

Aluminium Bronze: An Alternative to Duplex Steels in Pump Design

Bronze alloys are very well known for friction related applications whereas Aluminium Bronze or Nickel Aluminium Bronze alloys are much less known; yet, they offer unique corrosion characteristics as required by pumps, especially in sea water applications, along with interesting biofouling properties. Those two properties make them a preferred solution for all marine related applications (pumps, valves, heat exchangers and propulsion systems).

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Interesting properties of Aluminium Bronze for pumps

Aluminium Bronze is a family of alloys including copper, aluminium, nickel, iron and manganese. Each individual component can be easily adjusted to improve strength, corrosion resistance and/or machinability.

Those combinations allow a unique set of properties, (see Table 1) which are useful in many pump applications:

- High strength
- Excellent wear and galling resistance
- Density (5% lighter than steel)
- Non sparking
- Low magnetic permeability (of <math> <1.03\mu</math> in selected grades)
- High corrosion resistance
- Good stress corrosion properties
- Good cryogenic properties
- High resistance to cavitation
- High resistance to biofouling

With a main property being the protective oxide surface film, which has the ability to self-repair, it outlasts steel coated applications in the long run.

The family of Nickel Aluminium Bronze (NAB) is available according to various international standards (EN 1982, ASTM B148, BS...); each having specific properties, some examples are listed in Table 1 below.

Optimum corrosion protection is reached when:

- An additional heat treatment at 675°C for six hours is applied
- Aluminium should be less than $A1 \% < (8.2 + Ni / 2)$

Mechanical strength

Some design engineers, sometimes due to lack of data, consider copper based alloys as being of low strength resulting from the metallurgy not being widely covered in university courses and often being overshadowed by their rival stainless alloys, which are more highly publicised.

However, copper based alloys are high up in the mechanical strength ratings of cast alloys that require a

	Rm Tensile Strength Mpa min	Rp Proof Stress 0.2% MPa min	A Elongation % min	Hardness HBW min	Specifications Sand Cast
CuAl10Ni3Fe2	500	180	18	100	INOXYDA 3P
CuAl10Fe5Ni5	650	280	13	140	ASTM B148 C95800 INOXYDA 53H EN 1982-2018 CC333G
CuAl11Fe4Ni4	700	350	8	170	EN 1982-2018 CC334G INOXYDA 72 ASTM B148 C95500

Table 1: Properties of the Nickel Aluminium Bronze (NAB) family.



good degree of corrosion resistance. Although this does not represent the total picture, it is an important factor in design criteria. (Please see Figure 1.)

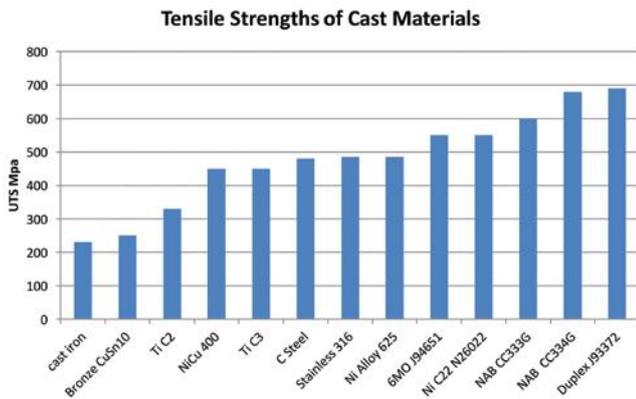


Figure 1: Tensile strengths of cast materials.

Here are some examples of parts that can be cast in various aluminium bronze alloys:



Figure 2: A cast pump impeller. Photo courtesy of Inoxyda SA.



Figure 3: Centrifugal Pump LP Casing. Photo courtesy of Inoxyda SA.



Figure 4: Gate Valve/Butterfly valves. Photo courtesy of Saint Remy Industrie.



Figure 5: Pre machined cryogenic pump casing. Photo courtesy of Saint Remy Industrie.



Figure 6: Impellers. Photo courtesy of Inoxyda SA.



Figure 7: Discharge Elbow. Photo courtesy of Inoxyda SA.

Cavitation: An issue in pump design

When liquid flows over a metal surface, rapid changes in pressure can arise. Small water vapour bubbles are formed from the turbulence at low pressure points and these can migrate to high pressure points where they collapse violently on the surface of the component causing eventually erosion at the point of contact. Nickel Aluminium Bronze has excellent resistance to this phenomenon and as such, is still the predominant alloy for propellers in the shipbuilding industry.

This property is also important in any water handling system particularly for pumps and valves.

