

Formulas

Statistical Process Control:

$$\sigma = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n}}$$

$$R = x_{\max} - x_{\min}$$

$$UCL_{\bar{x}} = \bar{x} + 3\sigma_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R}$$

$$LCL_{\bar{x}} = \bar{x} - 3\sigma_{\bar{x}} = \bar{\bar{x}} - A_2\bar{R}$$

$$C_p = \frac{USL - LSL}{6\sigma}$$

$$C_{pk} = \frac{\min\{|USL - \bar{x}|, |LSL - \bar{x}|\}}{3\sigma}$$

USL: upper specified limit

LSL: lower specified limit

Number of Observations in Subgroup n	Factors for \bar{X} Chart A_2
2	1.88
3	1.02
4	0.73
5	0.58
6	0.48
7	0.42
8	0.37
9	0.34
10	0.31
11	0.29
12	0.27
13	0.25
14	0.24
15	0.22
16	0.21
17	0.20
18	0.19
19	0.19
20	0.18

Upper control limit for $\bar{X} = UCL_{\bar{x}} = \bar{X}' + A_2\bar{R}$

Lower control limit for $\bar{X} = LCL_{\bar{x}} = \bar{X}' - A_2\bar{R}$

Table 1: Constants for Control Charts

Surface roughness:

$$Ra = \frac{\sum |y_i - \bar{y}|}{n}$$

$$Rq = \sqrt{\frac{\sum (y_i - \bar{y})^2}{n}}$$

Mechanics of materials

Elastic: $\sigma = E\varepsilon$

Plastic: $\sigma = K\varepsilon^n$ cold work
 $\sigma = C\dot{\varepsilon}^m$ hot work

$$e = \frac{\ell}{\ell_0} \quad \varepsilon = \ln \frac{\ell}{\ell_0}$$

Hardness

$$\text{UTS(MPa)} = 3.5 \text{ (HB)}$$

$$\text{UTS(psi)} = 500 \text{ (HB)}$$

Taylor's tool life equation:

$$VT^n = C$$

Tool life for minimum cost

$$T_{\min} = \left(\frac{1}{n} - 1 \right) \left(\frac{C_t + T_c C_o}{C_o} \right)$$

C_o : operating cost (\$/min)

T_c : time to change the tool (min)

C_t : initial cost of the tool (\$)

CT : cutting time (min)

$$\text{Total Machining Cost} = C_1 + C_2 + C_3 + C_4$$

$$C_1 = CT \times C_o$$

$$C_2 = \frac{C_t \times CT}{T}$$

$$C_3 = \frac{T_c \times C_o \times CT}{T}$$

$$C_4 = \text{handling cost}$$

Cutting mechanics:

$$\tan \phi = \frac{r_t \cos \alpha}{1 - r_t \sin \alpha} \quad \text{where } r_t \text{ is chip thickness ratio}$$

$$F_s = F_c \cos \phi - F_T \sin \phi$$

$$F_N = F_c \sin \phi + F_T \cos \phi$$

$$F = F_c \sin \alpha + F_T \cos \alpha$$

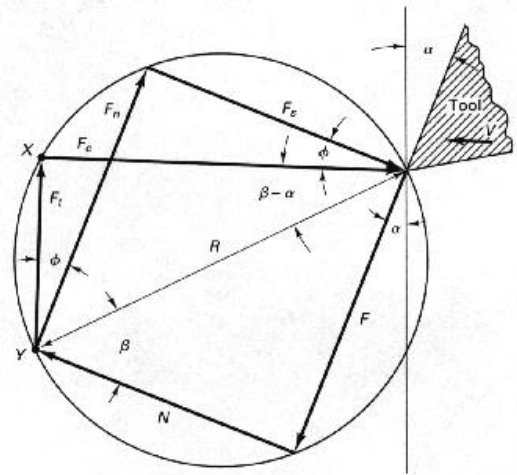
$$N = F_c \cos \alpha - F_T \sin \alpha$$

$$V_s = \frac{\cos \alpha}{\cos(\phi - \alpha)} V_c \quad : \text{shear velocity}$$

$$V_f = V_c \cdot r_t \quad : \text{chip velocity}$$

$$r_t = \frac{t}{t_c}$$

$$A_s = \frac{A_0}{\sin \phi} \quad : \text{shear plane area}$$



$$U_s = \frac{F_s \cdot V_s}{V_c \cdot f_r \cdot t}$$

$$U = \frac{F_c \cdot V_c}{V_c \cdot f_r \cdot t}$$

$$HP = \frac{F_c \cdot V_c (ft \cdot lb / min)}{33,000} \quad KW = \frac{F_c \cdot V_c (N \cdot m / min)}{60,000} \quad HP_m = \frac{HP}{E}$$

$$1 KW = 1.34 HP$$

Mean chip temp. rise across the shear plane

$$\theta_s = \frac{(1-\beta)U_s}{\rho C V_c t \cdot f}$$

$$R = \frac{\rho C V t}{k} : \text{thermal number}$$

- ρ : density
 C : specific heat of work material
 t : thickness of chip

Surface finish

$$R_a = \frac{R_t}{4} = \frac{f_r^2}{32CR}$$

Longitudinal Turning

$$\text{Cutting Speed} \quad V = \frac{\pi DN}{12} \text{ (fpm)}$$

$$\text{Material Removal Rate: } 12Vf_r t$$

Milling

$$\begin{aligned} \text{Cutting Time:} \quad & (\ell_c + \ell) / f_m = \text{slab} \\ & (2\ell_c + \ell) / f_m = \text{end and face} \\ & \ell_c = \sqrt{w(D-w)} \text{ for } w < D/2 \\ & \ell_c = D/2 \text{ for } w > D/2 \end{aligned}$$

Material Removal Rate:

$$MRR = w \cdot t \cdot f_m \quad \text{in}^3/\text{min}.$$