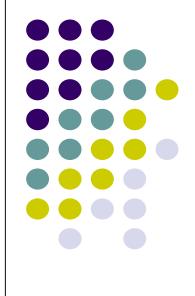
ME 216 – Engineering Materials II

Chapter 9

Nonferrous Industrial Alloys

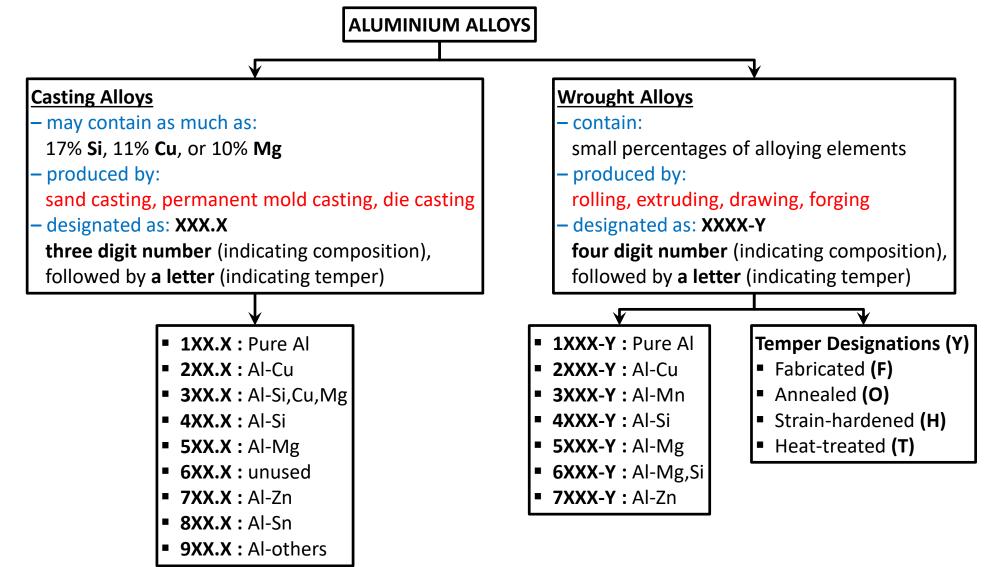




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- > Great use in reducing weight in machine parts, especially in aeronautical and automotive industries.
- > Low density and good corrosion resistance coupled with sound mechanical properties.





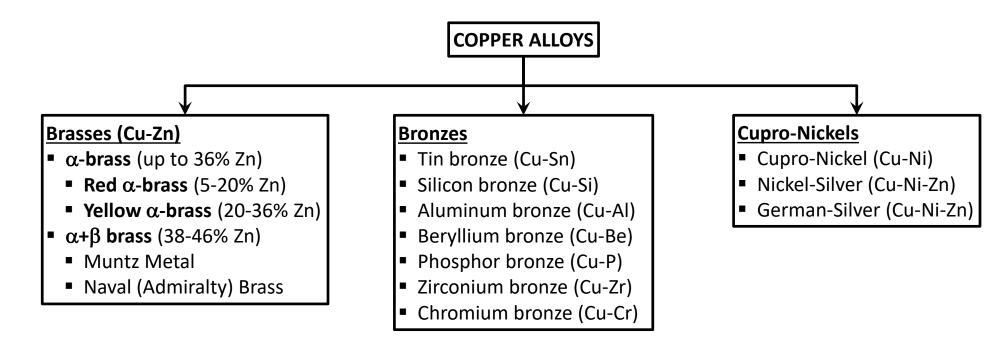
- AI-Cu (2XXX): Heat treatable, high strength alloys. May contain small amount of Si, Fe, Mg, Mn, Cr, Zn. Used in aircraft applications and for components requiring high strength and hardness.
 - 2017 (duralumin): With 4% Cu. Used as rivets in aircraft (Readily stored in fridge. After riveting, their temp. increases to room temp. and precipitation occurs, which increases the strength of rivets)
 - 2014: Stronger than 2017 with higher Cu and Mn. Susceptible to artificial aging. Used for heavy-duty forgings, aircraft fittings, truck frames, etc.
 - 2024: With 4.5% Cu, 1.5% Mg. The highest strength of natural-aged Al-Cu alloys. Difficult to fabricate.
- > <u>AI-Mn (3XXX)</u>: Not heat treatable due to limited solubility of **Mn**.
 - 3003: Good formability and weldability, resistance to corrosion. Typical uses are cooking utensils, food and chemical handling and storage equipment, gasoline and oil tanks, pressure vessels, and piping.
- > <u>AI-Si (4XXX)</u>: Not heat treatable. Excellent castability and resistance to corrosion.
 - 4032: With 12.5% Si. Good formability, low thermal expansion (forged automotive pistons)
- > <u>AI-Mg (5XXX)</u>: Not heat treatable. Good corrosion resistance, moderate strength.
 - 5005 (architectural extrusions), 5050 (aircraft fuel and oil lines), 5083 (marine and welded structures)
 - 214, 218 (dairy and food handling equipment, fittings for marine use, aircraft brake shoes)
- > <u>AI-Si-Mg (6XXX)</u>: Excellent corrosion resistance, more workable than other heat-treatable alloys.
 - 6053, 6061, 6063 (aircraft landing mats, canoes, tubings, railings)
 - 355, 356, 360 (aircraft applications, general-purpose castings)
- ► <u>AI-Zn (7XXX):</u> High strength, good corrosion resistance.
 - 40E: High mechanical properties, good corrosion resistance, machinable (aircraft fittings)

