Properties of Materials
BTM 2413

CHAPTER 8:

Copper and Its Alloys

by

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Introduction

- Aims
  - Make aware the importance of copper and its alloys from engineering material point of view

- Expected Outcomes
  - Identify the alloy designation method of copper
  - Identify properties, heat treatments and fabrication methods of copper…..
  - Know the alloy selection criteria of copper….

- Other related Information

- References

- Kenneth G Budinsky & Michael G Biddinsky, Engineering Materials: Properties and Selection, Ed 9, Prentice Hall

Copper

- Copper is our oldest tool material
- In the 21st century the property that makes copper one of the most important metals is the high electrical conductivity. (No other material has yet become a serious competitor).

- Copper is produced from the sulfide ores of lower grades using following process
- 1) Crushed and milled ores are floated and separated (and other physical separation method)
- 2) Roasting the ore in special furnace to remove volatiles
- 3) Smelting or melting roasted ore
- 4) Converting the molten copper matte (Cu_2S) to metallic copper by blowing air or oxygen
- 5) Electrolyte refining to further reduce impurities

Copper

Characteristics of Copper

- Easy to work, ductile and malleable
- Excellent resistance to corrosion
- Good machinability
- Non magnetic
- Good electrical and thermal conductivity
- Can be soldered, brazed and welded.
- Ease of forming alloys with other elements like Zn, Sn, Al, Pb, Si, Ni etc.
- Copper Alloys Brass (Cu+Zn)
- Bronze (Cu+Sn)

Copper Alloys

- In general,
- Copper plus zinc is Brass.
- Any other alloy of copper other than brasses is termed as bronze (previously only copper -tin alloy was called as brass)

Bronzes

- Tin bronze 2-4% Zn, 8-10% Sn remaining copper
- Pressure castings, bushings and bearings
- Leaded tin bronze 4%Zn, 6-8.5% Sn, o.5-1.5% Pb , remaining copper.
- Can be used upto 550 deg F
- Pressure castings,bushings, electrical castings, gears , pumps etc
- High leaded tin bronze:
- 1-3%Zn, 5-10%Sn, 7-15%Pb
- Bearings operating at high speeds and high pressure and for corrosion resistant pumps.

Bronzes

- Gun metal:

- 5-10% Sn, 2-5% Zn, remainder copper.
- Good tensile strength and resistance to corrosion.

- Used for bearings, steam pipe fittings, marine castings, hydraulic valves and gears.

Bronzes

- Aluminum bronze
- 1-4% Fe, 9-11% Al , remaining copper

- For heavy duty parts, marine equipment,
- gears, bearings, bushings,
- valve seats, guide stems,
- acid resisting pumps, parts resisting corrosion and oxidation,
- Components requiring strength at elevated temperatures.

Copper Alloy Brasses

- Alloys of copper and zinc
- Addition of zinc improves ductility and strength
- Good corrosion resistance and good working properties.

- 1.Alpha brasses-upto 36% zinc
- 20-36 % -yellow
- 5-20%-red
- 2.Alpha plus beta brasses contain 54 to 62 % copper

Copper Alloy: Brasses

- Yellow alpha brasses are subjected to a type of corrosion (called dezincification or pitting corrosion)
- When brass is in contact with water having a high percentage of oxygen and CO2.
- This is a start of dezincification. That results dissolution of the brass and a subsequent deposition of non adherent copper.
- This leads to leakage as the copper layers become porous.
- Addition of Small amounts of tin or antimony can reduce dezincification in yellow brasses.
- Stress relief annealing is recommended to reduce season cracking.
- Season cracking or stress corrosion cracking is due to high residual stress left in the brass after cold working process.
- These stresses make the brass more susceptible to intergranular corrosion.
- Intergranular corrosion is the corrosion happening preferentially at grain boundaries

Brasses

- Admiralty metal 71Cu-28zn-1Sn
- It shows good strength and high corrosion resistance.
- It is used for the tubes of condenser and heat exchanger in Power plans and air-conditioning plants

- Aluminum brass 76Cu-22zn-2Al
- It forms a tenacious self healing film. This helps in protecting the condenser tube against high cooling water velocities encountered in marine and land power stations.

