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TANTALUM 101

Corrosion Resistance, Equipment Design, Fabrication and Testing of Tantalum Lined / Explosion Clad Equipment For Process Industries

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Tantalum 101

Tantalum as A Material

Tantalum is a refractory metal that finds a niche in the chemical process industries in high concentration and high temperature, sulfuric acid, hydrochloric acid, nitric acid, and bromine applications. Being a refractory metal, Tantalum gets its corrosion resistance from a continuously regenerating oxide layer that is both corrosion and erosion resistant.

Tantalum has found its place as a perfect companion or replacement for glass or glass lined equipment in many chemical processes with almost identical, corrosion resistance to that of glass. Tantalum also shares several corrosion resistant vulnerabilities with glass and glass lined equipment. Hydrofluoric acid and compounds including fluorine based chemistry will attack tantalum very quickly and should not be considered for use as chemical process equipment. Sodium hydroxide can affect tantalum after long-term exposure causing potential hydrogen embrittlement therefore tantalum should not be used.

Tantalum and Tantalum Alloys

There are several different Tantalum and Tantalum alloys that can be used in chemical applications.

Pure tantalum, tantalum with 2 1/2% tungsten and Tantalum alloyed with ruthenium have been used successfully in chemical process equipment. The most common tantalum metal used in chemical process equipment is tantalum with 2 1/2% tungsten. The addition of 2 1/2% tungsten increases the strength of the tantalum by almost 50% and has no noticeable effects on the corrosion resistance relative to that of the pure tantalum metal.

The phenomenon of hydrogen embrittlement is possible with most metals. However, tantalum can be more susceptible to hydrogen embrittlement than other metals. The application of platinum spots on a 1 to 1000 ratio can eliminate the vulnerability of tantalum to hydrogen embrittlement of the tantalum in most applications.

Figure 1 - Platinum spot plating being applied on tantalum lined heat exchanger bonnet.

Platinum acts as a sacrificial anode, to attract the free hydrogen in the process to reduce or eliminate the possibility of hydrogen embrittlement in the tantalum.

In more severe applications where tantalum is susceptible to hydrogen embrittlement ruthenium can be added to stabilized tantalum. This is commonly used in heat exchanger tubing where platinum spot plating is more difficult to apply.

Design of Tantalum Equipment

The design of tantalum equipment poses several challenges because of the cost of the material and the fact that tantalum is not recognized by the ASME code for the design of pressure vessels. The price of tantalum follows a market that is controlled by the electronics industry. The cost of tantalum is often between $ 300.00 and $ 350.00 a pound which makes the utilization of the material for chemical process equipment complex.

Based on these two facts equipment that utilize tantalum as a material of construction is often loose lined or explosion clad to minimize the amount of tantalum required a given piece of equipment.

Loose Lined Tantalum Designs

The lining of tantalum equipment is similar to that of other lined chemical processing equipment. A substrate material is fabricated to the required pressure vessel design code, and then sheet lining materials are formed and then welded to line the substrate material to create a 100% corrosion resistant liner.

Figure 2 - Convolutions in tantalum lined pipe provide vacuum resistance and thermal expansion compensation

Convolutions are often used to give vacuum resistance, rigidity, and a thermal expansion compensation mechanism to the lined equipment. The shape and pitch of the convolution can be varied to accommodate different mechanical design characteristics that are required by the application. A full vacuum design can usually be accommodated in loose lined tantalum equipment up to approximately 30 inches in diameter. Vacuum resistance on flat covers and other flat surfaces in chemical process equipment can be achieved by using staybolts.

Staybolts are solid tantalum bolts that are threaded into the substrate material to connect the tantalum liner to the substrate material. The tantalum liner is welded to the substrate material to mechanically attach the liner to the substrate material. Convolutions are also added to the flat covers to increase the rigidity of the flat surface.

Loose lined designs do have limitations to vacuum resistance as well as heat transfer. Where full vacuum, thermal cycling and heat transfer through the Tantalum is required an explosion clad design is often applied.

