ADVANCED AEROSPACE INSULATION FINDS MANY USES IN INDUSTRIAL APPLICATIONS

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High performance microporous-based insulating products-the most efficient high temperature systems currently available-used by today's technology-driven aircraft manufacturers are also finding wide acceptance in industrial applications.

Microporous engineered systems range from partial encapsulation using metal foil to soft fabrications using a variety of textiles.

Design considerations for highly efficient thermal insulation systems for use in the aerospace industry led researchers to define an optimum theoretical thermal insulation. This is based on minimizing the primary modes of heat transfer involving the simultaneous action of solid conduction, gas conduction, and radiation and convection currents. A product model was required that could meet specific criteria including:

- Optimization of thermal performance without the use of a vacuum
- Service temperature use limit to 1000°C (1830°F)
- Very light weight
- High compressive strength
- Little or no out-gassing in service

The result of this research was a product consisting of a microporous fumed silica powder insulation quilted between two layers of fiberglass cloth. Microporous insulation accomplishes its excellent thermal performance through using a combination of fine particle packing, special material additives and precise production techniques.

MICROPOROUS INSULATION CHARACTERISTICS

The advantage of microporous insulation is its greatly reduced thermal conductivity for a given thickness compared with conventional insulation products. At 1000°F (538°C) for example, microporous insulation has a thermal conductivity 1/3 that of ceramic fiber blanket and 1/4 that of 2300°F (1260°C) class insulating firebrick (Fig. 1). Therefore, 1 in. (25 mm) thick of microporous insulation, such Thermal Ceramics' BTU-Block(tm), will give approxi-mately the same heat transfer results at 1000°F as 3 in. (75 mm) thick ceramic fiber blanket, or 4 in. (100 mm) thickness of equivalent class IFB (insulating firebrick).

Other benefits of microporous insulation products, in addition to their very low thermal conductivity and heat storage, are resistance to excessive compression and very low shrinkage. These materials resist extensive compression under heavy loads with little degradation of their thermal conductivity characteristics. Compression of the insulation actually improves its uniformity and thermal performance as it slightly deforms, and, unlike typical rigid insulation systems, microporous insulation products do not reach a critical load/deformation point. They have very low shrinkage in use as backup insulation at temperatures to 1800°F (982°C). The insulation also is easily installed in most applications, typically using fiber cements or sodium silicate to keep them in place.

FORMS OF MICROPOROUS INSULATION

Forms of microporous insulation systems, such as BTU-BLOCK™ and Min-K® from Thermal Ceramics, include panel, boards and shapes, flexible, ladle liner and moldable (Figs. 2 and 3).

Panel is a lower density product encapsulated in fiberglass textile, which provides mechanical protection, flexural strength and a substrate for bonding to walls or other insulation. The material offers high strength, good rigidity, low cost and the ability to be made in a variety of shapes/sizes.

Boards and shapes are rigid products with the highest density and greatest structural integrity of the microporous products and are avail-able in a variety of sizes and configurations.

Flexible product consists of the microporous core encapsulated between layers of high-temperature cloth and quilted in 1 in. (25 mm) squares. The quilting maintains core distribution in high vibration envi-ronments and allows the insulation to be wrapped or bent to conform to unique shapes during installation.

Ladle liner is fabricated much like the flexible product, but with parallel stitching to allow it to be wrapped around cylindrical or round vessels like ladles and crucibles.

Moldable product is a moist form of microporous insulation, which can be toweled or hand-placed into areas where other insulation systems cannot be installed. It is an excellent option for use in custom applications that lack engineering design support or for field fabrication work.

Certain applications have special considerations that require nonstan-dard material options. For example, a special hydrophobic core mate-rial for BTU-BLOCK products is used in certain applications to allow wet products like refractory castables to be placed directly on the microporous insulation without deterioration of the product structure. Thin foil coatings can be applied to increase the strength of the fabric coated microporous products (Fig. 4). A range of material densities from 14 to 25 lb/ft3 (224 to 400 kg/m3) allows selection to meet specific compressibility resistance requirements or cost constraints.

A new composite product combines the company's K-Shield® Felt AG with a microporous insulation core in a quilted form. The composite product is lighter than typical microporous insulation, 11 versus 16 lbs/ft3, without sacrificing insu-lation performance. By using the 2300°F felt material on the hot face side, the composite can be used at higher tem-peratures than the rated use temperature for the microporous core alone.

USES IN AEROSPACE INDUSTRY

The aerospace industry often requires high performance thermal management systems that maintain consistent operating temperatures, or that provide a fire barrier in addition to accomplishing their traditional goal of containing heat. These challenges may be combined with those of high vibration environments, space constraints and weight limitations.

Flexible and molded microporous insulation delivers the physical characteristics, durability and dimensional configurations needed for aerospace applications. Standard sizes or fabricated products meet customer requirements for immediate installation.

