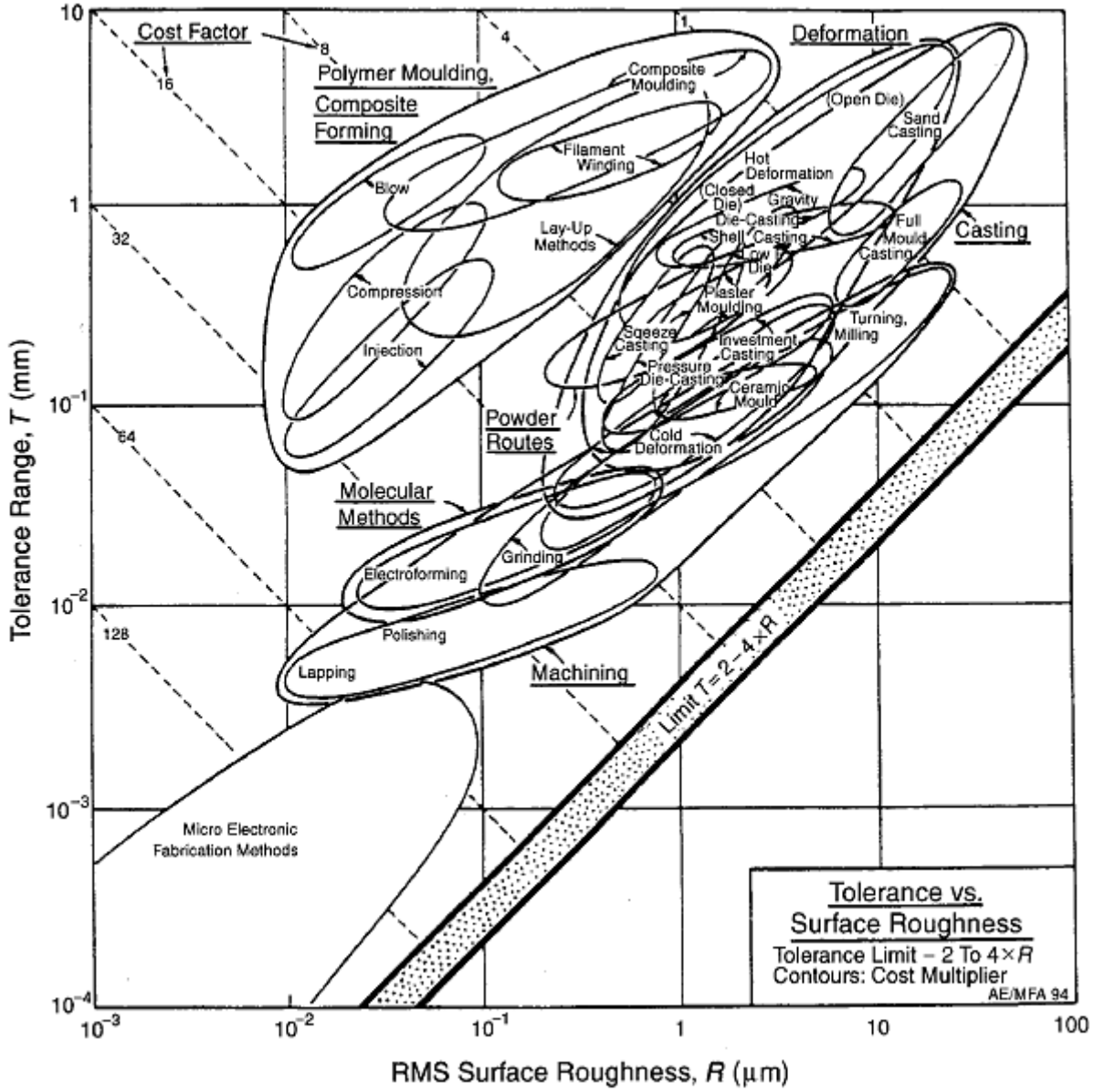
Chart P7: Tolerance range, *T*, against RMS surface roughness, *R*

No process can shape a part *exactly* to a specified dimension. Some deviation Δx from a desired dimension x is permitted; it is referred to as the *tolerance*, T, and is specified as $x = 100 \pm 0.1$ mm, or as $x = 50^{+0.01}_{-0.001}$ mm. Closely related to this is the *surface roughness* R, measured by the root-mean-square amplitude of the irregularities on the surface. It is specified as $R < 100\,\mu$m (the rough surface of a sand casting) or $R < 0.01\,\mu$m (a lapped surface; Table 11.2).

Manufacturing processes vary in the levels of tolerance and roughness they can achieve economically. Achievable tolerances and roughnesses are shown in this chart. The tolerance is obviously greater than $2R$ (shaded band): indeed, since R is the root-mean-square roughness, the peak roughness is more like $5R$. Real processes give tolerances which range from about $10R$ to $1000R$. Sand casting gives rough surfaces; casting into metal dies gives a better finish. *Moulded polymer* inherit the finish of the moulds and thus can be very smooth, but tolerances better than ± 0.2 mm are seldom possible because of internal stresses left by moulding and because polymers creep in service. Machining, capable of high dimensional accuracy and smooth surface finish, is commonly used after casting or deformation processing to bring the tolerance or finish to the desired level. Metals and ceramics can be *surface-ground* and *lapped* to a high tolerance and smoothness.

Precision and high finish are expensive: processing costs increase almost exponentially as the requirements for tolerance and surface roughness are made more severe. The chart shows contours of relative cost: an increase in precision corresponding to the separation of two neighbouring contours gives an increase in cost, for a given process, of a factor of two.

Achievable tolerances depend, of course, on dimensions (those given here apply to a 25 mm dimension) and on material. However, for our purposes, typical ranges of tolerance and surface finish are sufficient and discriminate clearly between various processes.


Cost Factor
Polymer Moulding, Composite Forming
Composite Moulding
Filament Winding
Blow
Lay-Up Methods
Compression
Injection
Deformation
(Open Die)
Sand Casting
Hot Deformation
(Closed Die)
Gravity Die-Casting
Shell Casting
Low Pressure Die-Casting
Plaster Moulding
Squeeze Casting
Investment Casting
Pressure Die-Casting
Ceramic Mould
Cold Deformation
Full Mould Casting
Casting
Turning, Milling
Powder Routes
Molecular Methods
Electroforming
Grinding
Polishing
Lapping
Machining
Micro Electronic Fabrication Methods
Limit T = 2 - 4×R
Tolerance vs. Surface Roughness
Tolerance Limit – 2 To 4×R
Contours: Cost Multiplier
AE/MFA 94
Tolerance Range, T (mm)
RMS Surface Roughness, R (µm)