Cryogenic pumps: Very low temperature requirements

A main requirement for cryogenic pumps is the resistance at low temperatures. Unlike most steels, copper based alloys do not embrittle and have a good dimensional stability at low temperatures down to -190°C. A main issue to be addressed in those applications is the possible presence of oxygen which reduces scope to bronze alloys; for other applications aluminium bronze is regularly used, for example the Inoxyda 3 Cryo alloy.

Magnetic permeability: For military applications

The aluminium bronzes can be manufactured to give low magnetic permeability, according to its composition, which in some military applications offers a real added value. (Please see Table 2.)

Alloy Designation	Magnetic Permeability μ
CuAl11Fe6Ni6	1.75
CuAl10Fe5Ni5	1.5
CuAl9Ni3Fe2	1.1
CuAl9Mn1.5	1.01

Table 2: Alloy designation and magnetic permeability.

Biofouling: A property often ignored in pumps

Biofouling can be a serious problem with any systems handling seawater, particularly at elevated temperatures with warm climates.

High copper alloys have considerable resistance to the growth of crustaceans, seaweeds and other marine organisms. (Please see Figure 8.) The slow dissolution of copper ions inhibits their growth and prevents mass population. The maintenance of sea water handling systems is expensive either by mechanical removal or by chlorination which can also have an impact on other



alloys corrosion resistance within the system.

The adherence of crustaceans on nickel alloys and stainless steels can have a massive impact on their corrosion resistance due to crevice corrosion caused by differential aeration associated with these growths.

Figure 8 is a photograph of a corrosion rack that has been immersed in seawater for 22 months. The rack contains titanium, nickel alloys and stainless steels all of which are heavily infested with marine growths. The copper alloys including sample (1) CuAl9Ni5Fe5, (25) CuAl9Ni5Fe4Mn and (26) CuAl10Ni5Fe4 are all free from marine organisms.

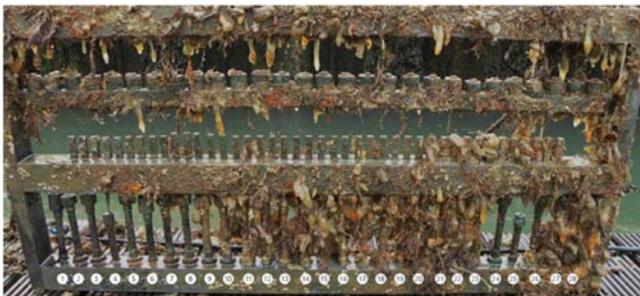


Figure 8: A corrosion rack containing titanium, nickel alloys and stainless steels that has been immersed in seawater for 22 months and as a result is heavily infested with marine growths. Photo: Copper Alloys Ltd UK & Copper Alliance UK (CDA).

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Machining & reparability

NAB alloys have two main advantages compared to duplex and super duplex alloys:

- Machining of Nickel Aluminium Bronze is easier and more cost effective
- Nickel Aluminium Bronze can easily be repaired by qualified welding technicians most of the time using TIG with corresponding feeder material. (It is important to use matching welding electrodes to minimise corrosion problems particularly in sea water applications, more details can be found in EN ISO 24373:2009.)

Technologies available to cast Aluminium Bronze pump components

Today's technology enables to cast most pump components using either sand casting for the large and complex parts or centrifugal casting for rings, bushings, risers and other circular components.

The field experience gained over the years crossed with the modern 3D simulation software considerably reduces the risks of initial casting. Today's 3D sand printing technology is now available for preparing complex core designs. All of these reasons add up to build good industrial solutions for pump components.



Figure 9: 3D sand printed impeller core. Photo courtesy of Saint Remy Industrie.

Summary

Due to its interesting properties, nickel Aluminium Bronze should be considered in comparison to all stainless steels alloys, including duplex and super duplex, for all pump and valve applications when confronted with corrosion, biofouling or non-sparking issues.

For more detailed technical data and a guide to Nickel Aluminium Bronze for Engineers, written by Ivan Richardson – Metallurgical Consultant and published by the Copper Development Association, please visit: <http://www.inoxyda.co.uk/telechargement.php>

About the Authors

Olivier Gouriou works as Sales Manager at Inoxyda. With 25 years experience in technical sales to answer custom application requirements for large size engineered products. Inoxyda is specialised in sand casting aluminium bronze since 1924 . With casting capacities up to 50To and after joining the LBI group, our experience enables us to cast most pump components up to 50To.

Laurent Robin works as Sales Manager at Saint Remy Industrie. With 25 years experience in technical sales in casting solutions. Saint Remy Industries is specialised in sand casting bronze and high copper alloys and have developed a specific knowhow for casting/machining cryogenic pump components.

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