Flexible insulation is a composite system consisting of a microporous core contained between high-temperature textile facings. The system is then quilted with high-temperature thread in one-inch squares to maintain core distribution while creating a flexible blanket. The thickness ranges from 0.125 to 0.500 in. (3 to 13 mm), with core densities of 8, 10 and 16 pcf. The quilted composite can be cut and fabricated into unique geometric shapes and used in place of traditional fibrous insulators, often reducing required thickness by 50 to 75%. Maximum standard temperature ratings (500, 1200 and 1832°F) typically are determined by the outer textile facing.

Flexible microporus insulation is used extensively in the aerospace industry in a variety of applications including insulating engine nacelles, or encasements, to prevent heat loss from the engine. This improves internal operating temperature consistency, increasing operating efficiency and protecting the outer casing. By passing qualification in a standard 2000°F/15 minute performance test, the product is also used as a fire barrier on auxiliary power unit enclosures. It also is used to insulate landing gear struts.

Molded microporus insulation is also used in various aerospace applications, most commonly as fire protection for flight data recorders (FDRs), often referred to as "black boxes." It can be pressed into a metallic casing and then machined to shape, or parts may be machined from standard molded board into freestanding enclosures. The material's exceptionally low thermal conductivity maintains the internal contents of the box, specifically the data collection system, at low temperatures to ensure recoverable data after a simulated fire.

The test procedure exposes the systems to 2000° F (1095°C) for one hour, using maximum internal temperature requirements based on the recoverability of data collection following the test. While the molded insulation offers extremely low thermal conductivity, the need for smaller FDR units, as well as units that can survive longer fire tests prompted the development of an improved system. A Molded Min-K formulation containing an endothermic component reacts to absorb heat at elevated temperatures. While the endothermic material does not alter the final steady state heat flux through the insulation, it takes the system longer to reach steady state, thus improving the overall performance of the system.

In addition to the fire tests, Min-K in FDR applications has also passed several stringent, durability tests intended to simulate aircraft impact upon failure.

INDUSTRIAL APPLICATIONS

Conventional refractories such as firebrick and castables have long been the workhorses of high-temperature lining construction. Given the energy-intensive nature of typical process industries like steel and non-ferrous metals and the rising trend in fuel costs, heat-processing equipment requires efficient, consistent backup insulation systems.

High-performance products such as microporous insulation are now meeting the stringent thermal insulation needs of industrial applications, and are beginning to find wide acceptance. Decreased thermal conductivity in the lining construction through the use of products like BTU-BLOCK insulation can have great energy saving benefits.

For example, several types of ladles, such as plant transfer and over-the-road ladles are ideal applications areas for microporous insulation. Ladles typically use lightweight castable, insulating firebrick or thin fiber insulation behind the hot face refractory. Microporous insulation as the backup product (Fig. 5) results in lower heat loss, ensures that the molten metal does not solidify should the metal stay in the ladle for extended periods and helps reduce the overall lining thickness so more volume is possible inside the ladle.

The following example illustrates the benefits to a large steel plant of using microporus insulation in ladles to minimize degradation of the expensive ladle shell due to hot spots and high shell temperatures and increase the safety of bot-tom pour ladle operation. The company also wanted a durable material to replace previous fiberboard systems that failed. Installing 0.375-in. (9 mm) thick BTU-BLOCK Board as backup in the 200-ton ladle reduced the outer shell tem-perature by 15%. Furthermore, reduced heat loss allowed emptying the ladle completely prior to metal solidification, process flow flexibility was improved due to a quicker cool down rate of heated ladles, and product quality was improved due to better molten metal homogeneity.

In another example, a primary aluminum producer wanted to reduce the thickness of its carbon bake furnace tubwalls to allow widening pit dimensions to incorporate larger anodes for electrolytic pots. A new design incorporating BTU-BLOCK insulation reduces the overall tubwall thickness by 6 in. (152 mm) while lowering the theoretical heat loss transfer by 30% vs. current tubwall design.

Aluminum casthouses and continuous cast steel facilities also are using significant amounts of microporous insulation in long launder sections to help keep the molten metal from solidifying and also in filter boxes and tundishes to keep the metal hot. This also helps eliminate the need to superheat the molten metal, which saves energy costs.

Other industrial applications for microporous insulation include backup in ceramic tunnel kilns, aluminum melter furnaces, chemical processing ethylene units and ceramic feeder bowls.

SUMMARY

The use of lightweight, ultralow thermal conductivity microporous insulation, such as BTU-BLOCK and Min-K products, in composite insulation systems offers several benefits including:

- Reduced energy consumption by minimizing heat loss through the lining
- Improved process flow by minimizing cool-down time in cyclic operating equipment
- Increased product output through the opportunity to reduce overall insulation thickness, thus increase equipment capacity in applications such as ladle linings
- Increased equipment life whereby the potential for a thinner insulation layer allows for an increase in the thickness of the refractory working lining
- Improved safety conditions around high temperature processes