Metal selection for severe corrosive applications

Corrosion in chemical processing facilities is a never-ending battle and may affect many types of materials including metals, ceramics, polymers and even plastics. Particular attention needs to be paid to corrosion sensitive equipment, which includes valves, fittings, and instrumentation, where metals are often preferred choices. For such type equipment even small amounts of corrosion could have a large impact on the performance.

Figure 1. Iso-corrosion curves for different metals in Sulfuric acid

Tantalum surface alloys, linings and coatings
Tantalum surface alloys, lining and coatings were developed with the idea of combining the best properties of multiple materials. In the case of corrosion protection, the goal is to utilize standard steel components and protect them with corrosion resistant materials which are typically more expensive. Surface alloys are a new advance category of tantalum protective solutions that is very different from coatings and linings in its final form and effectiveness. Recently, there have been developments in processing tantalum metal to create a surface alloy on standard steel valves, fittings, instrumentation, and other process related equipment, eliminating the traditional availability problem of tantalum in usable forms and costs. This surface treatment is based on a process that grows tantalum metal into a base substrate, like stainless steel.
until a thin, uniform, rugged surface of pure tantalum metal is created (see Figure 3). This surface exhibits all the chemical properties of pure tantalum, but without the cost. The resultant materials are extremely rugged and durable with the ability to withstand severe deformation such as 180-degree bends, indentations and scratches because these are surface alloys and metallurgically alloyed to the substrate (see Figure 4).

Having the corrosion resistance of tantalum and the ruggedness of standard materials, surface alloys are an excellent option for applications that require extreme corrosion resistance on complex process equipment like valves and instrumentation. Surface alloys are limited in size due to the reactors that they are created in but have the advantage of being utilized on standard and readily available steel substrates like valves.

**Zirconium**

Zirconium alloys exhibit excellent resistance to corrosive attack and work well in many organic and inorganic acids, salt solutions, strong alkalis, and some molten salts. Zirconium is produced as two major alloys for chemical processing applications; grade 702 is “pure” zirconium, while grade 705 is zirconium alloyed with 2.0 – 3.0% niobium. Of the alloys, Zr 702 has slightly better corrosion resistance in media like sulfuric acid than Zr 705; however Zr 705 has better strength properties due to the addition of niobium and is easier to form (1).

**Titanium**

Titanium is an established metal when dealing with corrosion applications. Titanium is available in a range of different alloys with the most corrosion resistant grades namely grade 7, grade 11 (containing 0.15% palladium), and grade 12 (containing 0.3% Mo and 0.8% Ni). In the chemical processing industry, titanium and its alloys offer good corrosion resistance in many process solutions and owe their corrosion resistance to the strong oxide film. This oxide film formed on titanium is more protective than on stainless steel due to titanium’s greater affinity for oxygen and its ability to more readily form its protective oxide layer. As a result, titanium performs well in media such as seawater, wet chlorine, and organic chlorides. While titanium offers good corrosion resistance to these solutions, it certainly is not immune to them, especially at elevated temperatures such as seawater at temperatures greater than 110°C (2).

**Nickel alloys**

Nickel alloys are a common material used when typical steel materials don’t offer the corrosion performance that is needed. When dealing with aqueous solutions to enhance the performance of nickel materials, the most important alloying elements are Fe, Cu, Si, Cr, and Mo; with Cr and Mo playing a major role in nickels corrosion resistance. By varying the concentrations of Cr and...
Mo in the nickel alloys, the corrosive environments in which nickel alloys can be successfully applied are varied; but they typically are found in a range of acid, salt and alkali applications. Addition of 15%-30% Cr improves the corrosion resistance to oxidizing solutions while addition of Mo up to 28% significantly improves the resistance to non-oxidizing acid (3, 4).

Material and product costs
When looking at material costs, it is far more advantageous to look at the total cost of ownership versus the initial out-of-pocket costs. In most cases, it is more cost effective to specify materials that will provide an extended valve life. This is especially true in areas that are difficult to replace or are critical to the safety and performance of the operation. Increased costs of a specialty metal valve are usually insignificant compared to the costs associated with loss of production time, out of specification products, and maintenance. Compared to 316 stainless steel or even polymer solutions, specialty metals are relatively expensive and are therefore reserved for applications that require specialty metal properties and characteristics. While metals prices are continuously fluctuating, the latest estimates for a solid specialty metal solution is anywhere from 4.5 – 20 times the cost of 316 stainless steel solution, with the exception of solid/tantalum lined valve, which could be 50+ times that of 316 stainless (see Figure 5). As a cladding, tantalum is still significantly more expensive than any of the specialty alloys; however as a surface treatment, since the tantalum metal is used very efficiently, the costs are competitive with other special metal solutions.

References:
1. ATI Wah Chang Allegheny Technologies, Zirconium in Sulfuric Acid Applications Technical Datasheet, 2003 p. 3

About the author
Bo Gillesberg,
Vice President and founder of Tantalone, graduated with a Master of Science and PhD degree from the Technical University of Denmark in Copenhagen. He started his career as a Material and Process Consultant at Danfoss’ Group headquartered in Denmark, where he became Chief Consultant in their technology centre. Recognized for his extraordinary entrepreneurial skills, Gillesberg joined Danfoss Ventures and was responsible for the company’s tantalum activities. He soon realized the huge potential of the Tantalone technology and initiated a management buyout supported by a consortium of investors. Up until late 2010 he worked as global CEO for Tantalone but decided to narrow his focus on the business development of the rapidly growing company.

Author contact: bg@tantalone.com
Website: www.tantalone.com