Solutions for corrosive environments: **casted aluminium bronze alloys**

Corrosion causes problems in many different industrial applications. It can be due to different causes including chemical reactions, stress, and fatigue. Selecting the appropriate alloy for a given application is therefore an important step.

The purpose of this resume is not to deal with all corrosion scenarios but rather to present the main properties of Nickel Aluminium Bronze (NAB) alloys so that their possibilities can be considered early in the design phase of future projects. This family of copper-based alloys is not very well known. Nevertheless, because of their properties, they are a solution worth considering for a number of applications, for even if these alloys are regularly ignored at the expense of titanium, duplex steels, and more generic bronze alloys, they nevertheless provide an excellent solution in many heat exchanger, valve, and pump applications.

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Corrosion

The corrosion resistance of NAB alloys is very well documented with regards to sea water corrosion (corrosion rate 0.05–and 0.075 mm/year) in particular due to their self-repairing copper/aluminium oxide film. This offers better protection than any paint/coating process which can obviously be damaged during the lifetime of the product. Fig. 1 shows a heat exchanger channel in a welded steel construction with a protective coating. Fig. 2 shows a butterfly valve in aluminium bronze after being in use for thirty years in the cooling system of a nuclear power plant.

What is much less known, yet is also documented, is the resistance of these alloys to major chemical products (though all these facts cannot be listed in this short article) are available in *the Guide to Nickel Aluminium Bronze* for Engineers published by the Copper Development Association.

The properties of NAB alloys are such that they can even be compared to the capabilities of titanium.

» *Fig. 1. Five-year old steel coated channel (credit TOTAL).*

» *Fig. 2. Aluminium bronze valve body during maintenance after thirty years (credit EDF).*

Mechanical Characteristics

Adjusting the percentage of the various components of an aluminium bronze alloy enables us to target the appropriate corrosion resistance but also to attain the mechanical properties required for engineered applications, which can be compared to alternative solutions. Adding nickel and iron helps to improve these properties when compared to standard copper alloys. Some example of minimum values commonly attained are shown in Table 1.

Some applications, have additional requirements with regards to:

- Cavitation for pumps.
- Low temperatures for cryogenics.
- Non-magnetic for mine hunter propulsion.
- Non sparking for improved safety on offshore platform.

Much more unusual, but nonetheless interesting, is that the presence of copper and aluminium gives excellent electrical and thermic conductivity capabilities as required for electrical motor cooling applications in sea water environment.

Casting technology

When facing corrosion, an important factor is the manufacturing technology used. Welded constructions are very often used in industry but these may lead to corrosion issues starting at the welded joints. When using casting technology, not only can the casting be improved by repeatability but the increased thickness and the use of a process without welds reduces all risk of leakage, which is a source of downtime in continuous chemical processes.

Table 1.

Specification	Grade	Rm Tensile Strength Mpa	Rp Proof Stress 0.2% MPa	A Elongation %	Hardness HB
	TITANIUM (TA6V)	895	825	10	340
ASTM/ASME	B148 C95800	585	240	15	(150)
EN 1982	CuAl10Fe5Ni5 (CC 333 G)	600	250	13	140
Steel	Super Duplex	800	550	15	
INOXYDA	I 154	750	450	8	200
INOXYDA	I 154 forged	800	500	10	240
INOXYDA	I 72	700	350	8	190
EN 1982	CuSn10 (CB480K)	250	130	18	70

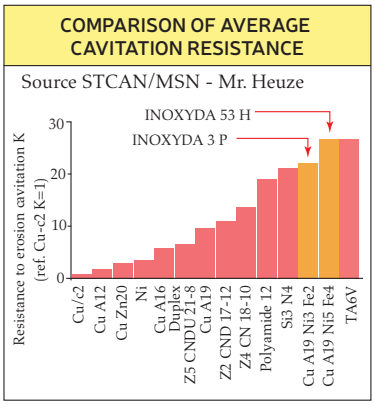


Fig. 3. Resistance to cavitation (credit Inoxyda).

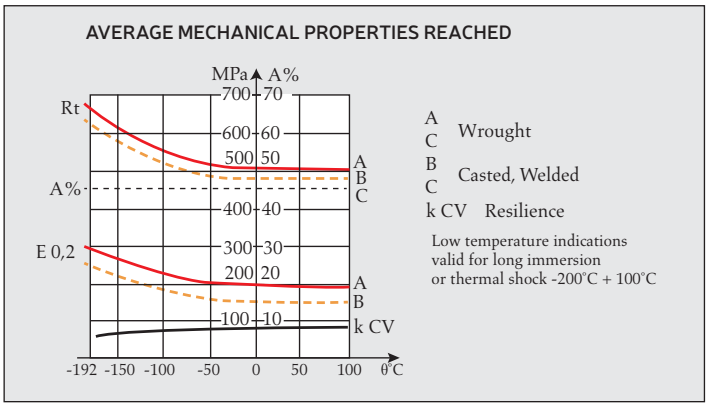


Fig. 4. Effect of temperature on mechanical properties (credit Inoxyda).

