A nanotechnology-based multicomponent thermal spray coating system provides resistance to thermal cycling and thermal shock high-temperature strength; and resistance to degradation due to wear, impact, and oxidation. Originally developed as a coating for furnace rolls used in the production of steel strip, the coating is highly resistant to pickup of contaminants that can cause dimples or other flaws on the strip surface.

The coating system, called KarGen 3, has a multilayer structure with cobalt based sublayers and an oxide-ceramic top layer, as well as proprietary sealing materials. The coating maintains its integrity even at ultrahigh temperatures (to 2400°F) on rolls in both vertical and horizontal furnaces. For water-cooled rolls, the coating enables a possible reduction or elimination of internal cooling water while maintaining the face temperature of the rolls.

The research and development program that led to the new thermal spray coating system, an explanation of how the layers work together to protect surfaces, and use of the coating in several applications are presented here.

Coating development

ASB engineers carried out a series of microstructural studies, chemical and phase analyses, thermal cycling tests, thermal shock experiments, and roll pick-up trials. Specific application procedures were developed along with the materials.

They first optimized thermal spray parameters to achieve dense, adherent coatings. Many powder compositions were selected for the study, and after establishing optimum parameters, specimens were coated and evaluated.

Sealing procedures were developed next. The sealant is a critical layer of the coating system, because it is in contact with the steel strip on the furnace roll, or with the hot abrasive environment in other applications. A range of sealant materials including polymers, metallic and ceramic powders, and solutions are used in the thermal spray industry to improve the function of sprayed coatings. Several application techniques are used to apply sealants including spraying, brush painting, spin-and-dry, and impregnation. Typically, a single sealant material and one application technique are selected from this variety of materials and processes.

However, because the furnace-roll coating has to meet a complex array of severe operating conditions, multiple sealant materials along with specific processing techniques for each were evaluated, and engineers selected a nano-oxide-based sealant system with multiple layers, in which each layer is applied using a specific technique.

Test results

After selecting materials and sealants, experiments were carried out to test performance in different operating environments. Specifically, a series of time-temperature studies were conducted. Specimens heat-treated at various temperatures and cycle times were evaluated using microscopy and x-ray diffraction (XRD). Microstructural and phase evolutions were recorded, together with substrate/coating interface characteristics.

Critical thermal cycling and thermal shock characteristics of three specimen conditions were evaluated:

- Sprayed (with different powders)
- Sealed (with different sealants and techniques)
- Heat-treated (with different schedules)

Specimens were heated to maximum operating temperature, soaked at temperature for one hour, and quenched in ambient water. After the specimens were soaked in water for approximately 30 minutes, they were pushed back into the furnace and reheated. This process was repeated many times for each specimen.

Representative specimens were taken out after each thermal cycle, characterized via microstructural analysis, and evaluated for thermal shock. Engineers looked for microcracks and bond failures. Specimens that retained structural integrity and remained bonded to the substrates were selected for further testing.

For furnace-roll coatings, pick-up resistance is the most important characteristic. Steel strip is typically processed at annealing temperatures, where it is soft and susceptible to damage. If oxide particles adhere to the roll surface, they can cause dimples and other flaws on the strip.

To evaluate pick-up resistance, experimental specimens were placed in contact with a typical “contaminated” steel strip, and a load was applied. The entire system was heated to maximum operating temperature, soaked at temperature for more than 100 hours, and cooled. These specimens were investigated visually and using optical microscopy and surface-roughness tests before and after pick-up experiments.

Based on the results, engineers selected the most successful cobalt-base alloy powder along with its optimized...
spray parameters, the best multiple sealant materials and corresponding processing techniques, and the optimum heat treatment schedule.

These materials and procedures produce a dense, adherent cobalt-base underlayer, along with a multilayer oxide sealant that functions very well on steel mill furnace rolls and components that operate in other severe environments.

Applications

Furnace Rolls: KarGen 3 coating is equally effective on rolls in both vertical and horizontal furnaces. For water-cooled rolls, the coating can reduce the amount of water needed, without reducing the face temperature of the rolls, thus saving energy. Its high-temperature strength and hardness enable it to function at temperatures as high as 2400°F under the most severe conditions. Most important, its pick-up resistance ensures defect-free surfaces on carbon steel, oriented silicon steel, and stainless steel strip.

Coal-fired power plants: Ultra-supercritical coal-fired power plants run at high temperatures in an extremely corrosive and abrasive environment. Coating with KarGen 3 enables boiler components and other equipment to operate longer, reducing downtime and costs.

Industrial mixers: Some industrial equipment requires mixing components that operate at high temperatures in corrosive and abrasive environments. Because KarGen 3 resists most chemicals in addition to high temperatures and abrasion, it can increase the life of these components and other equipment.

Oil and gas drilling equipment: KarGen 3 is an ideal coating for components used for deep drilling where high temperatures and abrasive slurries shorten tool life.

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