6. MATERIAL SELECTION CONSIDERATIONS FOR HOT-GAS CLEANUP SECTIONS OF COAL GASIFICATION SYSTEMS

Metallic materials will be used for many of the components of the hot-gas cleanup systems of gasifiers. These components include support plates, piping, and, possibly, the filters themselves. From the previous discussion, it is apparent that system deterioration by carbon deposition and the related alloy degradation by metal dusting are potential concerns associated with long-term operation of such systems, particularly if certain alloys are used. Ceramics such as alumina or those based on silicon are resistant to carbon-related degradation in the gasification environments. However, refractory liners containing iron can suffer from CO disintegration.[9] Furthermore, although not highly likely, if catalytic species form part of the trapped char/ash particles on ceramic filters, they could lead to material degradation. Therefore, depending on the specific application, ceramic parts may or may not be immune from carbon-induced problems.

Based strictly on metal-dusting considerations, nickel-based or high-chromium alloys would be favored as materials for hot-gas cleanup components over carbon or low-alloy steels.[2,3] However, nickel and alloys with high nickel concentrations can suffer from metal dusting, albeit at higher temperatures than iron-rich alloys (see Fig. 6). If oxidation conditions are such that continuous chromia scales can form, materials with substantial chromium concentrations are probably preferred because the oxide surface layer can provide true protection from degradation by carbon. Since the ability to reliably form the desired scale increases with increasing chromium availability, activity, and diffusivity, the commonly used austenitic stainless steels (with about 18% Cr) have been found to be marginal for this application in CO-containing gases.[22] In this regard, ferritic stainless steels, such as type 446, may be a better choice since they have relatively high chromium concentrations and higher chromium diffusivity.

As discussed previously, small concentrations of H_2S in the gasifier environment can significantly inhibit carbon and carbide formation and, therefore, metal dusting. However, even such small concentrations can still be sufficient to accelerate the corrosion of nickel-based alloys, steels, and other heat-resistant alloys at 600°C (1110°F) and above. As discussed in Sect. 5, a balance between the concentration of sulfur needed for inhibition and that which causes significant degradation by mixed-gas corrosion would be required. Obviously, the use of sulfidation-resistant alloys would allow greater freedom in limiting sulfur pressures in the gasifier environment. Iron-aluminide alloys offer some promise for use in hot-gas cleanup systems as they offer excellent sulfidation resistance in reducing environments with relatively high H_2S contents.[34] However, metal dusting of iron aluminides may be possible.[31] The formation of an alumina scale imparts sulfidation resistance to iron aluminides and should also be a barrier to metal dusting. Therefore, if preoxidized, iron aluminides should be more resistant to degradation by both carbon and sulfur, but this remains to be demonstrated. Nickel aluminides should be preferable to iron aluminides as alumina-forming alloys for metal-dusting resistance because nickel is less reactive in the product gas environment, although it can exhibit a type of metal dusting in which a Ni-C solid solution decomposes directly without formation of an intermediate carbide.[35] Nickel aluminides would not be suitable in the presence of H_2S because they are very susceptible to sulfur-accelerated corrosion (see, for example, ref. 36).

For materials that need to rely on a surface oxide of aluminum, chromium, or silicon for protection from metal dusting, any microstructural or compositional modifications that improve the adhesion, soundness, mechanical integrity, and erosion resistance of these layers will improve their performance in the hot-gas cleanup system of gasifiers. Mechanically worked, pore-free metal surfaces increase the ability to form adherent, protective scales relative to as-cast, rough surfaces or those retaining mill scale. Honed tubes have shown improved lifetimes compared with as-spun-cast tubes in some environments subject to carbon deposition.[37] The factors controlling such properties of oxide scales are not all known and form the subject of many present investigations. However, the ability to improve scale adhesion by addition of small amounts of certain reactive elements or oxides has long been recognized.[38] Any choice of materials that form alumina, chromia, or silica should be governed, in part, by whether these alloys have been optimized for scale adhesion and integrity. The use of materials that form such protective scales presupposes that they are stable in the gasifier environment. System modification to allow the growth of protective oxide films by selective oxidation during steam injection could also enhance oxide scale formation, as discussed in Sect. 5.

Materials selection is rarely based on corrosion performance alone. Cost considerations often preclude the use of the higher-alloyed materials or advanced ceramics. The relatively low costs of carbon and low-alloy steels make them the materials of choice for most power-generation systems in order to show an acceptable return on investment. However, the potential susceptibility of these materials to carbon deposition and metal dusting must be addressed in light of long-term operation of hot-gas cleanup systems of coal gasifiers. If the currently targeted H_2S contents can be achieved by hot-gas desulfurization, the increased potential for carbon-related material degradation will almost certainly impact gasifier design and operating conditions. Modifications such as lowering the exposure temperature, introducing a gas-phase inhibitor, and/or using surface protection (coatings, claddings, or liners) may be required. The surface protection approach may be required for accommodating off-normal conditions occurring in a system that has been designed to minimize carbon formation and dusting solely by process control. The choice of coatings, claddings, or liners would be governed by the same materials considerations discussed immediately above. For example, steels could be chromized, chromized/siliconized, or aluminized to facilitate formation of protective surface oxides. Ducts could be lined with a material resistant to corrosion by the carbon-containing environment or fabricated from co-extruded tubing that incorporates an appropriate surface in contact with the product gas.