The Lifecycle maintenance costs associated with the control of corrosion exposures can potentially be decreased using Thermal Spray Aluminum (TSA) technology on equipment in susceptible and harsh environments. A risk based approach is important to help optimize the application of this technique in the petrochemical industry.

Introduction

In 2001, a study by the US Federal Highway Administration (FHWA) revealed that the total annual estimated direct cost of corrosion in the U.S. was approximately $276 billion (3.1% of the US gross domestic product). In 2009 the World Corrosion Organisation reported that studies indicate the global direct cost of corrosion exceeds $1.8 trillion(1).

In the petrochemical industry equipment used in process plants are continuously exposed to a variety of corrosion mechanisms as a result of the process operating conditions and external environment. Corrosion effects are directionally more aggressive for processes operating at higher temperatures, and for equipment located within harsh environments (e.g. marine) and this typically leads to a faster degradation of mechanical components.

Over the past decade or so, the petrochemical industry has been facing up to the challenge posed by ‘aging assets’ and there has been some notable losses arising from poor control of corrosion mechanisms within process plants. As a result there has been increased regulatory interest in how effectively this is being addressed by plant owners.

Thermal Spray Aluminum technology has been demonstrated as an effective technique to control corrosion for harsh external environments such as is often found in petrochemical plants and offshore oil and gas structures. It is a technique that is sometimes overlooked in favor of more conventional corrosion protection techniques such as paint systems and hot dip galvanizing due to a higher initial outlay cost. However with proven protection of over 20 years to first maintenance in some applications the lifecycle maintenance cost of adopting this technique can be significantly less than other methods.
Discussion

What is Thermal Spray Aluminum?

Metal spraying involves the projection of small molten particles onto a prepared surface, where they adhere and form a continuous coating. Upon contact, the particles flatten onto the surface, solidify, and mechanically bond, initially onto the roughened substrate, and then onto each other as the coating thickness is increased.

Techniques for metallization started as early as mirror making, in 1835. The metallizing process is now recognized as a long-term solution for many industries.

![Image of thermal spraying](source: Metallisation, Thermal spray equipment and consumables, Reference 9).

Coating thickness can range from around 50 μ up to several millimeters for some metals. Typically, metal spray corrosion protection coatings vary from 100 to 350 μ.

The majority of metal spray coatings use zinc or aluminum or a combination of these as zinc/aluminum alloys. In general zinc coatings are used in lower corrosion applications and aluminum in harsher corrosion applications such as marine environments, in splash zones, and in high temperature services. Zinc/aluminum alloys are used in applications where the effective performance of zinc coatings is borderline.

The Metal Spray Process

Thermal spray processes may be categorized as either combustion or electric processes. Combustion processes include flame spraying, high velocity oxygen fuel (HVOF) spraying, and detonation flame spraying. Electric processes include arc spraying and plasma spraying. Only flame spray and arc spray are normally used for anti-corrosion coatings in marine, offshore, and petrochemical environments.

In the arc spray process, the raw material in the form of a pair of metallic wires is melted by an electric arc. The molten material is atomized by a cone of compressed air and propelled towards the work piece. Aluminum is particularly suited to arc spray.
In the flame spray process, a wire is fed by a driven roller system through the center of an oxygen-propane flame where it is melted. An annular air nozzle then applies a jet of high-pressure air, which atomizes and projects the molten material.

**Corrosion**

Corrosion is the degradation (i.e. deterioration of physical properties) of a material due to a reaction with its environment. In the case of metals corrosion occurs because the metal is used in a chemically unstable form. Considering most metals, apart from copper and the noble metals, are found in nature as minerals and ores. Metal corrosion is mostly electrochemical and involves the reaction of the metallic element with a non-metallic element (e.g. iron with oxygen to form iron oxide or rust). In the case of two dissimilar metals in contact, galvanic corrosion can take place in which one metal preferentially corrodes (called the anode) due to a difference in the galvanic potential between this and the other metal (called the cathode).
Corrosion Under Insulation (CUI)

Corrosion under insulation (CUI) has been a problem for the petrochemical industry for many years because it is not immediately visible and requires expensive procedures and time consuming practices to identify and control. CUI can be active over a wide temperature range, but it is recognized that the most critical temperature range is 30°C to 120°C (2). CUI occurs when insulation condition has deteriorated or has not been installed correctly allowing the ingress of water and the free availability of oxygen. This is particularly prevalent at low points in a system where water can collect. The problems are exacerbated when the original coating specification of the insulated steel is substandard.

