Paper No.
73

CORROSION97

METAL ALLOYS; CORROSION PROTECTION FOR THE FUTURE

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ABSTRACT

The use of metal alloys and their corrosion protective properties are well documented in oil field environments. There are many parts that can receive a "coating" of an alloy that will allow them to give the same performance as the alloy itself. Improvements in application technology have broadened the range of products that can be coated and the range of alloy coatings that can be utilized.

Keywords: Thermal spray, metalizing alloy, corrosion protection, erosion.

INTRODUCTION

This paper will discuss the use of "thermal spray" techniques to provide for corrosion and erosion protection of oil field pipe and downhole parts. Advances in application technology will be outlined with descriptions of various techniques.

Need for Alternate Coatings:

When the subject of protective coatings comes up, one immediately thinks of the organic coatings that have serviced the industry for the past fifty years. These coatings have proven their worth, but have limitations. No significant improvements have been made in several years. This has caused the industry to look for alternate methods of protection. Looking at the possible solutions, the obvious answer is metal alloys. Alloys continue to take a larger portion of the tubing and accessory market as availability increases and costs drop.

In keeping with this trend, application of metal alloys for use as corrosion and erosion protection is of major importance. There is already and established market for the application of alloys ranging from galvanizing and plating, to ion and vapor deposition. Right in the middle of these techniques lies "thermal spray". Plating and galvanizing have environmental problems. Ion and vapor deposition still need to become commercial and economical. This leave the emphasis on thermal spray.

Thermal spray employs several different techniques, some of which involve high temperatures requiring post treatment, while other applications are conducted using a "cold" process. The "cold" process will be defined as application of alloys in which the part to be coated does not exceed 400°F (204 C). Coating techniques involving spray application by Flame Spray, Arc Spray, Plasma, Detonation, and High Velocity Oxygen Fuel (HVOF) have proven performance in both corrosion and erosion protection.

There are literally hundreds of metal alloys that have been applied using thermal spray. Some of the categories of alloy include;

1. Iron based alloys
2. Zinc/aluminum alloys
3. Copper based alloys
4. Nickel based alloys
5. Cobalt based alloys
6. Carbide and Boride alloys

Flame Spray:

Flame spray is the oldest application technique having been developed in the early 1900's. These guns use a combination of oxygen and acetylene to both melt the particles and deliver the particles to the part. Flame spray has the lowest applied cost, a moderated deposition rate, and can use either powder or wire as feed stock. The quality control parameters for flame spray yield moderate adhesion (3 - 5,000 psi), and high porosity (8 - 10%). This limits the effectiveness of this application technique for corrosion protection. A seal coat of organic coating must be used to improve the corrosion resistance. Flame spray does provide erosion protection and refurbishment properties and is an excellent application technique for spray-and-fuse systems.

Arc Spray:

In the arc spray process, two metal wires meet in an atomizing gas. An electric potential difference causes the wires to atomize or melt and be deposited on the part. This can result in very large deposition rates

reducing application costs. Generally, adhesion and porosity properties are superior to flame spray yielding properties of 6 - 8,000 psi adhesion and 3 - 8% porosity. The most popular alloys deposited are zinc and aluminum, both of which can be efficiently applied. New technology of cored wires has broadened the range of alloys that can be applied. Arc spray is commonly used in many applications in the oil field industry.
Once again a seal coat of organic coating is necessary where corrosion protection is the key function.

Plasma Spray:

The 1950's saw the development of a new application technique called plasma spray. Plasma spray has the unique ability to apply both metal alloys, refractory oxides and carbides not capable of being applied by low temperature systems. Plasma spraying uses a DC arc between a tungsten alloy cathode and a copper nozzle anode. This arc heats an inert gas stream of argon or other gases to extreme temperatures causing a partial ionization of the gas, hence the term plasma. Temperatures in the gas stream can reach 30,000°F (17,000°C) resulting in high velocity deposition. Cost of application is high, film build is limited, adhesion is high, and porosity is low approaching 1%.

An offshoot of plasma technology is PTA, plasma transfer arc, which is a welding technique for cobalt alloys.

