instrumental in supporting entrepreneurial small companies as they commercialize technologies and products. The SBIR program is highly competitive and acts to stimulate high-tech innovation that meets specific R&D needs of the participating agencies. When a new material is of strategic significance, the SBIR is an example of how the government can greatly assist the push and pull of product development, which is of critical importance for small innovative companies.

As Touchstone scaled its CFOAM processes to commercialization, it had to find innovative technologies to achieve low cost and superior properties. One example is the use of Microwave Assist kiln Technology to shorten the processing time from days to hours, and reduce energy consumption.

To grasp the importance of MAT, it is first important to understand some of the properties of CFOAM. The carbon foam is made from coal in a high-pressure process. Green material properties, such as cell size and density, can be tailored for various applications. Large carbon-foam billets are fired under controlled atmosphere to convert the green foam into a strong product for machining to finished shapes.

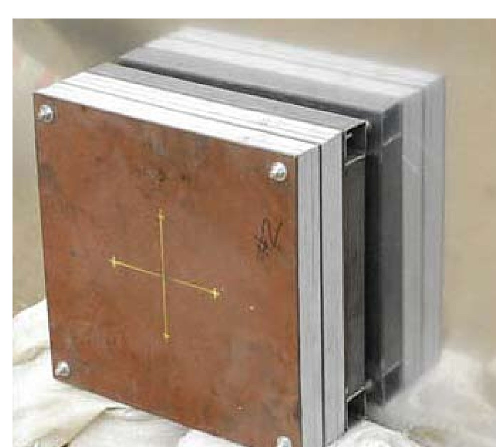
CFOAM is a poor thermal conductor and undergoes considerable shrinkage during processing that takes place in temperatures up to 1000°C.

Early on in Touchstone's scale-up efforts with CFOAM products, Harrop Industries was involved with toll firing and assisted in the development of firing curves using conventional furnace technology. As the demand for the product increased, a new manufacturing plant was built. Several large electrically fired atmosphere kilns were installed to process large batches of CFOAM. However, as is typically the case, large parts can demand longer firing cycles, to accommodate thermal gradients and prevent stress cracking. The optimized conventional process required seven days firing time.

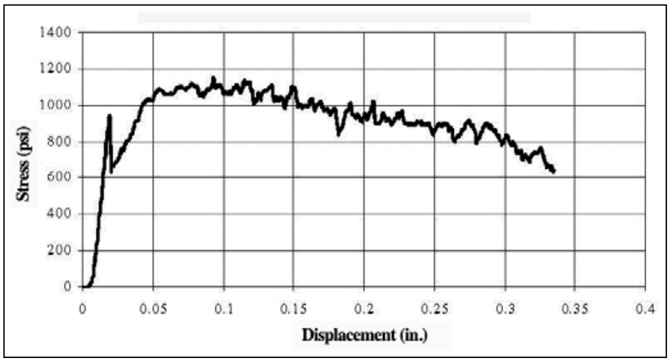
Because carbon materials are good absorbers of microwave energy, a new microwave-based approach to firing CFOAM was explored. Under a DOD SBIR Phase II contract to explore innovative processing methods, Touchstone worked with Ceralink Inc. to test the idea of using microwaves to improve heating uniformity and decrease the firing time.

Ceralink's Microwave Technology Center houses test equipment, and its engineers have unique training in microwave process development. In their laboratory, Ceralink demonstrated that microwaves could heat CFOAM five times faster than conventional heating and without cracking.

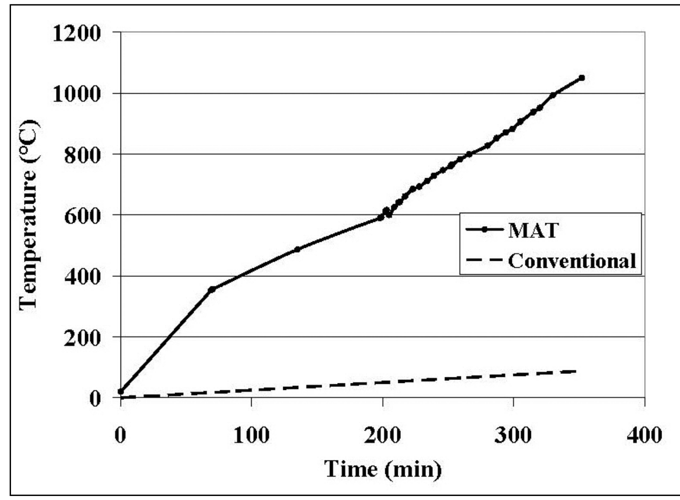
This work established feasibility and provided the data needed for scale up. The three firms determined that the best approach was to use MAT, a pat-



CFOAM blast energy absorbing panel.



