

thermal spray has been accepted and used by steel manufacturers. As thermal spray technology has grown, along with more reliable materials and equipment, manufacturers have been able to increase the number of applications in which thermal spray technology is used. Today (2013), high-velocity oxyfuel (HVOF) and detonation gun technology is more mainstream in steel manufacturing plants worldwide. Applications from the melting and transfer of steel from furnace to end product use all types of coatings, with WC-Co and Cr_3C_2 -NiCr cermets playing large roles. Coatings withstand all types of wear and corrosion and have resulted in longer production life and better final product quality of the steel strip, bar, pipe, or billet—enormous benefits that make thermal spray a welcome technology for many applications in the steel industry.

The Need for Coatings in the Steel Industry

Throughout the steel production process, components are exposed to a combination of high temperature, corrosive environments, and various wear mechanisms. This results in a wide range of degradation mechanisms, leading to a reduction in product quality, reduced operation efficiencies, and greater maintenance costs and downtime. Although thermal spray technology has been used since the 1970s, recent advances in materials, equipment, and processes are furthering applications in these markets. These improvements in thermal spray technology, along with growth in the automotive sector in traditional and developing countries, should expand the use of thermal spray products for this market. One area that has seen dramatic growth is in the implementation of HVOF technology along with key cermets such as WC-Co(Cr) and NiCr- Cr_3C_2 for many types of roll applications.

Figure 2 is a good view of the harsh conditions found in the manufacturing of steel.



Fig. 2 Hot steel coil being wound, showing the harsh conditions of steel manufacturing

Key areas of concern are heat, corrosion, and wear. To help enhance the life of equipment used in the production of steel, a number of thermal spray coatings are being used today (2013). Figure 2 shows a hot coil being wound from strip steel. Wrapper rolls, which force the strip to turn into a coil, use a nickel-base self-fluxing alloy that is combustion sprayed and fused. This is one of only a very few coatings that has worked in this extremely harsh environment. Other surface-modification processes, such as submerged arc or welded coatings, also can be used for this application. The temperature of the steel strip shown in Fig. 2 is estimated at over 1400 °C (2500 °F); note the high-pressure cooling water flowing onto the coil as it is being wrapped. This is one of the harshest environments in strip steel manufacturing.

Thermal Spray Applications in Steel Manufacturing

Many surface-modification processes are proprietary to the steel manufacturer or the coating applicator, but the basic thermal spray coating applications—along with the environment, process, and materials used in steel manufacturing—are listed in Table 1. As can be seen in Table 1, there is a significant amount of materials science and engineering involved in the understanding of which surface-modification process and material chemistry work best for a specific application. The quality of the final product and the surface finish is critical to the selection of the process and material.

Wires, rods, sheets, and billets are just a few of the forms that steel can take before its release to second-tier industries. Specific areas of steel production where coatings are used include:

- Gas ducting system from molten metal refining
- Gas injection tuyeres, lances, and nozzles
- Continuous casting molds
- Various types of processing rolls, for example, bridle, deflector, and annealing furnace rolls

It is important to review the many technical references that give a much more detailed description and overview of these applications.

Continuous Casting Molds. Figure 3 shows casting molds. The base material is copper, and the mold is water cooled. The main purpose of a casting mold is to control the rate of solidification and the shape of the resulting billet. Mold life (gaged by the number of pours and tonnage) is limited by the ability of the coating to withstand wear that could transfer marks unto the slab or billet. The coating materials used

for this type of application are carbides, cermets, and ceramics.

Coiling Mandrels. Figure 4 shows a continuous coiling mandrel. Typically in steel applications, hot mill strip products require further processing. The transfer of coils to other continuous process lines requires the coil to be unwound then rewound, holding the core of the coil tightly wrapped. Friction, grip, and long-wearing surfaces allow proper strip tension from the initial weld joining to final trimming and wrapping. Rolls with detonation gun and HVOF-applied carbide coatings have surfaces harder than the strip materials. In addition, optimized surface profiles and high friction coefficients support the gripping of strip to rolls without causing harm to the surface finish properties of the steel strip.

Annealing Line Rolls. Figure 5 illustrates the various rolls used in an annealing line. The type of coatings used are shown in Table 1 and discussed in reference articles (Ref 1, 2). Rolls in production today (2013) use either HVOF or detonation gun coatings. Proprietary coatings using oxidation-resistant MCrAlY cermets are used for extremely high furnace temperatures. For lower-temperature heat treatment of low-manganese steels, NiCr- Cr_3C_2 coatings are used. For high-temperature annealing of low-manganese steels, oxides and/or borides or cermets of MCrAlYs and alumina have been used in production. High-manganese steels result in more severe problems for rolls. Corrosion/oxidation products, typically in the form of oxides of chromium and aluminum on MCrAlY coatings, react with manganese from the steel, reducing the service life of the coatings and the quality of the steel sheets. Today (2013), there are many proprietary coating solutions that optimize MCrAlY chemistries, along with additions of alternative oxides and/or carbides.

Continuous Galvanizing Line. Degradation of sink rolls and other rolls associated with continuous galvanizing lines (Fig. 6) is due to zinc and/or aluminum reactions with iron from the steel rolls. These reaction products degrade the rolls and affect the surface of the steel products. Some of these reaction products are called dross particles. Today (2013), the most commonly used zinc baths are galvanized zinc with minor concentrations of aluminum, zinc with 0.5 wt% Al, and zinc with 55 wt% Al and minor amounts of silicon (Ref 3). Currently, coatings use tungsten carbide/cobalt powders applied via HVOF or detonation gun technology (Table 1). The success of these coatings depends on the spray parameters, powder manufacturing method, and sealant system. The key to increased life is to reduce the amount of free cobalt in the coating.

Conclusions and Future Growth

As thermal spray technology continues to evolve, coating systems are becoming more