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CARBON MICROSPHERE/FIBER/POLYIMIDE
BINDER SYNTACTIC COMPOSITE

PDO 6984899, Topical Report

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Topical Report

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CARBON MICROSPHERE/FIBER/POLYIMIDE BINDER SYNTACTIC COMPOSITE

BDX-613-1636 (Rev.), UNCLASSIFIED Topical Report, Published
September 1976

Prepared by R. J. McWhirter, D/861, under PDO 6984899

A manufacturing process for syntactic foam billets has been developed, and the progression through the mixing, blending, and molding operations is discussed. With basic requirements for a lightweight, thermally conductive, high strength foam, resolution was attained in a mix of a polyimide resin, carbon microspheres, and graphite fiber.

WPC-dvh

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SUMMARY

A process was developed to blend, mix, and mold a syntactic foam composite which can be machined into a final part configuration for case supports. The initial material selected was Imidite X-386 (Whittaker Corporation, San Diego) which was evaluated on PDO 6984878, *High Temperature Syntactic Foam*.¹ The material currently used is a composite of a polyimide resin (Kerimid 601, Rhodia Inc.), carbon microspheres, and a graphite fiber (Thornel VMA, Union Carbide Corporation).

Shortly after the initial material selection was made, new design criteria were received, requiring a material with a higher thermal conductivity. The following additional materials^{2,3} were then evaluated:

- Thermalthane 4003, with aluminum powder and graphite fibers;
- Aluminum honeycomb filled with urethane foam; and
- Kerimid 601 and carbon microspheres.

The third material was selected primarily because of its high compressive strength and retention at high temperature, although it did not have the thermal conductivity desired. Chopped graphite fibers were added at a later date to improve the thermal conductivity and to improve the flexural strength. However, the addition of chopped graphite fibers created a difficult mixing and blending operation, because the chopped fibers did not disperse throughout the material uniformly. In addition, the machined billets manufactured with chopped graphite fibers had numerous surface voids and protruding fibers. The chopped graphite fibers were replaced with Thornel mat grade VMA, improving both the dispersion of the material during the mixing process and the machined surface of the part. Thornel mat is also a graphite fiber, but it is nonoriented and is much longer than the chopped graphite fiber.

Mixing and blending processes, as well as a molding process, have been developed, which provide a billet of material that can be machined with a satisfactory surface finish. The compressive strength, density, thermal conductivity, and thermal resistance are predictable and well within the allowable range. Evaluation of test results indicated a density variation of +3 and -7 percent within the molded ring billet.

Future work will require optimizing the size of the billet molds to conserve material, possible reduction of the postcure time, and evaluation of a vibration table to replace the tamping method performed by the operator.

DISCUSSION

SCOPE AND PURPOSE

Structural parts for mechanical support and thermal protection are required for a current program. This project was initiated to develop a production capability in the processing of a syntactic foam material. The activities discussed in this report cover one endeavor on Process Development Order 6984899, *Syntactic Foam Insulators*, requiring scale-up in batch size from the small laboratory mixing, blending, and molding of test slabs and coupons to the production-size batch and full-size billets. Parts machined from this syntactic foam are to support development hardware and subsequent production schedules. The current plan is to mold billets (Figure 1), which can be machined into Inner and Outer Supports (Figure 2). Final machining of these parts is a slitting operation wherein the Inner Support is cut in half and the Outer Support is cut into four segments.

PRIOR WORK

Original material selection, accomplished on PDO 6984878, was reported in BDX-613-1534.¹ The initial material selection was Imidite X-386, a glass microballoon and polyimide resin blend, manufactured by Whittaker Corporation, San Diego. Molding of the Imidite billets was accomplished by using the basic molding process obtained while making a much smaller part, the Pedestal for a past program.⁴ No mixing or blending were required, since the material was furnished as a partially polymerized, premixed compound from Whittaker Corporation. The processing steps to produce ring-shaped billets from the Imidite X-386 material are listed in Appendix A. The billet size is 203.6 mm ID by 279 mm OD by 101.6 mm long (8.0 ID by 11.0 OD by 4.0 inches long). No further development work with the Imidite material is planned on this project.