CFOAM 17 stress-displacement curve.



MAT heating of CFOAM was five times faster than conventional oven methods for crack-free test blocks.

ented process that uses a combination of radiant heat and microwaves. The general potential for energy and time savings, as well as property improvements using MAT has already been well documented. (MAT was developed in the United Kingdom and is licensed by Ceralink. The company offers sublicenses, engineering services and equipment for its implementation.)

Although confidence was high that the process would be successful for large parts, there was still a risk in extrapolating from the test parts. Utilizing the SBIR program, a fourth company – Thermex Thermatron – joined the other three to design and build a world-first atmosphere-controlled MAT kiln.

The four companies combined had the needed expertise and equipment. Harrop was contracted to collaborate with Ceralink on the design and kiln material testing. Ceralink brought in Thermex Thermatron to supply the microwave power components and assist with the microwave kiln interface.

Touchstone successfully commissioned a 30-cubic-foot MAT elevator kiln, capable to 1620°C with atmosphere control. With the Harrop-Ceralink-Thermex team, the MAT kiln was put together seamlessly at Touchstone's West Virginia production facility, where it is achieving significant cycle time and energy consumption reductions.

Thus far, the firing cycle has been decreased from approximately 72 hours to less than 15 hours, and there is room for further optimization. The next step is to develop a MAT firing profile for CFOAM. Ceralink is developing modeling software to predict heating behavior, which will be useful in future MAT scale-up and optimization.

This approach serves as an example of the successful commercialization of a technology with funding support by the SBIR program. A similar program, the Small Business Technology Transfer Program, uses a similar approach to the SBIR program to expand public/private sector partnerships between small businesses and nonprofit U.S. research institutions.

On the technical side, MAT may be applied to processes throughout the ceramics and composites industries to save time and energy, and in many cases improve the properties of the finished product. The MAT kiln at Touchstone has already been used by Ceralink to speed up the firing of another product, one for Blasch Precision Ceramics. This material in this application is a ceramic composite of alumina and silicon carbide abrasion-resistant sleeves for the power-generation industry. After feasibility testing at Ceralink, a production firing was performed demonstrating seven-times-faster firing, as well as energy savings. A wide variety of ceramic products, including dental ceramics, wear parts, varistors, pigments, capacitors and nanoceramics, also have been effectively processed using MAT.

Because of the SBIR funding route, Touchstone, Ceralink, Harrop and Thermex have successfully proved a high-risk, high-reward technology that will continue to find new markets within the ceramics and composites industries.

About the Authors

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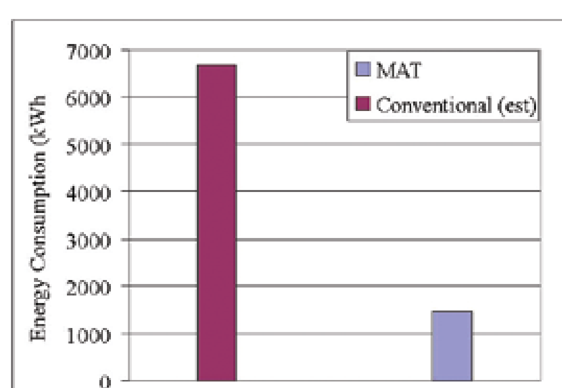
Editors Note

For more information on Small Business Innovative Research and Small Business Technology Transfer programs, see sbir.gov or syn.com/sbir.

For additional information on the companies involved in this project, see trl.com, ceralink.com, harropusa.com and thermex-thermatron.com. ■



Comparison of energy consumption during firings of Blasch's abrasion resistant tubes.