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Advanced Hot-Gas Filter Development

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Abstract

Coal is the most abundant fossil-fuel resource in the United States. "Clean coal" technologies, such as pressurized fluidized-bed combustion (PFBC) and integrated gasification combined-cycle (IGCC), require a hot gas filter to remove the corrosive and erosive coal ash entrained in the combustion gas stream. These hot gas filters, or candle filters, must be cost-effective while able to withstand the effects of corrosion, elevated temperature, thermal shock, and temperature transients. Ash loadings may range from 500 to 10,000 ppm by weight, and may contain particles as fine as 0.008 mils. The operating environment for the hot gas filter can range in pressure from 10 to 20 atm, in temperatures from 700 to 1,750 °F, and can be oxidizing or reducing. In addition, the process gases may contain volatile chloride, sulfur, and alkali species. Field testing of various commercially available, porous, ceramic filter matrices has demonstrated a loss of up to 50 percent of as-manufactured strength after 1,000 to 2,000 hours of exposure to these operating conditions, although full-scale elements have remained intact during normal process operations.

Ultramet, a small business specializing in advanced materials R&D, has developed a new class of hot gas filter materials that offers lower back-pressure, higher permeability, longer life, and high filtration efficiency in the PFBC and IGCC environments. Subscale Ultrafoam Duplex Filter elements have undergone accelerated corrosion testing at temperatures of up to 2,370 °F (at Ultramet), and have been subjected to over 2,800 hours of exposure to hot PFBC gases (in the Westinghouse Advanced Particulate Filtration System at Brilliant, OH) without any loss in strength in either case. The Ultrafoam Duplex Filter matrix demonstrated 100-percent particle-capture efficiency of coal ash, and had an initial pressure drop of 0.1 to 0.6 in·wc/fpm.

The Ultrafoam Duplex Filter is composed of a chemical vapor deposition (CVD), silicon carbide (SiC), reticulated, open-cell foam filter body supporting a porous mullite membrane filter. The reticulated foam structure is 70 to 90 percent porous, enabling high permeability, while the 3-D interconnected cellular lattice resists crack propagation. The CVD SiC material is fine-grained for maximum strength and corrosion resistance, and has no binders or impurities. The porous, mullite, membrane filter is impregnated into the outer surface of the CVD SiC Ultrafoam

filter element. The membrane bonds to the foam ligaments, while the foam ligaments reinforce and support the membrane. The mullite membrane, which acts as a barrier filter, is resistant to thermal shock and corrosion. The thin membrane minimizes pressure drop and thermal gradients. The composite Ultrafoam Duplex Filter was designed to combine optimal material selection with functional structural design to maximize corrosion resistance, thermal shock resistance, strength, toughness, and life while minimizing pressure drop and weight.

Oxidation rate, corrosion resistance, creep strength, compressive strength, and C-ring strength of the CVD SiC Ultrafoam filter body, and pressure drop and filtration efficiency for subscale Ultrafoam Duplex Filter elements, are reported.

Future work is targeted at the construction of full-scale hot gas filters, and will include further strength and accelerated corrosion testing of subscale sections of the filter body, the membrane, and the composite duplex filter elements.

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