A perfect example is the use of casted lids on Esterfier lines; not only was Inoxyda 3P found to be the best alloy to face the corrosion issue in that specific process but the casted constructions removed the risks that are linked to welding seams.

Different casting technologies are available to cover the scope of mechanical designs. Among these are:

- Sand casting for complex and large size parts (pump casings, impellers, valve bodies…).
- Centrifugal casting (bushings, rings, pressure screws…).
- Continuous castings (billets ready for machining small components or forgings).

And today in connection with the 3D sand printing process, the hassel of creating and storing patterns can be removed, thus creating another advantage for casting technologies.

Controlling the quality of casted components

In addition to commonly required dimensional controls, the quality of casted parts are controlled through a NDT tests such as

- Chemical analysis : spectrometer
- Mechanical properties : tensile test, charpy test, hardness
- Corrosion resistance : salt spray test or micrography,
- Surface defect : dye penetrant test,
- Internal defects : X rays,
- Water tightness : pressure test.

With complete inhouse capabilities including 3rd party inspections.

Biocide/biofouling : a property often ignored

Copper is already known for its biocide properties, which in association with nickel, offers excellent biofouling

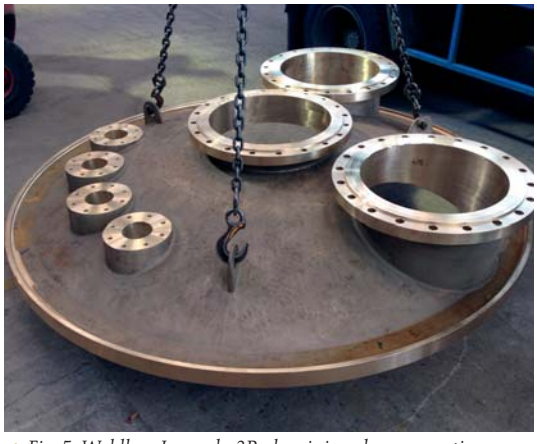


Fig. 5. Weldless Inoxyda 3P aluminium bronze casting.

Fig. 6. Valve casting using 3D printed cores (credit LBI Foundries).

» *Table 2.*

	Casting	Machining	Material cost	Corrosion	Heat treatment	Impregnation
Titanium	–	+++	++++	+++	Necessary	No
NAB alloys	+++	+++	++	++	Possible	No
Duplex steel	++	++	+	++	Necessary	No
Bronze alloys	++	+++	++	++	No	Often needed

performances. These are found to be interesting for all systems subject to marine organisms since they avoid the application of an additional chemical biofilm to protect infrastructures such as propulsion systems and heat exchangers.

Recyclability/cost/weight

When engineering complex systems different factors have to be taken into account throughout the lifecycle of a product. The end life of a product is not always considered in detail and, again, there are NAB alloys that offer interesting features:

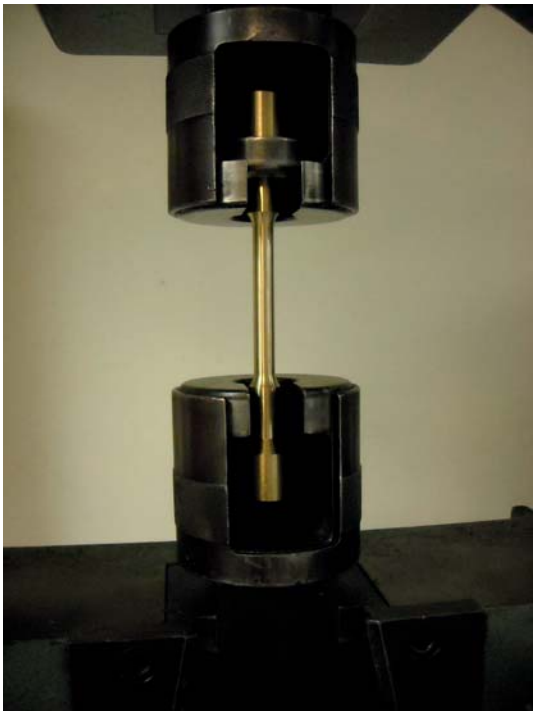
- Reduced downtime due to leakage.
- 100% recycling capabilities as these alloys can be produced from industrial scrap, thus reducing the pressure on world resources.
- Scrap still has an interesting value and can be reused thus increasing ROI even after full equipment has been amortized.

Due to the presence of aluminium, NAB alloys have a lower density (7,6) than bronze (8,7/9) which can also be an important consideration in terms of overall weight, in particular for large size components.

» *Fig. 7. Micrography of casted aluminium bronze showing optimal structure to prevent dealuminization (credit Inoxyda).*

» *Fig. 8. Pressure testing (credit Inoxyda).*

« *Fig. 9. Dye penetrant test of pre-machined casting (credit Inoxyda).*



« *Fig. 10. Test bar ready for tensile test.*

Summary

Faced with corrosive environments, engineers rarely consider Nickel Aluminium Bronze (NAB) alloys as being an interesting solution. Nevertheless, if their properties and advantages are considered, they can offer a wide range of capabilities to meet stringent design requirements.

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