Silicon Nitride-Bonded Silicon Carbide: A New Spin on a Proven Wear Product

Recent advances have led to improvements in wear resistance and thermal shock behavior, allowing SNBSC to reach new audiences and applications.

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For decades, silicon nitride-bonded silicon carbide (SNBSC) has been the de facto cost-effective material for many wear and corrosion applications. This material has a broad range of uses and can be formed into specialty custom shapes through a variety of methods. SNBSC has stood the test of time, with desirable properties such hardness, strength, thermal shock resistance and non-reactivity in many environments.

Typical Uses

SNBSC is a versatile material that finds use in areas including power generation, mining, non-ferrous molten metal contact, material processing and conveying. Power generation applications include material handling and environmental control in coal power. For instance, wear blocks, conical diffusers and deflectors are used prior to combustion for both wear reduction and to properly disperse coal/air mixtures for efficient combustion.

After combustion, flue gas scrubber nozzles for environmental control are a significant use worldwide for SNBSC, as well as the limestone slurry preparation and delivery systems that feed them. These scrubber systems are designed to reduce the amounts of sulfur and mercury that make it into the atmosphere.

The material's abrasion and chemical resistance attributes are useful in mining. Hydrocyclones, liners, apexes, inlet heads and vortex finders are common uses of SNBSC. The material also finds applications in material handling, particularly where mining material is redirected during conveying.

Molten metal contact applications use shapes such as pump parts, thermocouple protection tubes, and rotary degassers that benefit from the non-wetting behavior of this material. While not applicable to steel, SNBSC is compatible with non-ferrous molten metals such as aluminum, brass, copper and zinc.

Finally, SNBSC shapes are often used in powder milling equipment and wear linings for material handling such as frac and foundry sand, coal and limestone fines, and other materials. Commonly used shapes include pneumatic and mechanical pipe linings (straights and elbows) for conveying. SNBSC can be installed in fiberglass or metal housings with the appropriate connection styles to facilitate field installation.

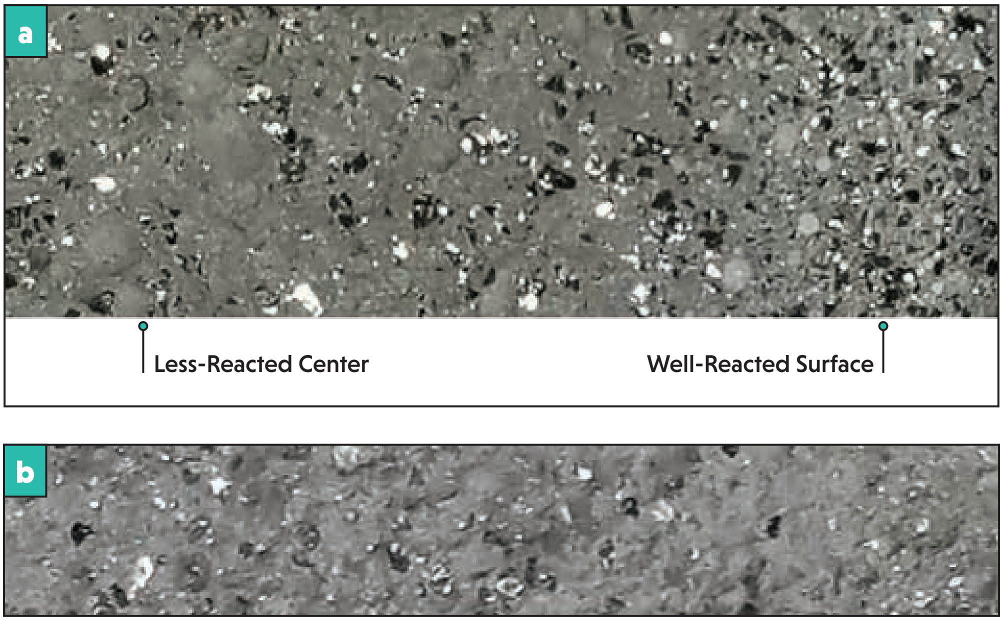

Figure 1 A traditional SNBSC material (a) will typically have a well-reacted outer layer and a less-reacted center, while the new material (b) is uniformly reacted throughout.

Basic Process/Limitations

On the surface, the SNBSC manufacturing process seems straightforward, but it has many subtleties. Raw materials include silicon carbide of varying grain size combinations and elemental silicon, as well as other processing aids. The silicon metal, in particular, has a fine particle size and therefore high surface area. This surface area increases reactivity during the nitriding step, where the presence of nitrogen gas converts the silicon into silicon nitride at temperatures generally in excess of 1,300°C.

