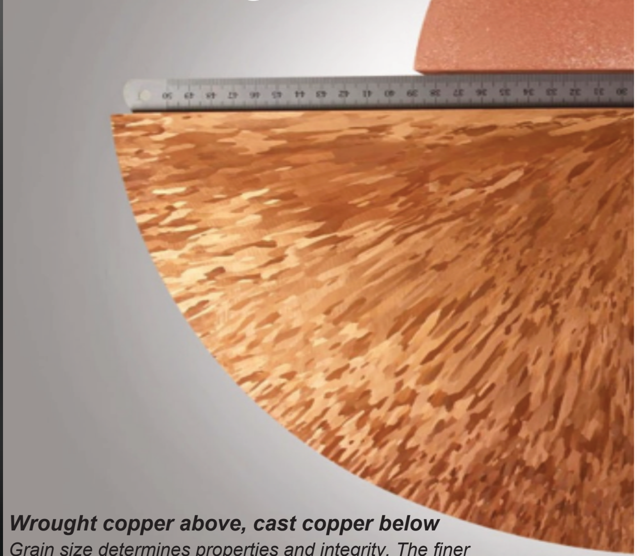
Examples of Excellence

Forgings vs. Castings

Forgings: high integrity **and** cost effective

"This is why we forge"



Wrought copper above, cast copper below
Grain size determines properties and integrity. The finer and more consistent, the better the metal.

3 Benefits of Forgings

1. Quicker & on-time delivery; risk of non-delivery reduced
2. High integrity - actual material properties are reported
3. Enhanced resistance to corrosion and general performance

3 Limitations of Castings

1. Actual component properties are unknown as reported properties come from separately cast test piece
2. Prone to metallurgical defects
3. No efficient method of volumetric inspection

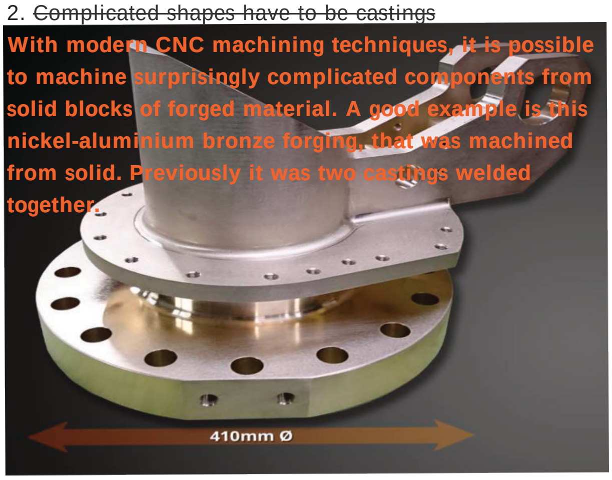
2 Myths about Forgings

1. ~~Forgings are more expensive~~

Due to the reliability of the production process, zero tooling costs and scalability of production, components made from forgings can be lower cost

2. ~~Complicated shapes have to be castings~~

With modern CNC machining techniques, it is possible to machine surprisingly complicated components from solid blocks of forged material. A good example is this nickel-aluminium bronze forging, that was machined from solid. Previously it was two castings welded together.



3 Reasons to Consider Forgings

1. Superior mechanical properties

By working the cast structure sufficiently, it is possible to more than double the strength and toughness of the material. Only Copper Alloys has developed the technology required to suitably penetrate the full section of some of the most advanced forged alloys available:

Cast copper-nickel-chrome - 240 MPa 0.2% Proof Strength in actual castings

Wrought copper-nickel-chrome - 650-750 MPa 0.2% Proof Strength (+290%)

2. Reliable production processes

Metal production commences with casting, and just casting metal can leave numerous metallurgical issues that unless dealt with, will only be known when the metal is being finish machined. The production of high integrity forgings puts the cast metal through its paces, indeed billets are likely to break-up when they are structurally deformed during the forging process if they contain significant defects. Any minor defects in the cast structure, which are normally the result of gas in the melt get closed up during the reduction of cross-section as a result of forging.

3. Ease of testing

The ability to easily test material throughout the production process and prior to spending money and time machining it is a distinct advantage forgings have over castings. The refined grain structure of forgings enable them to be penetrated easily by ultrasonic techniques which results in forgings being able to be tested at a fraction of the cost as castings, which require much more costly radiographic examination. Also, by using multi-directional ultrasonic scans, fine defects can be detected, which would be missed by radiography. Finally, as ultrasonic examination can be carried out in-situ, wall-section checks can be much lower cost by avoiding the cost of equipment for corrosion inspection. With castings, it is regularly deemed more cost effective to just replace components rather than radiographic examination.

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Theory applied: what do engineers actually get from using forgings instead of castings?

Wrought Copper-Nickel-Chrome	Cast Copper-Nickel-Chrome
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	Grain structure free from phases that can be prefer- entially 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.	Coarse grain structure scatters and absorbs ultrasound resulting in high attenuation. Can only be inspected volumetrically using radiography which is relatively expensive compared to ultrasonic inspection & does not detect oxide films.
In-service wall thickness measurements using ultrasonic thickness gauge can be carried out to check corrosion in-situ, without the need to remove to check corrosion damage (does not suffer SPC).	Corrosion rate cannot be monitored in-situ using ultrasonic thickness gauge techniques. Component needs physically removing to inspect corrosion dam- age.
No selective phase corrosion (SPC) High general corrosion resistance in seawater <0.02mm/year (<0.0008"/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)	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.	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: Specified as 300MPa / 44 Ksi minimum but is deter- mined 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 result- ing 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): Cannot be detected using radiography making surface inspection using eddy current techniques required, which only determines integrity of material at or near surface.