TIP 0402-32

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Guidelines for applying thermal spray coatings to protect pulp mill process equipment against corrosion

1. Scope

This technical information paper contains guidelines and describes quality evaluation procedures for field application of metallic thermal spray coatings that are applied for corrosion protection in pulp mill process vessels such as batch digesters, continuous digesters, flash tanks, evaporators, and concentrators. Many other thermal spray coatings, including metallic coatings for protecting recovery boiler tubes against corrosion, restoring Yankee dryer surfaces, hard-surfacing calendar rolls, and ceramic coatings used on various paper machine rolls are not covered by this document; although the basic, coating-related information and qualification procedures described herein apply to those coatings as well.

These guidelines inform equipment owners and mill engineers of the properties a thermal sprayed coating should have for the coating to perform adequately in service. Issues to address and items to include in a job specification are listed. Coatings are only generically described. No recommendations are provided for either types of coating or materials for specific applications.

2. Safety precautions

Different thermal metal spray applications involve the use of high voltage; the use and generation of combustible and toxic gases (such as CO); the generation of metal dust and fumes; the potentially harmful exposure of skin and eyes to high intensity UV radiation, and the generation of excessive noise. Ensure personnel by complying with applicable confined space entry procedures (if needed), mill safety and lockout procedures, and by using personnel protection equipment. Use personal protection equipment that provides suitable protection against UV radiation, noise, fumes, and dust generated by both the surface preparation and coating spray process.

Adequate ventilation can eliminate many health and safety concerns. While working in the open or in well-ventilated spaces, a simple dust mask may be sufficient. Continuous-flow air-line respirators may be necessary during blasting and spraying operations in less well ventilated conditions, especially inside a tank or vessel. Additional precautions and training of personnel may be required for application of sealants as a finishing step, especially if the sealant liquid produces harmful or combustible fumes.

3. Background information

Thermal spray coatings are applied by spraying metallic or non-metallic materials in a molten or near-molten form onto the surface to be protected after the surface is properly prepared. The materials to be sprayed are in the form of a wire or powder. The methods to feed the material into the heat source for melting and the gases used to propel the material at the surface vary among a number of processes (see Appendix).

Different application processes produce coatings with different physical properties such as oxide content, density, and structure (Ref. 1). Coating selection depends on the process environments. Chemical cleaning and shutdown conditions also need to be taken into consideration. Coating thickness requirements depend on inherent coating parameters such as porosity and oxide content, as well as the intended service life.

Coatings are applied either manually or with an automated system. Automated application typically provides more uniform coating thickness and better quality. Coatings can be used to protect large or small areas. Circumferential weld seams and weld overlay edges can be given localized protection.

A broad range of sprayable materials is available. The coatings that are typically used for corrosion protection in pulp mill equipment are stainless steels and nickel-based alloys. References 2 through 4 give examples of real-world applications of thermal spray coatings that are used for corrosion protection in major process vessels in pulp mills.

The bond between a thermal spray coating and the substrate is mechanical, not metallurgical. No diffusion or melting of the substrate takes place at the interface of the thermal spray coating and the substrate which remains physically discernible. Coatings adhere best when they are applied to surfaces that are properly prepared. This involves both thorough cleaning and providing the specified anchor profile on the surface. Bond strengths for the densest thermal spray coatings can exceed 10,000 psi. Achieving the specified or expected bond strength is very dependent on the application technique, the applicator, and on adequate quality control of the coating application process. [See ASTM C633-79, Test Methods for Adhesion or Cohesive Strength of Flame-Sprayed Coatings.]

One important characteristic of thermal spray coatings is that the coated surface typically does not get hotter than 250°C (482°F). Therefore, a thermal spray coating does not induce a heat-affected zone or significant residual stresses into the substrate although the thermal spray coating itself may have high internal thermal stresses.

Experienced applicators can normally apply thermal spray coatings relatively rapidly in the field. The finished product can be easily inspected and thermal spray coatings are readily repairable during application. Repairing of coatings after they have been in service differs for different coatings depending mostly on the coating porosity and the degree to which it has been permanently permeated and contaminated by the process environment.

As with protective coatings of every kind, high quality application is essential to ensure good coating performance. Success depends on proper selection of both the material and the application process, careful application, and diligent follow-up inspection.