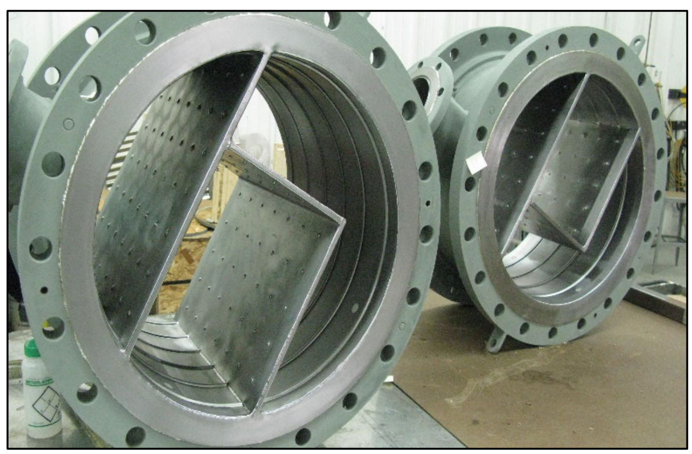

Figure 3 - Staybolts used in heat exchanger pass partition to secure tantalum lined to plate.

Explosion Clad Tantalum Designs

Explosion clad tantalum chemical process equipment has been applied in applications where vacuum resistance, thermal cycling and heat transfer are required for larger diameter equipment. The cost of tantalum explosion clad tantalum equipment is considerably more expensive than other alloys or glass lined equipment therefore the chemical process that is utilizing the tantalum explosion clad equipment needs to require the mechanical attributes that can be given only by an explosion clad construction.

The process of explosion cladding joins two dissimilar metals by detonating explosives on top of the two metals creating a metallurgical bond between the two plates. The result is a single plate with a thin, corrosion resistant layer of metal and a substrate material design to the thickness required by the chemical process pressure requirements. The two are mechanically attached creating a single plate.

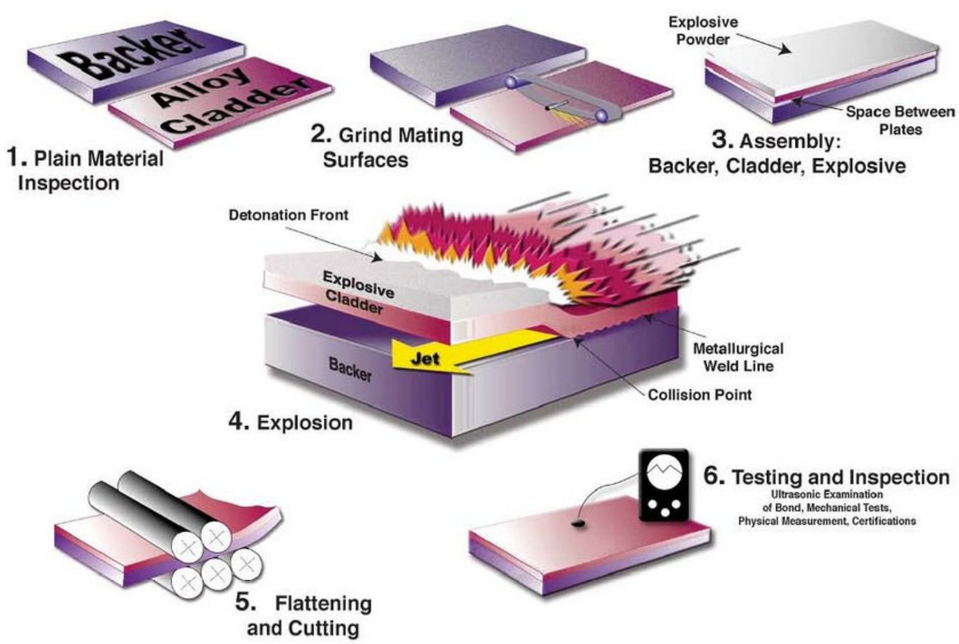

Figure 4 - Explosion Clad Manufacturing Process (Courtesy of Nobel Clad)

Reactors, columns and cyclones have been successfully manufactured utilizing tantalum explosion clad designs.

