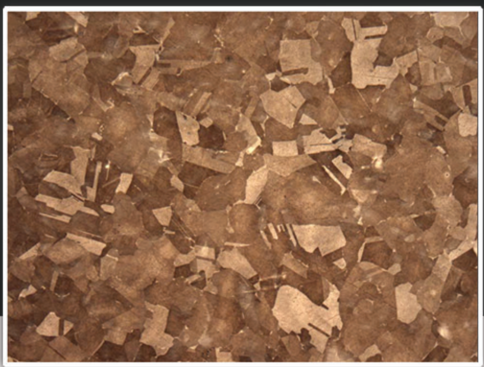
Unsurpassed for critical applications

"You acheived what I thought was impossible"

Senior Metallurgist, Ministry of Defence



Wrought CNC structure etched 100x magnification grain size around 45μm.png

About Copper Alloys Ltd

- www.copperalloys.net
- Stoke-on-Trent, England
- Producing speciality metals and components for critical engineering applications

Project Goals

- Create the ultimate alloy for nuclear submarines
- Engage with end users to steer innovation
- Develop process technology to standardise production and reduce cost

Approach

- The application of deep knowhow from previous alloy development
- Enhanced foundry control to ensure forgability
- Provide formats suitable for use in the marine industry

Results

- Genuine new material technology
- Enhanced options for design authorities
- Customer "you achieved the impossible"

Examples of Excellence

The 'impossible' problem

British manufacturer Copper Alloys Ltd revolutionises the art of marine forgings.

What was the project?

For marine applications, engineers have long been aware of the limitations in corrosion resistance of Aluminium Bronzes and steels, especially for applications requiring extreme performance over an extended life time.

Typically this issue has been managed by a twin approach of:

1. Designing thicker sections to allow for corrosion
2. Replacing components at intervals throughout the life time

Clearly both options are sub-optimal as they do not address the root cause of the problem. To address this, the Ministry of Defence commissioned trials to try to forge a copper-nickel-chrome alloy [DEF STAN 02 824], which had only previously been produced in a cast and very limited closed die forged condition.

Compared to aluminium bronze, copper-nickel-chrome is in general ten times more corrosion resistant and is five times more resistant to shock, with comparable cost (see overleaf).

In the early 1990s, extensive funding was given to forging companies to make a batch of wrought copper-nickel-chrome. The trials were a disaster, with billets breaking up on forging. Despite the support, the companies at the time failed and gave up and the Ministry of Defence abandoned the project.

An elegant solution

The technical control and process technology developed at Copper Alloys Ltd in order to successfully deliver previous complex alloy development over previous years was put to good use. The unique knowhow of melting, alloying, casting and combined with forging parameters, were key to creating high integrity forgings in copper-nickel-chrome.

Material creation

The development was successful, enabling Copper Alloys Ltd to identify reliable process routes and offer wrought copper-nickel-chrome in a comprehensive range of formats including blocks, rings, discs, bars and customised sections within a 5,000kg envelope.

The next generation of marine alloys

This range of copper-nickel alloys represents the first genuine new material technology for the marine defence industry in years. It is offered as one of three Elite Marine Alloys, which present design authorities with an innovative approach to through-life cost saving and enhanced performance.

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CAL Wrought CNC versus NAB and cast CNC

Overview of benefits of CAL wrought CNC-1 and CNC-2 compared with Nickel Aluminium Bronze (NAB) and cast CNC

