Tantalum and Niobium Materials for the Pharmaceutical Industry

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This article defines tantalum and niobium and describes how these refractory metals can be used in corrosion- resistant applications when designing equipment for the pharmaceutical industry.

Introduction

Tantalum and niobium are members of the refractory metals family, characterized by their very high melting points. In nature, tantalum and niobium are found together in several minerals, including tantalites, columbites and pyrochlores. In addition, significant amounts of these metals are recovered from tin slags.

Niobium was discovered in 1801 by C. Hatchett, an English chemist and tantalum was discovered by Anders Ekeberg, a Swedish chemist, in 1802.

The similarity of these two metals goes far beyond their occurrence and discovery. Their chemical properties are so similar that it was difficult to positively establish their individual identities in early work. Both tantalum and niobium are tough, ductile metals which can be formed into almost any shape. Because of their resistance to chemical attack and their excellent formability, they are used in corrosion-resistant applications for environments which no other metals can withstand. Their major limitation is reactivity with oxygen and nitrogen in the air at temperatures above 300° to 400°C.

Tantalum and niobium have many unique applications as pure metals and from the basis for a family of alloys having similar chemical, physical and high-temperature properties.

Corrosion resistance is the crucial requirement for any kind of equipment designed for the chemical and pharmaceutical industry. Thus, it follows that the properties of metals to be used in the fabrication of such equipment must be thoroughly assessed as part of earliest stages of planning and selection. Metallurgical performance must, in turn, be combined with comparative economic evaluations. This is because there are certain applications in which initially higher priced metals can provide long term savings by virtue of their superior ability to withstand the ongoing rigors of corrosive environments.

From the standpoint of cost effectiveness, sufficiently corrosion-resistant metals are often specified for the lining rather than the entire piece of equipment. Design and fabrication are based up on determination of the wetted surface exposure of the equipment. Thin cladding can reduce fabrication costs considerably where applications for optimum performance depend upon the specific end use of the equipment in the process environment.

Material Properties

Tantalum and niobium are tough, ductile, silvery gray metals with a unique combination of mechanical and physical properties

Niobium has a density close to that of copper, but only about half the density of tantalum and tungsten. The good thermal conductivity values for both tantalum and niobium make them reliable materials for heat transfer applications.

Regarding chemical characteristics, niobium resists most organic and mineral acids at all concentrations below 100°C, expect hydrofluoric acid. Tantalum is more corrosion resistant to these environments at higher temperatures and concentrations. Because of their ability to form stable, passive oxide films, niobium and tantalum can provide unique solutions to many corrosion problems. A good example is the use of niobium heating components in fluoride catalyzed chrome plating operations. Neither metals, however, can be used in air at temperatures above 200°C for niobium or 300°C for tantalum.

Because of their body centered cubic crystal structure, niobium and tantalum are very ductile metals which can undergo cold reductions of more than 95 percent without failure. Heavy sections can be heated for forging to approximately 450C without protection. Both metals can be rolled, drawn and extruded to produce a wide range of products.. Tantalum and niobium have a tendency to adhere to tooling during metal forming operations.

As a result, specific lubricants and die material combinations are required in forming operations.

Niobium and tantalum can be clad onto such other metals as steel, nickel and copper to produce cost effective fabrications.

Niobium and tantalum can be machined using standard equipment and cutting tools. Water soluble oil is used as a cutting fluid for turning, drilling, milling and sawing. Halocarbon is used as an assist for tapping.

Both these metals are more expensive than other specialty engineering materials. When the metal costs are incorporated into finished equipment costs, however, the cost differences are not nearly as great as one might expect.

Tantalum and Niobium Applications

Since the metals have a high degree of fabricability, almost any equipment design can be constructed from tantalum and niobium mill products. In view of their highly favorable engineering properties, a wide range of both standard and custom designed equipment is appropriate using either tantalum or niobium. Typical product examples are reactor vessels, columns, bayonet heaters, shell and tube heat exchangers, lined piping, valves, thermowells, spargers, rupture disks and orifice plates.

The factor of essentially zero metal loss due to corrosion resistance in the correct applications contributes importantly to the following features in the use of tantalum and niobium as heat transfer equipment:

- It allows the use of the absolute minimum thickness of metal. In conjunction with the metals' favorable modulus of elasticity, excellent component rigidity can be obtained in fabrication of equipment.
- Absence of scaling and fouling avoids the reduction of heat transfer effectiveness by conduction and convection as well as hindrance of flow by obstruction.

The overhead condenser is manufactured to the maximum advantage of these characteristics. On standard fabrication of a tantalum exchanger, the tube to liner weld is extended away from the tubesheet to eliminate weld contamination. However, this geometry causes liquid hold up in vertical units. A flush face tubesheet was designed to solve this problem. The flush face puts the tube to liner weld lower than the tubesheet liner for a completely sanitary and drainable tubesheet.

Bayonet heaters and shell and tube exchangers with tube metal and sheet thicknesses in the range of 0.015" to 0.040" are indicative of tantalum's and niobium's good formability, weldability and adaptability to precision fit. The use of thinwall tubing also contributes an economic advantage by allowing for the predominant use of seam-welded tubing from sheet.

The following three basic types of construction are used to fabricate tantalum or niobium into vessels and other components for the pharmaceutical and chemical industry:

- Solid
- Integrally clad
- Loose-lined

Vessels made from solid tantalum or niobium are not the most economical selection of fabrications. As a consequence, this method of fabrication is infrequently specified. The fabrication of integrally clad vessels uses explosively bonded tantalum or niobium to a base metal which is usually carbon or stainless steel. The thickness of the tantalum or niobium sheet (0.040" to 0.125") is considerably reduced from the solid construction, but the welding and fabricating techniques required still make this a very expensive method of fabrication.

In loose lined construction, the tantalum or niobium liners are fabricated and formed into the shell without bonding. Since the loose lining sheet can be reduced to 0.020" thick sheet, it is the most economical and therefore most widely used method of fabrication.

The high initial cost of tantalum or niobium fabrication in the chemical process industry is usually negated over the life cycle of the equipment.

In summary, there have been hundreds of successful applications for tantalum and niobium operating in severe corrosion environments over a wide range of temperatures and concentrations. The chemical and pharmaceutical industries are well aware of the cost of unplanned downtime. It makes continuous and uninterrupted operations of these plants a necessity.

These manufacturing industries are increasingly achieving gains in productivity, product purity and operating safety by selecting the optimum material of construction for production equipment.

Tantalum and niobium are two of the most effective anticorrosion materials for use in certain severe applications. Over time, both of these materials will provide sizable economic benefits to the chemical and pharmaceutical industries.

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About the Author

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