Welding Job Knowledge

Copper and copper alloys

Weldability of materials

Job Knowledge

Copper and copper alloys are chosen because of their corrosion resistance and electrical and thermal conductivity.

The various types of copper alloys are identified and guidance is given on processes and techniques which can be used in fabricating copper alloy components with a view to maintaining their corrosion or mechanical properties whilst avoiding the introduction of defects into the welds.

Alloy types

The main categories of copper and copper alloy are listed below:

Table 1. Frequently used copper alloys and recommended filler metals

Alloy type	Recommended filler
Coppers (tough pitch, phosphorus deoxidised)	Cu 1897, Cu 1898
Brasses (low Zinc)	Cu 6328, Cu 6560

Nickel Silvers (20%Zn/15%Ni type)	Cu 6328, Cu 6560
Silicon Bronze (3%Si)	Cu 6560
Phosphor Bronze (4.5% to 6%Sn/0.4%P)	Cu 5180
Aluminium Bronze (<7.8%Al)	Cu 6240, Cu 6100
Aluminium Bronze (>7.8%Al)	Cu 6180, Cu 6328
Aluminium Bronze (6%Al/2%Si)	Cu 6100
Gunmetal (low lead)	Cu 5180, Cu 6560, Cu 6180
Cupro-Nickel (10%Ni)	Cu 7061, Cu 7158
Cupro-Nickel (30%Ni)	Cu 7158

- Pure copper
- Copper with small alloy additions (less than 5% in total)
- Brasses e.g. copper-zinc (Cu-Zn)
- Nickel silvers e.g. copper-zinc-nickel (Cu-Zn-Ni)
- Bronzes e.g. copper-tin (Cu-Sn) (phosphor bronze alloys also contain phosphorus)
- Gunmetals e.g. copper-tin-zinc (Cu-Sn-Zn) (some alloys may contain lead)
- Aluminium bronze e.g. copper-aluminium (Cu-Al) (most alloys also contain iron and many nickel)
- Cupro-nickels e.g. copper-nickel (Cu-Ni)

The most frequently used copper alloys are listed in Table 1, together with a range of welding electrodes for fusion welding as per BS EN 14640:2005. Similar filler wire compositions are given in AWS A5.7/A5.7M:2008 and covered electrodes are specified in A5.6/A5.6M:2007.

It should be mentioned that welding of Nickel Silvers (45%Zn/10%Ni), leaded Gunmetal and high Zinc Brasses (40%Zn) is not recommended.

Copper alloys have quite different welding characteristics due to differences in thermal conductivity. For example copper, due to its high thermal conductivity, may require substantial preheat to counteract the very high heat sink. However, some of the alloys which have a thermal conductivity similar to low carbon steel, such as cupro-nickel alloys, can normally be fusion welded without a preheat.

Copper

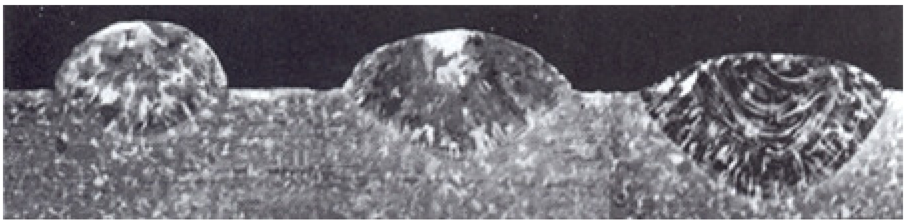
Copper is normally supplied in the form of

- oxygen bearing, tough pitch copper
- phosphorus deoxidised copper
- oxygen-free copper

Tough pitch copper contains stringers of copper oxide (<0.1% oxygen as Cu_2O) which does not impair the mechanical properties of wrought material and it has high electrical conductivity.Oxygen-free and phosphorus deoxidised copper are more easily welded.

TIG and MIG are the preferred welding processes but oxyacetylene and MMA welding can be also used in the repair of tough pitch copper components. Helium and nitrogen-based shielding gases, which have higher arc voltages, can be used as an alternative to argon to counteract the high thermal conductivity of coppers.

Avoiding weld imperfections



During fusion welding of tough pitch copper, the high oxygen content of the alloy often leads to embrittlement in the heat affected zone (HAZ) and weld metal porosity. Phosphorus deoxidised copper is more weldable but residual oxygen can result in porosity in autogenous welds especially in the presence of hydrogen. Porosity can be avoided by using appropriate filler wire containing deoxidants (Al, Mn, Si, P and Ti).