ACTIVITY

Shortly after Imidite X-386 had been selected,^{5,6} new product requirements for higher thermal conductivity and reduced thermal resistance were received. Considering these criteria, the elevated temperature properties of the Imidite would make this material too costly. In addition, the future availability of Imidite was a potential problem. Therefore, it became necessary to evaluate additional materials.

Figure 1. Ring Billets for Inner (Right) and Outer (Left) Supports

Figure 2. Inner (Right) and Outer (Left) Supports, Machined

Description of Materials

A polyurethane foam, an aluminum honeycomb, and a syntactic material were all selected as candidates to evaluate as replacements for the Imidite X-386.

Polyurethane Foam

One of several alternate materials considered for a replacement for Imidite was Thermathane 4003 foam, with chopped carbon fiber as a filler material. The initial billet had 8-percent-by-weight chopped fiber, but it was so viscous that it did not mix well. Several billets were made, using a smaller percentage of chopped fiber. However, this provided very little improvement in thermal conductivity.

During the same period, aluminum powder was used as a filler material with identical results.

Aluminum Honeycomb

Another alternate material considered as a replacement for the Imidite was an aluminum honeycomb, using various fillers. The aluminum honeycomb was to furnish the increased thermal conductivity requirement, with the fillers providing additional strength. The aluminum honeycomb selected was a 6.35-mm (0.25-inch), hexagonal cell of 0.0254-mm (0.001-inch) thickness.

Parts and coupons were made, using epoxy, phenolic, silicone, and polyimide resin, all of which were to use glass microspheres as a filler. Radial orientation of the hexagonal cells was considered because longitudinal orientation interrupted the conductive path when machined to the part configuration. Later, an additional process, using aluminum plasma spray, was attempted in order to enhance conductivity on the inner surface of the Inner Support. Tests conducted by the Design Agency revealed that the aluminum honeycomb was detrimental to the weapon's function. Therefore, further development work on honeycomb was discontinued at Bendix and the Design Agency, and work commenced on the prime alternate material, composed of Kerimid 601 polyimide resin and carbon microspheres.

Kerimid 601 and Carbon Microspheres

The Kerimid 601/carbon microsphere composite became the prime candidate because of its density, compressive strength, and thermal conductivity.⁷ A brief description of each of the components follows.

Kerimid 601 Polyimide Resin. Made by Rhodia Incorporated, France, this material is an addition-type polyimide as opposed to the condensation type. With the addition type, the polyimide linkage is formed before final cure. The addition type is preferred in this application because the condensation type polyimide linkage is formed during the final cure, with the loss of water. Also, the addition reaction provides a process in which essentially no weight loss or shrinkage occurs during cure. The Kerimid 601 is a dry, fine, yellow powder with a melt temperature range of 90 to 110°C (194 to 230°F) and a density of 1.3 g/cm³.

Thornel Mat Grade VMA. This product is procured from Union Carbide Corporation. The mat is composed of high-strength, high-modulus carbon or graphite filaments in a random-layered orientation. The filaments, which are 25.4 to 76.2 mm (1 to 3 inches) long, are mechanically bonded to form a continuous web of material. The material is procured in various thicknesses 0.56 m wide by 12.2 m long (22 inches wide by 40 feet long). The diameter of the filament is 8 μm (0.00032 inch).

Carbon Microspheres. Versar Inc. manufactures this material under the trade name *Carbo-Spheres*. This material is in the form of small, thin-walled, hollow, carbon spheres. The bulk density is 0.13 to 0.14 g/cm³, with particle size of 5 to 150 microns. The TGA in nitrogen shows a weight loss of 2 to 4 percent at 700°C, with an ash content of approximately 2 percent. The elemental analysis shows the microspheres to be 90-percent carbon, with the major constituents of the ash being sodium and silica. The outgassed products by mass spectrometry are water, air, carbon monoxide, and carbon dioxide. These tests indicate that the microspheres are essentially inert carbon and are thermally stable in an inert atmosphere.

Carbon Fibers (Type AS). This material was the initial additive to the Kerimid 601/carbon microsphere composite, to improve the thermal conductivity of the mixture. Carbon Fibers (Type AS) material, which is procured from Hercules Incorporated, is made from graphite rope, placed in a chopping gun, and furnished in 6-, 3-, and 1-mm lengths. The 6-mm fiber had a type MS sizing for thermoset materials, but the 1- and 3-mm lengths did not have any sizing. Milled fiber, approximately 0.1 mm (0.004 inch) long was made from the 1-mm fiber by grinding it in a mulling mill.