Tantalum Heat Exchanger Design

Tantalum as a material makes an excellent heat transfer material as it has a very high thermal conductivity and has very unique heat transfer fouling characteristics as well as a full welded metal design. Tantalum is often a cost-effective replacement for both silicon carbide, graphite block and graphite shell and tube heat exchangers.

The erosion resistant characteristics allows us to design a tantalum heat exchanger utilizing much higher tubeside liquid velocities than other materials. The higher velocity on the tube side of the heat exchangers allows for better heat transfer as well as longer operational lives in between heat exchanger cleanings. When the attributes of tantalum are considered during the thermal design of a tantalum heat exchanger there can be significant surface area reductions when compared to heat exchangers made from SIC or graphite.

Fabrication of Tantalum Equipment

The manufacturing workplace requirements for the fabrication of tantalum equipment needs to be in a segregated area that is isolated from contaminants that are typically found in a metal fabrication shop. The hand-tools, cleaning and grinding supplies used in the fabrication of tantalum should only be used for that of Tantlaum and not shared with other metals.

The melting temperature of tantalum is approximately 5600 °F (3093 °C), which is approximately twice the temperature of the typical substrate material. This means that the tantalum welds on the chemical process equipment need to be far enough away from the substrate material so to not contaminate the tantalum weld with the substrate material during welding. To accommodate this, there needs to be special consideration in the design of the substrate to ensure that the tantalum welds are far enough away from the substrate material. This can be achieved by ensuring that the tantalum weld is flared away from the substrate material or special preparations to remove the substrate material is made in the design of the equipment.

The welding of tantalum is often completed by using welding processes including GTAW (TIG), PAW (Plasma Arc Welding) and laser welding.

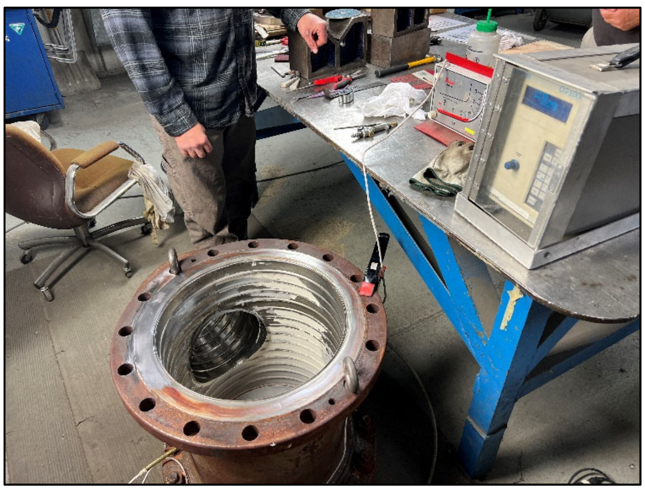

Figure 5 - Argon flow meters and oxygen sensor used to ensure proper inert gas purge welding conditions

Tantalum, being a refractory and reactive metal, requires a special welding process where the metal needs to be extremely clean and welded in a 100% argon purge. The design of the tantalum lined equipment needs to be able to accommodate the secondary and tertiary argon purge required for the welding. This can be an important detail that is overlooked by in an inexperienced tantalum equipment manufacturer.

Special care needs to be taken in monitoring the flow rates of the argon purge during welding. Flow meters should be used to monitor the flow of the argon for the secondary and tertiary purges. An oxygen sensor should be used to ensure that the welding Environment meets the requirements for welding the tantalum. Tantalum is commonly welded in donut shaped argon distributors. Since argon is heavier than air the argon fills like a liquid in the distributor until a 100% argon purge.

