Chart P3: Volume, *V*, against slenderness, *S*

Manufacturing processes vary widely in their capacity to make thin, slender sections. For our purposes, slenderness, S, is measured by the ratio t/ℓ where t is the minimum section and ℓ is the large dimension of the shape: for flat shapes, ℓ is about equal to $\sqrt{A}$ where A is the projected area normal to t. Thus

$$S = \frac{t}{\sqrt{A}}$$

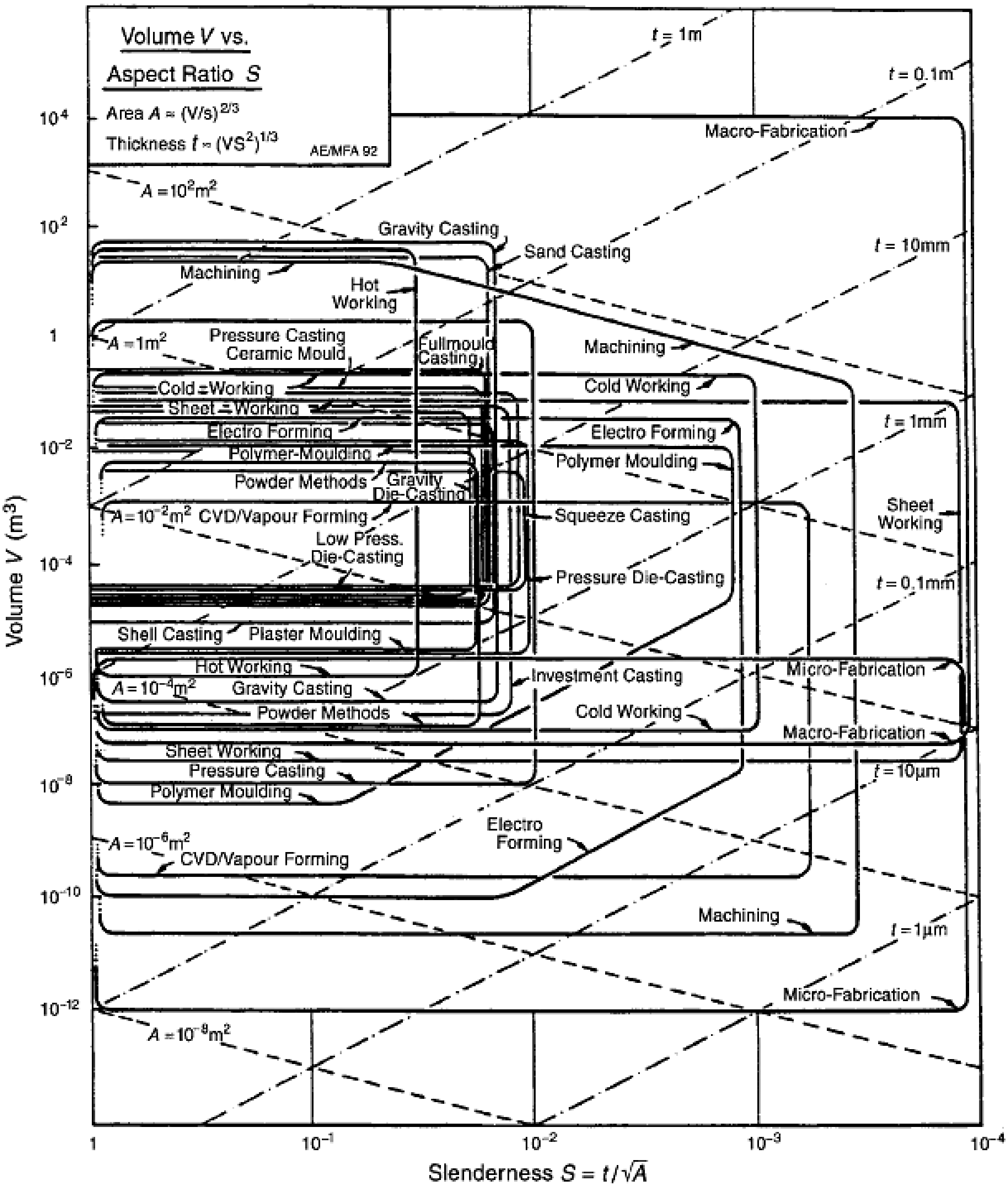
Size is defined by the minimum and maximum volumes of which the process is capable. The volume, V, for uniform sections is, within a factor of 2, given by

$$V = At$$

Volume can be converted approximately to weight by using an 'average' material density of $5000\,\mathrm{kg/m^3}$; most engineering materials have densities within a factor of 2 of this value. Polymers are the exception: their densities are all around $1000\,\mathrm{kg/m^3}$.

The size-slenderness chart is shown opposite. The horizontal axis is the slenderness, S; the vertical axis is the volume, V. Contours of A and t are shown as families of diagonal lines. *Casting processes* occupy a characteristic field of this space. Surface tension and heat-flow limit the minimum section and the slenderness of gravity cast shapes. The range can be extended by applying a pressure, as in centrifugal casting and pressure die casting, or by preheating the mould. *Deformation processes* — cold, warm and hot — cover a wider range. Limits on forging-pressures set a lower limit on thickness and slenderness, but it is not nearly as severe as in casting. *Machining* creates slender shapes by removing unwanted material. *Powder-forming* methods occupy a smaller field, one already covered by casting and deformation shaping methods, but they can be used for ceramics and very hard metals which cannot be shaped in other ways. *Polymer-forming methods* — injection moulding, pressing, blow-moulding, etc. — share this regime. *Special techniques*, which include electro-forming, plasma-spraying, and various vapour-deposition methods, allow very slender shapes. *Joining* extends the range further: fabrication allows almost unlimited size and complexity.

A real design demands certain specific values of S and V, or A and t. Given this information, a subset of possible processes can be read off.


Volume V vs.
Aspect Ratio S
Area A ≈ (V/s)^2/3
Thickness t ≈ (VS^2)^1/3
AE/MFA 92
t = 1m
t = 0.1m
Macro-Fabrication
A = 10^2 m^2
Gravity Casting
Sand Casting
t = 10mm
Machining
Hot Working
A = 1m^2
Pressure Casting
Ceramic Mould
Fullmould Casting
Machining
Cold Working
Cold Working
Sheet Working
Electro Forming
Electro Forming
t = 1mm
Polymer-Moulding
Polymer Moulding
Powder Methods
Gravity Die-Casting
Sheet Working
A = 10^-2 m^2
CVD/Vapour Forming
Squeeze Casting
Low Press. Die-Casting
Pressure Die-Casting
t = 0.1mm
Shell Casting
Plaster Moulding
Hot Working
Investment Casting
Micro-Fabrication
A = 10^-4 m^2
Gravity Casting
Cold Working
Powder Methods
Macro-Fabrication
Sheet Working
Pressure Casting
t = 10μm
Polymer Moulding
Electro Forming
A = 10^-6 m^2
CVD/Vapour Forming
Machining
t = 1μm
Micro-Fabrication
A = 10^-8 m^2
Volume V (m^3)
10^4
10^2
1
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
1
10^-1
10^-2
10^-3
10^-4
Slenderness S = t/√A