Composite Properties of Kerimid 601/Carbon Microspheres. Current requirements are as follows:

Thermal Conductivity	0.376 W/m · K
(minimum)	(4 x 10 ⁻⁴ cal/cm · s · °C)

Compressive Strength at 20°C (minimum)	4.86 MPa (700 psi)
Compressive Modulus at 20°C (minimum)	207 MPa (30,000 psi)
Density (maximum)	0.30 g/cm ³
Survive Impulse Test (minimum)	2000 taps $\left(\frac{\text{dyne-sec}}{\text{cm}^2} \right)$

Material Mixing and Blending

The initial time required to mix Kerimid 601 resin and carbon microspheres was 1 hour, to achieve a homogeneous mix, using a Twin Shell Blender (Figure 3).

The introduction of graphite fibers to the blending operation added an important variable to the process. The fibers are chopped to a length of 6 mm from a graphite rope. Separating these fibers from the bundles and dispersing them uniformly throughout the Kerimid 601/carbon microsphere mixture became a significant problem.

One method of separation was to place the fibers in the Twin Shell Blender with the intensifier bar (Figure 4) in an attempt to separate the fibers within the bundle prior to introducing the Kerimid 601/carbon microspheres. This method did a fair job of separating the bundles; but after introducing the Kerimid 601/carbon microspheres, the fibers did not disperse well.

The other method, which was more successful, was to place the bundles of fibers in the blender on top of the Kerimid 601/carbon microspheres and blend the mixture, using the intensifier bar. This method, which provided better results, was continued with the objective of improving the process.

Time was varied from 30 seconds to 8 minutes, and the blades of the intensifier bar were varied from L-shaped, straight, (Figure 4) to Y-shaped. Many batches of material were blended with variations of as little as 15 seconds from one blend to the next.

The L-shaped blades seemed to bunch the material around the blades. In an attempt to minimize buildup on the blades, straight blades were fabricated. These blades did not achieve quite as good blending and dispersion results, and the blending time had to be increased. Y-shaped blades, which were then evaluated, gave good results without the buildup on the blades.

Figure 3. Twin Shell Blender

Figure 4. Twin Shell Blender With Intensifier Bar and Beater Blades

The equipment manufacturer, Paterson Kelley Inc., suggested that the problem could be partially overcome by doubling the batch size. All batches up to that point had been 5000 grams of the Kerimid 601/carbon microsphere mixture with 250 grams of fibers. In order for the equipment to function properly, the material level should be over the intensifier bar.

The batch size was increased to 11,000 grams of the Kerimid 601/carbon microsphere mixture and 550 grams of fibers. This changed the quality of the blend significantly. However, this improvement still did not produce an acceptable blend.

Experimentation with Thornel mat showed that it eliminated the problem by thoroughly dispersing throughout the Kerimid 601/carbon microsphere mixture. The physical properties of the mat were similar to those of the fiber. Therefore, this change in materials was incorporated into the design. The development work was terminated after a few batches which included Thornel mat were successfully blended.

The following process, conducted entirely within an area controlled to 10-percent maximum relative humidity, is currently in use for mixing and blending.

1. Sieve the drum of Kerimid 601 through the Sweco Vibro Separator (screen size 4, 5, and 20 mesh).
2. Sieve the drum of carbon microspheres through the Sweco Vibro Separator (screen size 4, 5, and 20 mesh).
3. Weigh out materials to the recipe below.
4. Blend the Kerimid 601 and carbon microspheres in the Twin Shell Blender for 1 hour at 25 rpm, without the intensifier bar.
5. Add Thornel mat, and blend for 2.5 minutes (25 blender rpm) (2000 intensifier bar rpm), using the "Y" beater blades.

Material Recipe

Blend, parts-by-weight, 40/60/5:

- Kerimid 601, 4400 grams;
- Carbon microspheres, 6600 grams; and
- Thornel mat grade VMA, 550 grams.

