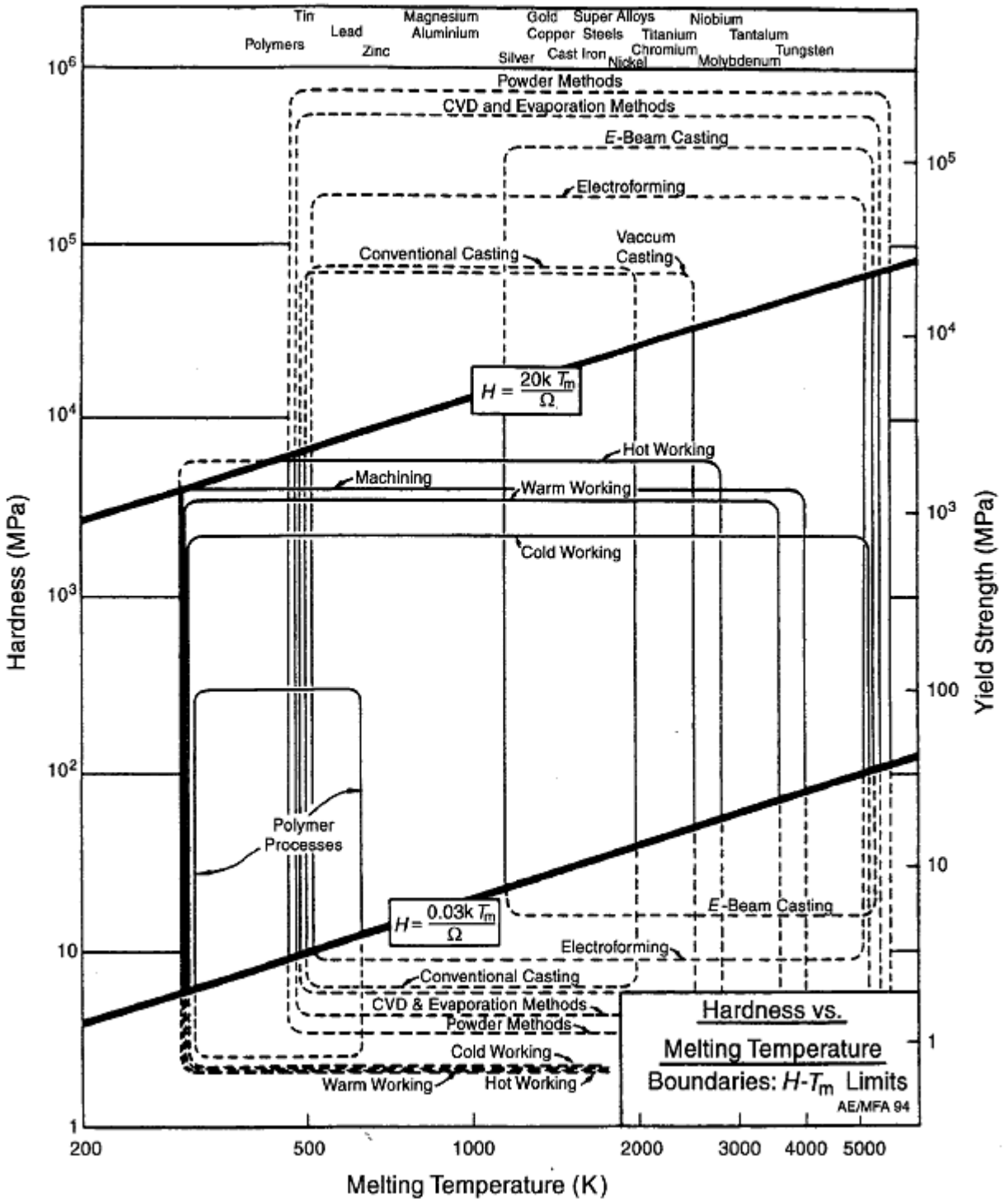
Chart P2: Hardness, H, against melting temperature, T_m

The match between process and material is established by the link to material class of Chart P1 and by the use of the melting point–hardness chart shown here. The melting point imposes limits on the processing of materials by conventional casting methods. Low melting point metals can be cast by any one of many techniques. For those which melt above 2000 K, conventional casting methods are no longer viable, and special techniques such as electron-beam melting must be used. Similarly, the yield strength or hardness of a material imposes limitations on the choice of deformation and machining processes. Forging and rolling pressures are proportional to the flow strength, and the heat generated during machining, which limits tool life, also scales with the ultimate strength or hardness. Generally speaking, deformation processing is limited to materials with hardness values below 3 GPa. Other manufacturing methods exist which are not limited either by melting point or by hardness. Examples are: powder methods, CVD and evaporation techniques, and electro-forming.

The chart presents this information in graphical form. In reality, only part of the space covered by the axes is accessible: it is the region between the two heavy lines. The hardness and melting point of materials are not independent properties: low melting point materials tend to be soft; high melting point materials are generally hard. This information is captured by the equation

$$0.03 < \frac{H\Omega}{kT_m} < 20$$

where Ω is the atomic or molecular volume and k is Boltzmann's Constant (1.38×10^{-26} J/K). It is this equation which defines the two bold lines.


Tin
Lead
Zinc
Polymers
Magnesium
Aluminium
Gold
Copper
Silver
Cast Iron
Super Alloys
Steels
Nickel
Niobium
Titanium
Chromium
Tantalum
Molybdenum
Tungsten
Powder Methods
CVD and Evaporation Methods
E-Beam Casting
Electroforming
Conventional Casting
Vaccum Casting
H = 20k Tm / Ω
Hot Working
Machining
Warm Working
Cold Working
Polymer Processes
H = 0.03k Tm / Ω
E-Beam Casting
Electroforming
Conventional Casting
CVD & Evaporation Methods
Powder Methods
Cold Working
Warm Working
Hot Working
Hardness vs.
Melting Temperature
Boundaries: H-Tm Limits
AE/MFA 94
Hardness (MPa)
Yield Strength (MPa)
Melting Temperature (K)
10^6
10^5
10^4
10^3
10^2
10
1
100
200
500
1000
2000
3000
4000
5000