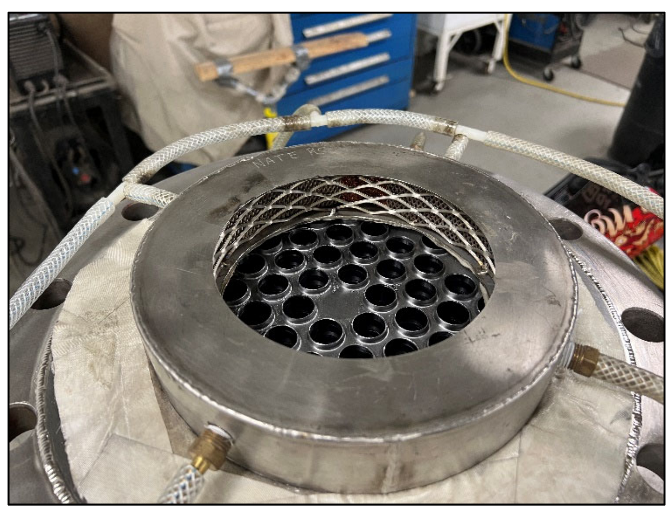

Figure 6 - Argon distributor used for tantalum welding

Testing and Inspection

Testing of tantalum and tantalum lined equipment is similar to that of other welded metal chemical process equipment. Material traceability per the design for code is followed. The substrate material that is used in the tantalum chemical process equipment is tested as would carbon or stainless steel chemical process equipment. Dye penetrant testing, helium leak testing and hydrostatic testing is a standard requirement for all tantalum, tantalum lined and explosion clad tantalum fabrications.

Common Applications for Tantalum

Tantalum has found a niche and several different chemical applications where it is the preferred metal for the specific application.

Sulfuric / Nitric Acid Concentration

Tantalum bayonet heat exchangers are often used as evaporators for the concentration of sulfuric and nitric acid during the manufacturing process for dinitro toluene, polycarbonate, MDI and TDI.

Pharmaceutical / API (Active Pharmaceutical Ingredients) / Fine Chemicals

Tantalum is used as heat exchangers, condensers and lined pipes in active pharmaceutical ingredient and fine chemical applications where high concentration acid and solvents are used. Tantalum lends itself in these applications as it has many of the attributes necessary to excel in the manufacture of these chemicals including high heat transfer, clean-ability, and the ability to utilize sight glasses or solid glass end covers to view the condensation process during operation.

Steel Picking Applications

The cleaning of carbon steel prior to painting or other surface treatments is often completed using a hydrochloric acid cleaning process where the acid is heated to approximately 190°F and the carbon steel is pushed through tubs of acid. The heating of the acid is done by shell and tube or immersion coil heat exchangers often utilizing tantalum. Tantalum has proven itself in this application to be a superior metal in this application because of its high heat transfer, fouling resistance, and rugged fully welded metal design.

Mining Applications

Tantalum is commonly used in nickel mining applications where high-pressure acid leach (HPAL) and gold mining where pressure oxidation (POX).

Equipment found in these applications are often tantalum lined titanium acid spargers and solid tantalum oxygen lances. In both of these applications, tantalum has a long history of exceptional operational life.

Bromine

Tantalum has shown good corrosion resistance in bromine applications where heat exchangers have been used for steam heating, cooling, vaporization and condensation of bromine and bromine compounds.

Corrosion Resistance of Tantalum / Tantalum 2 ½% Tungsten

Media	Concentration	Temperature	Corrosion Rate (MPY)
Bromine	Dry	200°F	Nil
Chlorine	Wet	220°F	Nil
Chromic Acid	50%	Boiling	Nil
Hydrochloric Acid (HCL)	5%	200°F	Nil
Hydrochloric Acid (HCL)	30%	200°F	Nil
Hydrofluoric Acid (HF)	All	Room	Rapid Attack
Nitric Acid	65%	Boiling	Nil
Sodium Hydroxide	10%	Room	NR*
Sulfuric Acid (H_2SO_4)	40%	Boiling	Nil
Sulfuric Acid (H_2SO_4)	99%	400°F	Nil

*Long term exposure to sodium hydroxide has shown potential for hydrogen embrittlement and loss of ductility

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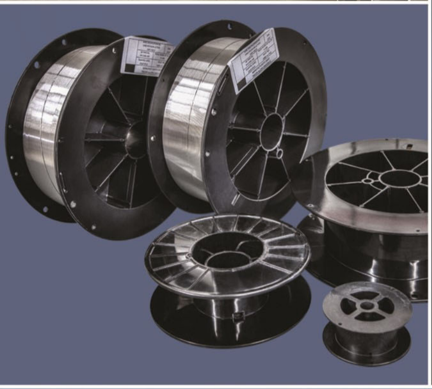

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