Sealers are sometimes applied to thermal spray coatings to seal the porosity at the surface. This is done to slow down permeation into the coating by the environment. The sealer must have appropriate chemical resistance to the service environment. Sealers can be re-applied as necessary. Sealers used for thermal spray coatings include sodium silicate solutions and penetrating epoxy sealers. Thermal spray coatings in liquor evaporators have been sealed with epoxy paint. The angular roughness of some thermal spray coatings, especially arc-sprayed coatings, provides a good anchor for top-coating with an organic paint.

4. Creating a coating project specification

A comprehensive job specification for most thermal spray application projects typically will address and define the following fifteen coating-related items:

A. <u>Substrate-related:</u>

1. Surface areas to be coated.
2. Substrate materials and their condition, including roughness.
3. Surface preparation, including the anchor pattern and how it will be tested.
4. Nondestructive testing before coating.

B. <u>Application-related:</u>

5. Ambient conditions required (humidity, temperature, dust management, etc.)
6. Spray process (more than one may be used).
7. Automatic or manual application (both may be needed).
8. Coating material(s).
9. Coating thickness.
10. Density of the coating and how it will be tested.
11. Coating repair procedure(s).
12. Sealant (if required).

C. <u>Quality-related:</u>

13. Procedure documentation.
14. Quality control requirements, including equipment setup, surface preparation, coating application and the finished coating. (This Technical Information Paper should be referenced.)
15. Jurisdictional, code and insurance requirements.

When the coating is not thick enough, additional coating can be applied provided the surface of the sprayed area is still clean and suitable for applying additional coating. When a maximum thickness is specified - a necessity with some coatings - and the coating thickness exceeds this limit, the entire coating shall be removed from the nonconforming area and then reapplied, after proper surface preparation.

7.2.2 *Density*

The apparent density of the coating on the nozzle insert coupons should be determined by metallographic evaluation of the density (porosity) per MIL-STD-1687. However, this usually is done after the job is completed unless otherwise agreed to by the owner and the coating contractor.

7.2.3 *Surface Soundness*

The ease of inspecting the surface quality depends on the roughness and coarseness of the coating. As a minimum, the surface appearance and soundness should match those obtained on acceptable examples of the qualification test panels.

HVOF coatings typically are smooth enough to be visually and dye penetrant tested (PT'd) to ensure they are free of cracks, pinholes, or other undesirable defects. The surface of an HVOF coating should be smooth to the touch and the coating should be free of spits, unmelted particles, or other features (e.g., sharp edges or grooves) that may interfere with the PT. At least 25% of the HVOF coated area should be PT'd to ensure adequate soundness.

Test areas should be selected to represent the work of every operator. If this testing scope reveals areas with unacceptable coating soundness, the area tested should be doubled, and so on, until the entire coated surface is PT'd if necessary (see Section 8).

8. Stripping and reworking

Any coating that fails to meet the quality criteria should be removed by grinding or abrasive blasting, taking special care not to damage acceptable coating on adjacent areas. Stripped areas should be reworked and re-coated as per the relevant sections of this Technical Information Paper.

Tie-ins can be either feathered or step-edged (masked). The method of tying the coating patches together should be verified by metallurgical examination of test coupons to provide coating tie-ins that meet the quality requirements of this Technical Information Paper.

It is good practice to make at least two, roughly 200 cm^2 (30 square inch) patches of coating repair to allow long term evaluation of the suitability of the specified repair method in the service conditions. These patches may result naturally from repairs of actual coating flaws or be specially made to meet this requirement. The locations of these repair test patches and the repair method(s) used should be fully documented and included in the project records.

9. References

1. R.P. Krepski, *Thermal Spray Coating Applications in the Chemical Process Industries*, MTI Public. No. 42; [ISBN: 1-877914-59-2] Published by NACE International, Houston TX (1993).
2. J. Croopnick, *Performance of HVOF Coatings in Digester Environments*, Paper 279, Corrosion 99, Conference, San Antonio, NACE International, Houston, TX (1999).
3. C.E. Guzi, *Inspection Techniques and Preventive Measures with reference to Cracking in Continuous Digesters*, Proc. Fourth International. Symposium on Corrosion in the Pulp and Paper Industry, Stockholm, Swedish Corrosion Institute and TAPPI Press (1983).
4. A. Wensley, *Thermal Spray Coatings for Corrosion Protection of Continuous Digesters and Flash Tanks*, TAPPI Engineering Conference, San Antonio, TX (2001).