Molding

The molding operation consists of loading the mold, packing, curing, closing the mold, and then post curing the part outside

the mold. Loading of the mold is accomplished by adding a small amount of material to the mold and tamping the material with a rod (Figures 5 and 6). It is necessary to repeat this procedure several times to completely fill the mold, and this technique helps to rid the mixture of excess air. The cap is placed loosely on the mold, and the mold is placed in an oven which has been preheated to 191°C (375°F). When the mold temperature reaches 121°C (250°F), the mold is removed from the oven, placed in the press, and pressure is applied to the mold cap to close the mold. The mold is again placed in the oven and left for 1 hour.

The strip pins operation is conducted next in two stages. First, the inner ring detail of the mold is removed; the mold is again placed in the oven for cooldown, and the remaining details are removed. The billet is then placed in a retort for postcure under an argon or nitrogen flood (to prevent oxidation) at elevated temperatures. The mold details are then cleaned, and mold-released in preparation for the next molding operation.

Initial molding of coupons and test slabs indicated that the part volume and charge weight relationship would require a compression operation to obtain the density required. By increasing the resin ratio slightly, the force required to close the mold is decreased. If the resin ratio is increased to a point where no force is required, the possibilities of voids in the billet, or a mold without a complete fill of material, are greatly increased. If the resin ratio is decreased, the force required to close the mold becomes greater; thus, breakage of microballoons, non-closure of the mold, or higher density at one end of the billet can all occur. Ideally, a small amount of mold closure (Figure 7) is desirable to ensure a full mold and removal of some of the excess air.

The syntactic postcure temperature profile is shown in Figure 8. As shown, the heat cycle temperature difference is in excess of 37.8°C (100°F). However, equilibrium is reached in approximately 1 hour. During cooldown, the temperature does not exceed a 10.0°C (50°F) difference, and the slope is spread over 4 to 5 hours to reach the part removal temperature. The Kerimid 601 resin and carbon microsphere mixture (without the Thornel mat) is slightly less responsive to temperature. The 16-hour cure was developed on a convenience basis; that is, by loading the oven at the end of the work shift, the operators could turn off the oven upon arrival the following day and allow time for cooldown. This eliminated the need for an operator on the next shift, who would only be there to turn off the ovens. It is known that a cure of 3 or 4 hours is required to maintain compressive strength; however, yet to be determined are the effects on other parameters before a process change can be made, to decrease the cure time. Figure 9 shows the part in process of being removed from the mold.

The molding process currently in use is outlined in Appendix B.

Figure 5. Tamping Material in Mold

Figure 6. Operator Loading Mold

Figure 7. Closing Mold

Figure 8. Postcure Temperature Profile for Kerimid 601/Carbon Microballoons

Figure 9. Removal of Part From Mold

ACCOMPLISHMENTS

- Process techniques were developed to prepare, blend, and mix production-size lots of syntactic composite material components.
- Techniques were developed to mold ring blanks for machining the Inner and Outer Supports.
- The surface finish, compressive strength, density, thermal conductivity, and thermal resistance are predictable and within the allowable range.

FUTURE WORK

Additional evaluations are necessary in the mixing and blending operations, and in molding of syntactic billets. Evaluation of a vibration table as a method to replace the tamping method by the operator may result in a more uniform initial packing method. Evaluation of a Vibro-Fluidizer as a replacement for the sieving operation (Vibro Separator) is also a potential process improvement.

Optimizing the ring blank mold size to minimize the amount of material required for each type of mold also remains to be accomplished. In addition, it is anticipated that the postcure time of 16 hours can be reduced significantly; however, the effects on parameters other than compressive strength remain to be evaluated.

Other work on the project, although of comparable significance, is outside the scope of this report on mixing, blending, and molding of billets. Included are the following activities: bonding of other pieceparts to the syntactic material; molding-to-size as a backup process; processability of a backup material; machining; handling of fragile parts; and evaluation techniques.

REFERENCES

¹H. M. McIlroy, *High Temperature Syntactic Foam* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1534, June, 1976.

²P. B. Rand, *An Aromatic Polyimide Syntactic Foam*. Albuquerque: Sandia Corporation, Report SC-DR-710131, May, 1971.

³H. M. McIlroy, *Fabrication of Polyimide Syntactic Foam Parts* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-582 (Rev.), December, 1971.