> Cu can be used as unalloyed; but Zn, Sn, Al, Si serve as solid solution hardeners.

- > Unalloyed (pure) copper with high electrical and thermal conductivity is used in electrical industry.
- Electrolytic tough-pitch (ETP) Cu is the cheapest industrial copper used for production of wire, rod, plate.

Copper Alloys

➤ Important alloys of copper are classified as: brasses, bronzes, cupro-nickels.



- Brasses: Alloys of Cu & Zn (with small addition of Pb, Sn, Al). Characterized by corrosion resistance combined with strength and hardness. Difficult to weld (due to loss of Zn during welding).
 - Cap Copper: Red color with 2-5% **Zn**. Very ductile. Used for ammunition priming cases.
 - Gliding Metal: Golden color with 5% Zn. Used for deep drawing, jewellery, coins and medals, etc.
 - Cartridge Brass: Yellow color with 30% Zn. Suitable for deep drawing due to high ductility. Used as cartridge cases, electric sockets, flash light casings, etc.
 - Muntz Metal: α+β alloy with 40% Zn. Very suitable for hot working, corrosion resistant. Used in sheet form for condenser heads, architectural works, etc.
 - Naval (Admiralty) Brass: Contains 39% Zn, 1% Sn. Very good resistance to seawater corrosion. Used for propellers, shafts, condenser plates, etc.
- **Bronzes:** Rich brown alloys of **Cu**. Suitable for casting, good corrosion properties, moderate strength.
 - P-bronzes: With 1-11% Sn (P is added to remove oxides of Sn & Cu). High tensile/fatigue strength, toughness, corrosion resistance. Used as instrument parts (e.g. diaphrams, bellows, springs).
 - Si-bronzes (Everdur, Herculoy): High-strength alloys (up to 750 Mpa).
 - Al-bronzes: Having 4-11% Al, with high strength (up to 680 Mpa) and low ductility. Used in electrical and marine hardware, propellers, tubings, pumps.
 - Be-copper: Up to 1.9% Be. Highest-strength bronze. Good fatigue strength, formability, resistance to corrosion and wear. Due to its hardness, used as non-sparking hand tools (e.g. wrenches).
 - Zr-copper & Cr-copper: Heat treatable. Used for resistance welding tips, switch parts.

Cupro-Nickels (Cu-Ni): 15-20% Ni (condenser tubes in seawater), 40-45% Ni (wires in thermocouples)

- Nickel-silver (Cu-Ni-Zn): 5-30% Ni, small addition of Zn (ornamental works)
- German-silver (Cu-Ni-Zn): 22% Ni, 26% Zn (for cases requiring extremely low thermal conductivity)



Lead Alloys:

- > In general, Pb does not form useful alloys except with other metals of low melting point.
- > In free-machining leaded alloys, **Pb** is an inclusion (not an alloy ingredient).
- ► However, pure **Pb** is alloyed to increase its low strength (17 MPa). Two types of alloys are in use:
 - Tellurium lead (Pb-Te): addition of less than 0.1% Te
 - Antimonium lead (Pb-Sb): addition of maximum 11% Sb
- > The solders are the most commonly used alloys of Pb & Sn (having 5-50% Sn).

Magnesium Alloys:

- > Lightness, weldability, and ease of machining greatly reduces its cost of manufacture.
- > Components made of Mg alloys must be protected either by painting or anodizing.
- > The alloys may be divided into two classes: wrought alloys & cast alloys
- ➤ Currently, the lightest commercial Mg alloy contains 14% Li, 1.25 % Al.
- Most Mg alloys are used for light-weight equipment as in aircraft, space vehicles, ladders, portable power tools, luggage or dock boards, etc. The famous type is AZ31B alloy (with 3% AI, 1% Zn).

Zinc Alloys:

- Major use is in alloys for die-casting. Zinc die-casting alloys are low in cost and easy to cast, and have greater strength than other die-casting metals (except copper alloys).
- ➤ The most popular type is Zn-Al alloy (a lamellar eutectic forms at 382 °C and 5% Al).



