

## Lecture 19: Zinc

MMat 380

### Zinc

- General characteristics, uses
- Common alloys and additions
- Phase diagram
- Advantages to die casting
- Advantages and disadvantages of Zn in Engineering design

## Mechanical properties of wrought Zn alloys

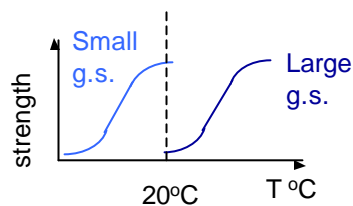
Alloy composition	Cold-rolled Orientation	Tensile strength		Elongation, %	Typical uses
		MPa	ksi		
Zn-0.08 Pb	Longitudinal	145	21.0	50	Drawn battery cans, eyelets, fuse links, and a variety of articles drawn, formed and spun
	Transverse	186	27.0	40	
Zn-0.06 Pb-0.06 Cd	Longitudinal	150	22.0	40	Drawn battery cans, eyelets and grommets; extruded battery cans; address plates, laundry tags
	Transverse	200	29.0	30	
Zn-1.0 Cu	Longitudinal	170	25.0	45	Weatherstrips and drawn and formed articles requiring stiffness
	Transverse	210	31.0	28	
Zn-0.8 Cu-0.15 Ti	Longitudinal	210	31	40	Corrugated roofing, leaders and gutters, and other uses requiring maximum creep resistance
	Transverse	280	40	25	
Superplastic Zn alloy					
Zn-22 Al-0.5 Cu-0.01 Mg	As rolled	310	45	27	Electronic enclosures, cabinets and panels, business machine parts
	Annealed	400	58	11	

## Zn alloys: General Characteristics

- M.P. = 420°C
- $\rho = 7.13 \text{ gm/cm}^3$
- $T_H = 0.42 \text{ @ RT}$  ( $T_H = T/T_{mp}$  (°K))
  - Zn recrystallizes and creeps near R.T.
  - Cannot be strain hardened significantly
  - Applications for wrought Zn limited
- Crystal structure HCP

## Zn alloys: General Characteristics

- Industrial pure Zn: UTS = 110 MPa
- Alloying with Al 413MPa
- Ductile-brittle transition



## Applications of Zn

	USA	World
• Largest use: galvanizing:	52	45
– Dipping		
– Electroplating		
• Alloying element in brass	14	21
• Pressure die casting	23	15
• Other uses	11	19
• Very little wrought		

# Applications of Zn

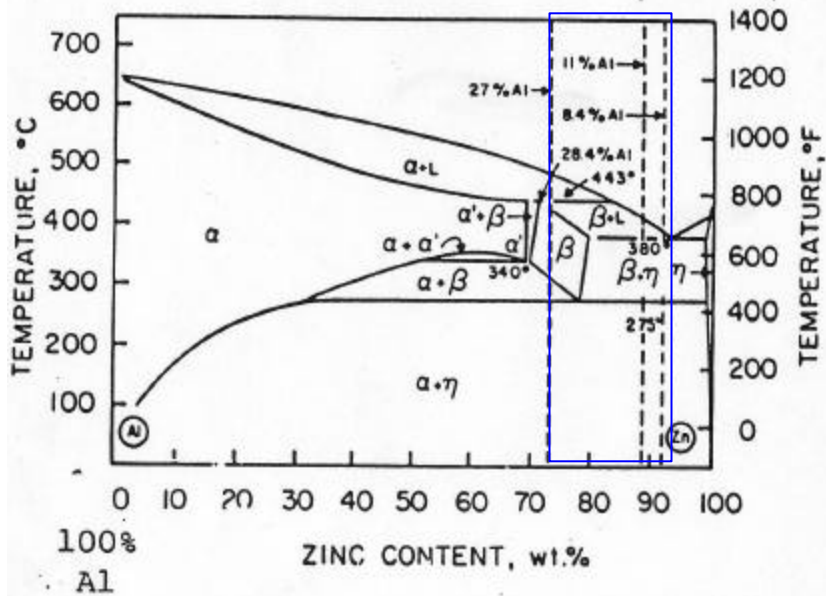
Architectural – Chan Centre



## Common alloys

- Conventional based on hypoeutectic:
  - Zn-4%Al composition
  - High castability, easy finishing, good mechanical properties, freedom from intergranular corrosion
- Al added for:
  - Strengthening
  - Reducing grain size
  - ↑ fluidity
  - **But:** with 5% Al, Zn-Al eutectoid forms: brittle