Thin section material can be welded without preheat. However, over 5mm thickness all grades need preheat to produce a fluid weld pool and avoid fusion defects. Thick section components may need a preheat temperature as high as 600 deg.C.

Copper with small alloying additions

Low amounts of sulphur or tellurium can be added to improve machining. However, these grades are normally considered to be unweldable.

Precipitation hardened alloys contain small additions of chromium, zirconium or beryllium. and have superior mechanical properties. Chromium and beryllium coppers may suffer from HAZ cracking unless they are heat treated before welding. When welding beryllium copper, care should be taken to avoid inhaling the welding fumes, which are poisonous.

Brasses (copper-zinc alloys) and nickel silvers

When considering weldability, brasses can be separated into two groups viz. low zinc (up to 20% Zn) and high zinc (30 to 40% Zn). Nickel silvers contain 20 to 45% zinc and nickel to improve strength. The main problem in fusion welding these alloys is the volatilisation of the zinc which results in white fumes of zinc oxide and weld metal porosity. Only low zinc brasses are weldable using fusion welding processes such as TIG and MIG.

Avoiding weld imperfections

To minimise porosity, a zinc-free filler wire should be used, either silicon bronze (Cu 6560) or an aluminium bronze (Cu 6180). High welding speeds will reduce pore size.

TIG and MIG processes are used with argon or an argon-helium mixture but not with nitrogen. Preheat is normally used for low zinc (<20% Zn) to avoid fusion defects due to the high thermal conductivity,. Although preheat is not needed for higher zinc content alloys, slow cooling reduces cracking risk. Post weld heat treatment also helps to reduce the risk of stress corrosion cracking in areas where restraint is high.

Bronzes (tin bronze, phosphor bronze, silicon bronze and gunmetal)

Tin bronzes typically contain between 1% to 10% tin. Phosphor bronze contains up to 0.4% phosphorus. Gunmetal is essentially a tin bronze with up to 5% zinc and it may have lead additions up to 5%. Silicon bronze contains 3% silicon and 1% manganese approximately and it is probably the easiest of the bronzes to weld.

Avoiding weld imperfections

Matching filler compositions are normally employed for welding bronzes. Autogenous welding of phosphor bronzes is not recommended due to weld metal porosity. However, this risk can be reduced by using a filler wire with a higher level of deoxidants. Gunmetal is not considered weldable since it is susceptible to hot cracking.

Aluminium bronze

There are essentially two types of aluminium bronzes; single phase alloys containing between 5 to 10% aluminium, with a small amount of iron or nickel, and more complex, two phase alloys containing up to 12% aluminium and about 5%of iron with specific alloys also containing nickel, manganese and silicon. Gas shielded welding processes are preferred for welding this group of alloys. In TIG welding, the presence of a tenacious, refractory oxide film requires AC(argon), or DC with a helium shielding gas. Due to its low thermal conductivity, a preheat is not normally required except when welding thick section components.

Avoiding weld imperfections

Rigorous cleaning of the material surface is essential, both before and after deposition of each welding pass, to avoid porosity. Single phase alloys can be susceptible to weld metal and HAZ cracking under highly restrained conditions. It is often necessary to use matching filler metals to maintain corrosion resistance but a non-matching, two phase, filler can also reduce the risk of cracking. Two phase alloys are easier to weld. For both types, preheat and interpass temperatures should be controlled carefully to prevent cracking.

Cupro-nickels

Cupro-nickel alloys contain 5 to 30% nickel with specific alloys having additions of iron and manganese; 90/10 and 70/30 (Cu/Ni) alloys are commonly welded grades. These alloys are single phase and generally considered to be weldable using inert gas processes and, to a lesser extent, MMA. A matching filler is normally used. 70/30 (Cu 7158) is often regarded as a 'universal' filler for these alloys. The thermal conductivity of cupro-nickel alloys is similarto low carbon steels, and therefore preheating is not required.

Avoiding weld imperfections

Cupro-nickels do not contain deoxidants, and therefore, autogenous welding is not recommended due to the risk of porosity. Filler metal compositions contain typically 0.2 to 0.5% titanium, to minimise weld metal porosity. Argon shielding gas is normally used for both TIG and MIG but in TIG welding, an argon-hydrogen mixture, with appropriate filler, improves weld pool fluidity and produces a cleaner weld bead. Gas backing (usually argon) is recommended, especially in pipe welding, to produce an oxide-free underbead.