⁴D. D. Smith, *Syntactic Foam Evaluation* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-177, March, 1971.

⁵A. H. McLeod, *Development of Imidite SA Foam Tests and Material Specifications*. San Diego: Whittaker Corporation, Report D688346, June, 1969.

⁶H. M. McIlroy, *Evaluation of a High Temperature Syntactic Foam* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1178 (Rev.), June, 1974.

⁷H. M. McIlroy, *Thermally Conductive Syntactic Foam* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1409, December, 1975.

Appendix A

PROCESS FOR MOLDING IMIDITE
SA X-386 RING

Appendix A

PROCESS FOR MOLDING IMIDITE SA X-386 RING

1. Disassemble and clean mold, using Acetone. Apply Frekote 33 mold release, and bake for a minimum of 30 minutes at 204°C (400°F). Assemble mold except compression ring and top plate.
2. Weigh out material as required. Place approximately one-half of material into mold cavity. Tamp material to bottom. Load remaining one-half of material into mold, and tamp.
3. Tape thermocouple lead to inside diameter of inner mold detail. Feed lead through hole in top plate.
4. Assemble compression ring into mold and top plate on top of compression ring.
5. Place mold into oven preheated to 149°C (300°F). Monitor thermocouple temperature. Remove mold from oven when mold temperature is 121°C (250°F) (approximately 1 hour). Place mold in press, and close mold. Lower oven temperature to 121°C, and return mold to oven for 1 hour. [NOTE: On thicker parts, oven preheat is 177°C (350°F), and mold temperature is 138°C (280°F) for material temperature to be 121°C at mold closure.]
6. Remove mold from oven, and remove top and bottom plates. Support mold on blocks, and press inner ring from mold.
7. Place mold and part in vacuum chamber in oven preheated to 121°C. Evacuate chamber to 10 mm Hg, and start cure cycle, using cam, as below. Maintain vacuum during complete cure cycle.

Time (Hours)	Temperature (°C) (°F)	
0.5	149	300
1	177	350
1	204	400
1	232	450
1	260	500
1	288	550
0.5	316	600

8. Remove part from chamber after cooldown. Place part in oven retort, and flood with argon gas. Post cure part, using cam, as below. Maintain argon flood during post cure.

Time (Hours)	Temperature	
	(°C)	(°F)
2.5	Room temperature to 371°C (700°F)	
1	371	700
1	427	800
0.5	427 to	800 to
	454	850

9. Remove part. Measure diameters and height; weigh, and package.

Appendix B

PROCESS FOR MOLDING KERIMID
601/CARBON MICROSPHERES/FIBER

Appendix B

PROCESS FOR MOLDING KERIMID 601/CARBON MICROSPHERES/FIBER

1.0 MOLD LOADING

- 1.1 Weigh out material according to Table B-1. (In the case of special parts, weigh out material according to the Process Engineer's instructions.)
- 1.2 Position mold on stand in front of hooded bench.
- 1.3 Fill mold. Stop at various stages to tamp the material.
- 1.4 Place cap on mold.

2.0 CURING

- 2.1 Preheat oven to 191°C (375°F).
- 2.2 Load mold; thermocouple inside diameter of inner ring.
- 2.3 Heat mold to 121°C (250°F).
- 2.4 Close mold.
- 2.5 Return mold to oven. Hold mold in 191°C (375°F) oven for 1 hour.
- 2.6 Remove from oven; strip inner mold detail, and return to oven for cooldown.
- 2.7 Cool oven, and remove mold when oven temperature is 93.3°C (200°F), or lower.
- 2.8 Remove part from mold when cool enough to handle, and post cure for 16 hours at 249°C (480°F) under argon flood.
- 2.9 Weigh part; record. Label part with S/N and set number.

Table B-1. Specifications for Inner and Outer Rings

Mold	Tool	OD (mm) (in.)	ID (mm) (in.)	Height (mm) (in.)	Charge Weight (40/60/5)* (grams)
Inner Ring	6984899- 002	277 (10.9)	160 (6.30)	260 (10.25)	3270
Outer Ring	6984899- 003	328 (12.9)	257 (10.10)	191 (7.5)	2000
*Density = 0.30 g/cm ³ .					

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