Detonation Gun:

The D-gun technology was developed by Union Carbide in the 1950's. Proprietary control of the technology was retained by Union Carbide limiting its usage in the industry.

The D-gun is essentially a small cannon. Oxy-acetylene gas and powder are injected into a chamber, then ignited by a spark plug. The detonation forces the powder to be deposited at high velocities and high temperatures resulting in coating film with excellent properties. The D-gun has developed a reputation for application of wear resistant coatings.

High Velocity Oxygen Fuel (HVOF) Systems:

If the D-gun is a cannon, then HVOF systems can be equated to rocket engine. A fuel gas is injected with oxygen into a combustion chamber. The combustion gases are discharged through ports in the combustion head which increases the gas velocity to hypersonic speeds. Powder is injected using a carrier gas such as argon into the intersection of the discharge ports. The gases carrying the powder travel at speeds of 4,900-6,500 ft/s (1,000- 2,000 m/s), or on the order of five (5) times the speed of sound. Shock diamonds are visible in the exit gas stream. Flame temperatures are relatively low at 5,250°F (2,900°C). This system is not recommended for ceramics. The high velocity and low temperature of application require a finer particle powder and tighter particle size control than other spray techniques. The system does generate the lowest porosity (>1%) and greatest thickness control of all spray devices. Adhesion of HVOF applied coatings are rated at 10

- 12,000 psi. The low porosity allows for the use of HVOF applied alloys in many corrosion environments with out the use of an organic sealer although one is normally recommended.

In addition to improved coating quality, the HVOF system advantages include superior deposition efficiency, reduced sensitivity to spray angle, and fewer critical process variables.

Quality Control Parameters:

As with any application system, quality control is of prime importance. Parameters to be considered are surface preparation, powder/wire specifications, gun operating parameters, and operating parameters.

It is recommended that all applications be done over a clean abrasive blasted surface. Cleaning can be done by thermal cleaning or solvent degreasing depending upon the part. The need for control of the applied alloy is of prime importance. Composition, particle size, particle range, and other properties should be considered. Each alloy has a specific set of spray parameters that provide optimum deposition and properties. These should be established and adhered to for each system. Automatic/robotic application creates a more uniform application than manual and should be utilized wherever practical.

Areas of Utility:

The primary focus is enhanced products for the oil and gas industry but is not limited to that industry. The leaders in utilization and development of thermal spray technology have been the aircraft and automotive industries. In both of these industries, thermal spray application is established as $100M/yr segments. There is great need for this technology to service the mining, marine, and pulp and paper industries.

There are two types of applications that need to be viewed; automatic and custom. Automatic denotes daily operation in a continuous production environment, while custom relates to batch production of limited pieces. Some automatic production includes;

1. Spray metal rod: coating of sucker rods with stainless steel to improve the abrasion/wear resistance of the rods.
2. End protection for tubing: stainless steel or Hastalloy C is applied to the nose of tubular goods. This provides for either corrosion protection of the ends from mechanical damage or erosion protection. The tubing can receive an organic coating over the alloy deposition to seal the remaining porosity.
3. Beveled ends of line pipe: This allows line pipe to be welded giving a non-corrosive girth weld area.
4. Subsea piping: Booster lines, choke and kill lines and risers are externally arc sprayed with aluminum using a silicone aluminum seal coat for Subsea piping.
5. Exterior of subsea line pipe coated with aluminum/sealer.

Some custom production includes;

1. Coating of gate and ball valve surfaces.
2. Coating wear surfaces on directional drilling components (mud motors).

3. Exterior of submersible pumps.
4. Edges of rotors and fan blades.
5. Repair pump shafts (gouges, galling).
6. Coat splash zone of drilling platform legs.
7. Coat derrick with aluminum.
8. Interior and exterior of chemical tanks.

Conclusions:

- Thermal spray has a proven place in the oil field for improved corrosion and erosion protection.
- A wide variety of parts can be protected by either automatic or custom application.
- Improved application techniques will lead to further usage.

Acknowledgments:

The author wishes to thank ICO Inc. for allowing this article to be presented. Special thanks goes to my co-workers for developing systems and applications to use thermal spray within our company.

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