CAL Forged CNC-1 and CNC-2	NAB	Cast CNC
Fine, homogeneous, equi-axed grain structure* free from phases that can be preferentially attacked in sea water. Hot forging densifies the structure, eliminating micro cavities. *ASTM E112 grain size 5-6 typically observed	Complex multi-phase microstructure with risk of semi-continuous anodic phases.	Grain structure free from phases that can be preferentially attacked in sea water. Coarse cast structure with coring (alloying element segregation across grains), with inter-granular and inter-dendritic micro cavities and non uniform grain size between sections of differing thickness.
Ability to be easily penetrated using conventional ultrasonic pulse-echo techniques, permitting detailed volumetric inspection to (for example) Def-stan 02-729 Part 5, rather than expensive radiography.	Wrought version (Def Stan 02-833) can be ultrasonically inspected whereas cast version (Def Stan 02-747) in practice, needs to be radiographed which is more expensive.	Coarse cast grain structure scatters and absorbs ultrasound resulting in very high attenuation. Can only be inspected volumetrically using radiography, which is relatively expensive compared with ultrasonic inspection and does not detect metal oxide films.
In-service wall thickness measurements using ultrasonic thickness gauge can be carried out to check corrosion rate in-situ, without the need to remove to check corrosion damage (does not suffer SPC).	Wrought version (Def Stan 02-833) can be checked using ultrasonic thickness gauge whereas cast version (Def Stan 02-747) cannot. Selective phase corrosion, in particular in hard to reach crevices, limits it's use.	Corrosion rate cannot be monitored in-situ using ultrasonic thickness gauge techniques. Component needs physically removing to inspect corrosion damage.
No selective phase corrosion (SPC) High general corrosion resistance in seawater <0.02mm/year (<0.0008"/year)	Selective phase corrosion 0.5-1.0mm / 0.002-0.04" General corrosion resistance in seawater ≈ 0.025-0.05mm/year (0.001-0.002"/year)	No selective phase corrosion (SPC) High general corrosion resistance in seawater <0.02mm/year (<0.0008"/year)
Homogenous refined wrought structure induces a high combination of mechanical properties IN THE ACTUAL PRODUCT, far higher than the Def-Stan 02-824 part 1 (see mechanical property section)	Wrought version (Def Stan 02-833) has integral test pieces however cast version (Def Stan 02-747) does not and actual test results obtained from castings often fall short of specification minimum values which are for separately cast test bars	Coarse cast grain structure differing from thin to thick sections of castings may result in actual mechanical properties in the product significantly less than the specification minimum requirements, which are determined on a separately cast test bar.
Very high Impact Strength ≈ 100J higher than NAB and over 2 x cast CNC: CAL CNC-1 Guaranteed ≥ 110J/ 81 ft lbf (typical 120-150J / 89-111 ft lbf) CAL CNC-2 Guaranteed ≥ 90J / 66 ft lbf (typical 105-125J / 77-92 ft lbf) Determined on samples taken from the actual product - highly representative.	Low impact strength: Castings Def Stan 02-747 Not specified, typically ≈ 17-25J / 13-18 ft lbf on separately cast test bar Wrought Def Stan 02-833 Specified as 23-27J / 17-20 ft lbf minimum (size dependant) Typically ≈ 30-40J/ 22-30 ft lbf - integral test sample for wrought grades	Moderate impact strength: No specified requirement for cast material Typically ≈ 45-60J / 33-44 ft lbf on a separately cast test bar NOT from cast product.
High 0.2% proof stress ≈ 2 x that of NAB and cast CNC: CAL CNC-1 Guaranteed ≥ 350-390MPa / 51-57Ksi (depending on section size) Typically 380-480MPa / 55-70 Ksi CAL CNC-2 Guaranteed ≥ 600 MPa / 87 Ksi Typically 650-750MPa / 94-109 Ksi Determined on samples taken from the actual product - highly representative	Low 0.2% proof stress: Castings Def Stan 02-747 specified as > 250MPa / 36 Ksi on separately cast test bar (castings themselves would typically be lower). Wrought Def Stan 02-833 specified as 245-325MPa / 36-47 Ksi (size dependant) Typically 280-380MPa / 41-55 Ksi - integral test sample for wrought grades	Low 0.2% proof stress: Specified as 300MPa / 44 Ksi minimum but is determined on a separately cast test bar unrepresentative of the actual properties in the castings. Specification guide-line is design on a minimum expected proof stress in the castings of 240MPa / 35Ksi
Issue of linear oxide films from reactive alloying elements (Cr, Ti, Zr): Wrought CNC-1 and CNC-2 is free from detrimental linear oxide defects. The small grain size and resulting low attenuation to ultrasound permits detailed volumetric inspection and this, combined with dye penetrant inspection, can confirm material is within the defect acceptance criteria as required by Def Stan 02-729 parts 5 & 4 respectively.	Issue of linear oxide films from reactive alloying elements (Cr, Ti, Zr): Non-issue	Issue of linear oxide films from reactive alloying elements (Cr, Ti, Zr): Cannot be detected using radiography making surface inspection using eddy current techniques required, which only determines integrity of material at or near surface.