CUI inspection and maintenance programs are often difficult and expensive because access to piping and equipment invariably requires scaffolding or the use of specialist ‘rope access’ services, and because corrosion can occur at any point, it requires the complete removal of insulation throughout each ‘process system’ to ensure a thorough assessment. Additionally systems that are prone to CUI require more frequent inspection.

In this respect, the application of TSA can significantly decrease the maintenance costs in the long run, as well as reduce the likelihood of a loss of containment from piping systems or process vessels. These thermal spray coatings provide corrosion protection by excluding the environment by acting as a barrier coating (like paints, polymers, and epoxies), but unlike typical barrier coatings they also provide sacrificial anodic protection.
Thermal Spray Coating Cost and Service Life

Thermal sprayed aluminum coatings provide long-term (>20 years to first maintenance) corrosion control. This application is usually more expensive than painting or galvanizing. However, the improved capabilities and productivity of metallizing equipment for aluminum and zinc spraying has resulted in an improving cost difference between metallizing, paint, and galvanizing.

Even though the initial application cost of metallizing may be higher, the life cycle cost (LCC) and average equivalent annual costs (AEAC) are potentially significantly lower than paint coating systems.

The effectiveness of the coating is dependent on a number of factors such as bond strength, porosity, oxide content, and free corrosion potential (i.e. effectiveness as a sacrificial anode). The method of application is usually determined by a combination of these factors and other practical issues such as deposition rate, ease of operation, ease of automation, etc. The table below shows how these factors vary between different application methods.

<table>
<thead>
<tr>
<th>Coating type</th>
<th>Deposition efficiency (DE) [%]</th>
<th>Deposit rate (DR) [kg / h]</th>
<th>Coating cost (*) [GBP/m²]</th>
<th>Coating characteristics and properties</th>
<th>Free corrosion potential (Ecorr) [mV SCE]</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS (flame sprayed)</td>
<td>64</td>
<td>0.8</td>
<td>32.43</td>
<td>Porosity Vol. % 4.7</td>
<td>Oxide wt. % 0.5</td>
</tr>
<tr>
<td>AS (arc sprayed)</td>
<td>43</td>
<td>2.5</td>
<td>13.52</td>
<td>Porosity Vol. % 6.3</td>
<td>Oxide wt. % 2.1</td>
</tr>
<tr>
<td>PC (pure coat inert gas arc spray)</td>
<td>75</td>
<td>4.6</td>
<td>16.15</td>
<td>Porosity Vol. % 5.4</td>
<td>Oxide wt. % 1.0</td>
</tr>
<tr>
<td>HV (high velocity flame spray)</td>
<td>70</td>
<td>1.4</td>
<td>24.21</td>
<td>Porosity Vol. % 2.4</td>
<td>Oxide wt. % 1.0</td>
</tr>
</tbody>
</table>

Source: Reference 3 (Sept 2005)

(*) Cost estimated taking into consideration the consumable, labor (GBP 30 / h) and power (electric or oxy-fuel combustion) costs.
**Advantages of Thermal Spray Aluminum (TSA)**

The TSA corrosion protection system offers a wide range of benefits:

- Reduced maintenance requirement with >20 years to first maintenance having been demonstrated in very aggressive environments such as marine splash zones
- Reduced risk of CUI and chloride induced stress corrosion cracking (CISCC)
- Moderate outlay costs
- Good adhesion qualities
- Resistant to mechanical damage
- Large operating temperature range (-45°C to 538°C) and can be applied at high or low temperatures
- No health hazard from solvents or other organic substances
- No drying time; can be handled immediately after application
- Heat distortion not normally a problem
- Equipment is portable and can be used for large structures and isolated weld repairs
- Provides a sacrificial anode effect on steel in marine environments
- Guided by industry standards and specifications

**Guidance**

**Thermal Spray Aluminum Applications**

Users of the metal spray process commonly include the offshore, oil and gas, and marine industries for the protection of structures, vessels, pipelines, and storage tanks. The variety of metallized coatings is vast, but can be broken down into two main categories. These include:

- Finishing coatings such as anti-corrosion or decorative coatings
- Engineering coatings such as wear resistant and thermal barrier coatings