- Cartridge brass Cu70, Zn30. and yellow brass Cu65, Zn 35
- Generally used in automobiles, electrical components and hardware and ammunition components
- Automotive – radiator cores, headlight reflectors,
- Electrical-lamp fixtures, socket shells
- Hardware-fasteners, screws, rivets, springs

Copper Alloy: Brasses

- Red brass
- 5-20% zinc

- It shows more corrosion resistance compared to yellow brasses It is not susceptible to stress corrosion cracking

- Gliding metal 95Cu-5Zn coins, medals, tokens, emblems, plaques, base for items to be gold plated.

- Commercial brass 90Cu-10Zn excellent cold working- so used in costume jewelry, marine hardware, forgings, rivets and screws.

- Silicon brass: 80Cu-14Zn-4Si-0.5Pb
- For die cast parts and small gears

Cupronickels

- Copper nickel alloys that contain up to 30%Nickel
- Copper nickel phase diagram is of solid solution type.
- At all compositions, the cupronickel alloys are single phase in nature.
- Not susceptible to heat treatment and their properties can be altered only by the process of cold working.
- Have high corrosion fatigue resistance.
- High resistance to corrosive and erosive action usually observed in rapidly moving sea water.
- Used for Condenser, distiller, evaporator and heat exchanger tubes. (where evaporation of salts are expected)

Cupronickels-Nickel silver

- Alloys of copper, nickel and zinc
- Constituents Copper-50-70%, Nickel-5-30% and Zinc-5-40%
- Addition of nickel to Cu-Zn gives a pleasing silver -blue-white colour and good corrosion resistance to food chemicals, water and atmosphere.
- Used for rivets, screws, table-ware, radio dials, costume jewelry.

Babbit Metal

Babbitt metal (white metal)

It is an alloy used to make the bearing surface in plain bearings. Babbitt metal has a typical characteristics of showing the resistance to galling.

Common compositions of Babbitt Metal:

ι) 90% Sn 10% Cu

ιι) 89% Sn 7% Sb 4% Cu

ιιι) 80% Sn Pb 15% Sb 5%

Babbit Metal

Babbit metal is soft in nature hence could be damaged easily.,
Looking at first it might be not suitable for making bearing surface.
This nature is deceptive
The alloy is made up of small hard crystals dispersed in a matrix of softer alloy.

As the bearing wears, the harder crystal is exposed,
with the matrix eroding somewhat to provide a path
for the lubricant between the high spots
that provide the actual bearing surface.

Effect of Tin and Zinc

•Use of Tin makes the bronzes (alloys) strong'.

•Zinc also adds strength. The use of more Zn (>4%) may result in reducing antifrictional properties in alloys. This nis certainly not recommended in bearing alloys.

• The tin bronzes are strong, hard and exhibit very high ductility.

•This properties when combined the result is the ally

- high load-carrying capacity,
- good resistance to wear and
- the ability to withstand against pounding.

•The alloys are noted for their corrosion resistance in seawater and brines

Tin Bronzes

- **The tin shows a good hardness.**

•They must be used with a clean and reliable lubrication system as their contact with dirt should be avoided

•They require a shaft hardness between 300-400 BHN.

•Tin bronzes operate better with grease lubrication than other bronzes;

•They are more suitable to boundary-film operation. As they have an ability to form polar compounds with small traces of lubricant.

•Differences in mechanical properties among the tin bronzes are not great. Some contain zinc as a strengthener in partial replacement for more-expensive tin to reduce cost.

Aluminum Bronze

•The aluminum bronzes are the strongest and most complex amongst all copper-based bearing alloys.

•Their aluminum content provides most of their high strength. It also makes them the only bearing bronzes that can be heat treated.

•Their yield strength is 68000 psi and tensile strength is 120000 psi. This allows them to be used at 50% higher load conditions as compared to other bronzes

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•They show fairly low ductility and hence do not conform or embed well.

•They consequently require shafts hardened to 550-600 BHN.

•Surfaces must also be extremely smooth, with both shaft and bearing finished to 1520 in RMS.

Aluminum Bronze

- Alloys do not show anti seizing characteristics. Hence lubricant quality should be extremely clean

- They show very good corrosion resistance. This property makes them suitable for to be used in making marine propellers and impellors of pumps

- The aluminum bronzes also have superior elevated temperature strength. They are the only bronzes - and the only conventional bearing material that can be operated at temperatures up to 260 deg C.