Shapes can be created by casting, pressing or extruding, depending on the quantities and geometries required. Many variables in the raw materials and processing techniques used by various manufacturers can result in wide variations in performance. Unlike metals, no standards exist for most ceramic materials; the properties, performance and consistency are therefore dependent on the manufacturer.

Traditionally, SNBSC does have some limitations. Because the reaction is gas/solid, and the formation of the silicon nitride bond phase takes place within existing porosity, a structure difference generally results between the surface and the centers of thick cross section parts. The parts are often reacted well in the first 3/8-1/2 in., and not as well as the reaction proceeds deeper. This "candy coating" is not always a problem, as the well-reacted layer is sufficient for the life of the part in many cases. In some especially severe applications, however, it is not.

New Development

An unusually demanding application involving the redirection of mining material led to the development of a new SNBSC material.* Unscheduled downtime is problematic for this application due to its remote location, and this led to the creation of a fully reacted material with predictable wear performance. The new SNBSC material was created through a proprietary combination of raw materials, particle packing optimization and processing variables. While traditional SNBSCs will typically have a less-reacted center as a result of grain pull-out rather than the desired grain fracture, the new SNBSC is completely and uniformly reacted throughout cross sections of 3 in. and greater (see Figure 1).

The benefits of the new material include more predictable wear throughout its useful life; with this predictability comes the benefit of reduced unscheduled downtime. Normal SNBSC wears well until the area of less bond is encountered, at which time the wear rate increases substantially. An additional benefit of the new SNBSC is that it has demonstrated excellent performance in thermal cycling conditions, which is a property that is useful in refractories, particularly kiln furniture.

The new material and a more traditional SNBSC underwent testing by an accredited third-party labora-

*Silicon Carbide Products' SCProbond TN10™

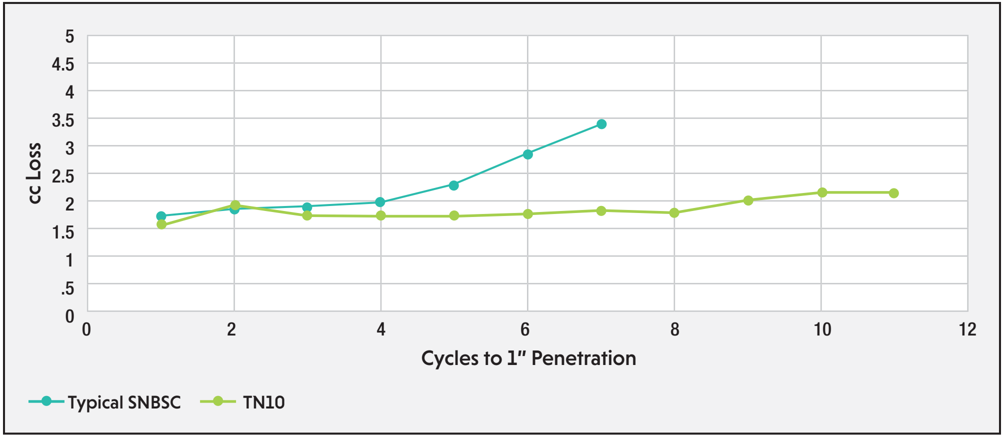

Figure 2 Results of a modified ASTM C704 grit blast test to 1-in. penetration.

tory. Based on the ASTM C704 grit blast test, the testing used a grit impingement at a specified grit size and pressure for a given amount of time, after which the volume loss was measured. To understand the performance differences under severe conditions, the test was repeatedly run to a penetration depth of 1 in.

Figure 2 illustrates that the new SNBSC shows a very linear wear performance, taking a full 11 cycles to reach the target depth. The more traditional material reaches the 1-in. depth in seven cycles, with increasing wear/cycle in the inner portion of the test sample.

Another interesting property of the new SNBSC material is its resistance to thermal cycling strength degradation. When thermally cycled per ASTM C1171, it is not uncommon for typical SNBSC materials to lose approximately 40% of their strength (modulus of rupture). This test consists of five cycles of heating to 1,200°C in a gas-fired kiln with an air quench. The new material showed a 10% gain in strength upon thermal cycling. Consequently, it is currently being evaluated in refractory kiln furniture applications.

Broader Scope

Silicon nitride-bonded silicon carbide is a familiar and time-tested material. Recent advances have led to improvements in wear resistance and thermal shock behavior, allowing SNBSC to reach new audiences and applications. Ci

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