## Zn-Al phase diagram



## Zinc casting alloys: compositions

	% Al	% Cu	% Mg	% Ni
Alloy 3	4.1	0.10*	0.04	
Alloy 5	4.1	1.0	0.045	
Alloy 7	4.1	0.10*	0.015	0.015
ZA-8	8.4	1.0	0.022	
ZA-12	11.0	0.87	0.022	
ZA-27	27.5	2.2	0.015	

Impurity limits are Pb, 0.004%; Cd, 0.003%; Sn, 0.002%; Fe, 0.075% except 0.01% for ZA-8 and ZA-27.

\*Maximum impurity limit.

## Zinc casting alloys: mechanical properties

Property	No. 3 AG-40A	No. 5 AC-41A	ZA-8		ZA-12			ZA-27		
	Die cast	Die cast	Permanent mold cast	Die cast	Sand cast	Permanent mold cast	Die cast	Sand cast	Sand cast HT	Die cast
Tensile strength, lb in <sup>-2</sup> ×10 <sup>3</sup> (MPa)	41 (283)	48 (331)	32-37 (221-255)	53-56 (365-386)	40-46 (276-317)	45-50 (310-345)	57-60 (393-414)	58-64 (400-441)	45-47 (310-324)	50-65 (407-441)
Yield strength, 0.2% offset, lb in <sup>2</sup> ×10 <sup>3</sup> (MPa)			30 (207)	41-43 (283-296)	30 (207)	36-40 (248-276)	45-48 (310-331)	53 (365)	37 (255)	52-55 (359-379)
Young's modulus, lb in <sup>-2</sup> ×10 <sup>6</sup> (GPa)			12.4 (85.5)	—	12.0 (83)	12.0 (83)	—	10.9 (75)	11.5 (79)	
Elongation, % in 2 in, (51 mm)	10	7	1-2	6-10	1-3	1.5-2.5	4-7	3-6	8-11	2.0-3.5

## Die Casting

- Major structural use of Zn
- Requires 99.99%+
  - Need low content of Fe, Pb, Cd and Sn
  - Otherwise unstable dimensions and properties
- If >0.007 Pb, 0.008 Cd or 0.005 Sn
  - Cause “subsurface network corrosion”
- Steel die:
  1. Close dimensional tolerances
  2. Good surface

## Advantages of Zn die casting

1. Excellent physical and mechanical properties
2. Low material cost
3. Machines can operate up to 18000 cycles/hr, low m.p. and high fluidity
4. Close dimensional tolerance and uniformity – intricate design
5. Thin sections (to 0.015) easily cast
6. Surface can be painted, plated, sprayed etc. with little cost because of good surface

## Wrought Zn alloys

- Limited use because:
  1. Pure Zn ductile and creeps at R.T.
  2. HCP structure
- Additions:
  - Pb and Cd added to increase strength and ductility
  - 0.5-1.5%Cu added to Zn to increase hardness, stiffness and creep resistance

## Advantages of Zn alloys in engineering design

1. Die cast @ high rates – productivity
2. Near-net shapes of intricate design, close tolerances, good surface finish
3. Finishing: castings can be machined, bent, swaged or coined
4. Joinability: Can be riveted, welded and soldered
5. Corrosion resistance relatively good
6. Strength usually sufficient
7. Cost: competitive with Al and Cu

## Disadvantages of Zn alloys in engineering design

1. Insufficient strength/hardness above 95°C
2. Relatively high density 7.1 g/cm<sup>3</sup>
3. HCP structure, limits plastic deformation