Nickel Alloys:

- > Like Cu & Fe, Ni is capable of producing a wide range of alloys adopted to special applications.
- > Cu is the most important alloying partner, forming solid solution in all proportions.
- > The most commonly used alloys are as follows:
 - Monel (more Ni than Cu): used for sinks, kitchen equipment, washing machines, marine equipments.
 - Standard Monel (400): 66% Ni, 31.5% Cu, 1% Fe, 1% Mn
 - R-monel (R-405): 66% Ni, 31.5% Cu, 0.05% S
 - K-monel (K-500 & K-501): 66% Ni, 31.5% Cu, 2.8% Al, 0.5% Ti
 - Inconel (Ni-Cr-Fe alloy): 78% Ni, 14% Cr, 6.5% Fe, 0.2% Cu (high temp. applications, turbine blades)
 - Hastelloys (alloys of Ni-Cr-Fe & Ni-Mo-Fe): varying amount of elements (high corrosion resistance)
 - Nilvar & Invar: up to 36% Ni (lowest thermal expansion coefficient)
 - Beryllium-Nickel (Berlyco-Nickel 440): 1.95% Be & 0.5% Ti (in addition to Ni & Cu)
 - Constantan: 45% Ni, 55% Cu; Alumel: 95.3% Ni, 1.75% Mn, 1.2% Si; Chromel: 90% Ni, 9.5% Cr

Titanium Alloys:

- Titanium has HCP structure (α-Ti) at room temp, which transforms to BCC structure (β-Ti) at 882 °C. Addition of alloying elements influences transformation temperature. Thus, Ti-alloys can be in phases of α, α+β, β where relative amounts of phases affect mechanical properties:
 - α alloys: stabilized with AI, weldability & high temp. strength (aircraft tailpipe assemblies, missile fuel tanks)
 - α + β alloys: stronger than α alloys, best examples is **Ti-6AI-4V** (aircraft compressor blades and disks)
 - β alloys: can be strengthened by heat treatment (high strength fasteners and aerospace components)

Die-Casting Alloys:

- Wide range of nonferrous alloys can be die-cast.
- The principal base metals in order of commercial importance:

Zn, Al, Mg, Cu, Pb, Sn

- ➤ They can be further classified as:
 - Low-temp. alloys (casting temp. below 550 °C): Zn, Sn, Pb
 - High-temp. alloys (casting temp. above 550 °C): AI, Mg, Cu

Alloy	Alloy Name	Composition (%)							
Туре		AI	Cu	Mg	Pb	Si	Sn	Zn	
Zn Based	903	4.1	0.1 (max)	0.04	-	-	-	rem.	
	925	4.1	1.0	0.04	-	-	-	rem.	
	13	rem.	-	-	-	12	-	-	
	43	rem.	-	-	-	5	-	-	
ΑΙ	218	rem.	3	8	-	-	-	-	
Based	360	rem.	-	0.5	-	9.5	-	-	
	380	rem.	3.5	-	-	9	-	-	
	389	rem.	3.8	-	-	12	-	-	
	Z30A	-	57	-	1.5	-	1.5	30	
Cu			(min)					(min)	
Based	ZS331A	-	65	-	-	1	-	rem.	
	ZS144A	-	81	-	-	4	-	rem.	
Mg	AZ91A	9	-	rem.	-	-	-	0.7	
based	AZ91B	9	0.3	rem.	-	0-5	-	0.7	





Bearing Alloys:

- > Bearings are used to transmit loads between relatively moving surfaces, involving sliding contact.
- Bearing alloy must be relatively soft to align itself to journal under pressure (conformability). In addition, bearing must be strong (compressive & fatigue strength) with low friction and wear-resistant surface.
- Such combination of properties is generally not obtained in a single-phase alloy. Thus, bearing metals are traditionally two-phase alloys. In these materials; harder, low friction particles are held in malleable, soft, solid solution (or eutectic) matrix.

Alloy Type	Cu	Sn	Pb	Sb	AI	Bearing Hardness (HV)	Recommended Journal (HV)	
Sn-base babbitt	3.5	89	-	7.5	-	23-25	140	
	4	87	-	9	-	27-32	150	
Pb-base babbitt	1	12	74	13	-	26	140	
Pb-bronze	70	-	30	-	-	35-45	25-500	
	74	4	22	-	-	40-45		
	75	5	20	-	-	45-70		
	80	10	10	-	-	65-90		
	85	5	10	-	-	45-70		
P-bronze	rem.	10	0.5 (min)		n)	70-150	500	
Al-alloys	1	6	-	-	rem. (1% Ni)	45-60	250	
	1	20	-	-	rem.	40	250	