Hundreds of bridges have been thermal sprayed (metallized) over the past 100 years. There are many documented cases of >50 years of corrosion protection provided by thermal spray coatings. Offshore oil rigs operating in severe conditions rely on thermal spray aluminum for corrosion protection. More than 20 years of service life with no maintenance has been documented. High temperature (>900°F/480°C) steam valves and associated piping have been protected by thermal sprayed aluminum on naval ships. It is documented that these coatings lasted longer than 5 years in areas where paint coatings had lasted only months.
Petrochemical Industry Applications

The potential uses of TSA in the petrochemical industry are widespread:

- Piping under thermal insulation
- Cyclical and high temperature services ambient to 538°C (1000°F)
- Piping systems in exposed environments
- Pipe valves
- Storage tanks
- Process vessels
- Flare stacks
- Sheet piling
- Marine fenders

The initial capital outlay for using thermal spray technology can be a deterrent versus other more conventional techniques. However, the performance of aluminum coatings has been demonstrated to be superior to these traditional methods and to reduce the corrosion risk exposure.

A combination of risk assessment and cost benefit analysis is required to focus attention on the most critical process systems and to confirm the benefits of using the TSA technique.

Figure 8 – TSA in progress (Source: Metallisation, Thermal spray equipment and consumables, Reference 9).
Conclusion

The high corrosion resistance of aluminum makes metallic thermal spray coatings based on aluminum alloys a natural choice to help protect steel equipment from exposure to many corrosive environments. TSA is also ideally suited for a variety of high temperature applications making it suitable for use in the petrochemical industry.

Users that employ TSA will potentially realize significant savings in installed and long-term maintenance costs because the need for sacrificial anodes is reduced and coating repair intervals of corrosion susceptible equipment can be prolonged.

References


- **Reference 2**: Corrosion under insulation of plant and pipework v3, UK, SP/TECH/GEN/18, Health and Safety Executive: March 2011


- **Reference 4**: [http://www.nace.org](http://www.nace.org), NACE: The National Association of Corrosion Engineers is the leader in the corrosion engineering and science community, and is recognized around the world as the premier authority for corrosion control solutions.

- **Reference 5**: Duplex Al-based thermal spray coatings for corrosion protection in high temperature refinery applications, Adriana da Cunha Rochal, Fernando Rizzol, Chaoliu Zengil, Marcelo Piza Paes Pontifícia, Universidade Católica do Rio de Janeiro, PUC-RIO Department of Materials Sciences and Metallurgy Marquês de São Vicente 225, sl 540L, Gávea, 22453-900 Rio de Janeiro - RJ, Brazil


- **Reference 7**: [http://www.globalcoatings.co.uk/](http://www.globalcoatings.co.uk/)

- **Reference 8**: An evaluation of the corrosion resistance of thermal-sprayed aluminum coatings in chloride solution, César Vitório Franco and Rogaciano Maia Moreira, Departamento de Química, CFM Universidade Federal de Santa Catarina UFSC, Campus Trindade, 88040-900, Florianópolis-SC, Brasil


- **Reference 10**: [http://pro-tectcoatings.co.uk/](http://pro-tectcoatings.co.uk/)
Page intentionally left blank.
Zurich Insurance Group Ltd.
Mythenquai 2 CH-8022 Zurich – Switzerland
www.zurich.com

The information contained in this document has been compiled and obtained from sources believed to be reliable and credible but no representation or warranty, express or implied, is made by Zurich Insurance Group Ltd. or any of its subsidiaries (hereinafter “Zurich”) as to their accuracy or completeness.

Some of the information contained herein may be time sensitive. Thus, you should consult the most recent referenced material.

Information in this document relates to risk engineering / risk services and is intended as a general description of certain types of services available to qualified customers. It is not intended as, and does not give, an overview of insurance coverages, services or programs and it does not revise or amend any existing insurance contract, offer, quote or other documentation.

Zurich and its employees do not assume any liability of any kind whatsoever, resulting from the use, or reliance upon any information, material or procedure contained herein. Zurich and its employees do not guarantee particular outcomes and there may be conditions on your premises or within your organization which may not be apparent to us. You are in the best position to understand your business and your organization and to take steps to minimize risk, and we wish to assist you by providing the information and tools to assess your changing risk environment.

In the United States of America, risk services are available to qualified customers through Zurich Services Corporation and in Canada through Zurich Risk Services as also in other countries worldwide, risk engineering services are provided by different legal entities affiliated with the Zurich Insurance Group as per the respective country authorization and licensing requirements.

©2010/2013/2015/2017 Zurich Insurance Group Ltd.