Formulas for Exam 1 of ME363

Statistical Process Control:

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

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

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

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

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

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

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 $\bar{X} = \text{UCL}_{\bar{x}} = \bar{\bar{X}} + A_2\bar{R}$
Lower control limit for $\bar{X} = \text{LCL}_{\bar{x}} = \bar{\bar{X}} - A_2\bar{R}$

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*

$$e = \frac{\Delta\ell}{\ell_0} \qquad \varepsilon = \ln\frac{\ell}{\ell_0}$$

Hardness

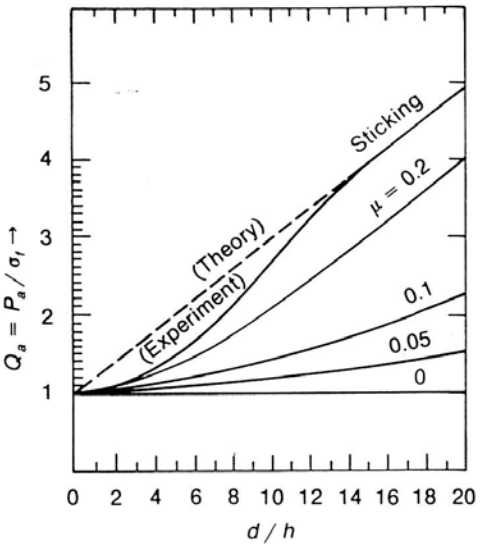
UTS(MPa) = 3.5 (HB) UTS(psi)=500 (HB)

Forging Process:

Hot working: $\dot{\varepsilon} = \frac{v}{h}$ $\sigma_f = C\dot{\varepsilon}^m$

Cold working: $\varepsilon = \ln\frac{h_1}{h_0}$ $\sigma_f = K\varepsilon^n$

Average pressure: $P_a = \sigma_f Q_a = \sigma_f\left(1+\frac{\mu d_1}{3h_1}\right)$



Rolling Process

$L = \sqrt{R\left(h_o - h_f\right)}$

$\dot{\varepsilon} = \frac{V_r}{L}\ln\frac{h_o}{h_f}$ $\varepsilon = \ln\frac{h_o}{h_f}$

$h_o - h_f = \mu^2 R$

$\sigma_{fm} = Y_{avg} = \frac{K\varepsilon^n}{n+1}$ $(cold\ work)$ $\sigma_f = C\dot{\varepsilon}^m (hot\ work)$

$Y'_{avg}: average\ flow\ stress = \frac{2}{\sqrt{3}}Y_{avg}$

$F = LwY'_{avg}$ $: without\ friction$

$F = LwY'_{avg}(1+\frac{\mu L}{2h_{av}})$ $: higher\ friction$

$KW = \frac{2\pi FLN}{60,000}: metric$ $F: Newtons\ L: meters\ N: rpm$

$HP = \frac{2\pi FLN}{33,000}: English$ $F: lbs\ L: feet\ N: rpm$

Extrusion Process

$$e = \frac{A_o - A_1}{A_o} \qquad R = \frac{A_o}{A_1}$$

$$\varepsilon = \ln R = \ln \frac{A_o}{A_1} \qquad \dot{\varepsilon}_m = \frac{6 v d_o^2 \tan\alpha}{d_0^3 - d_1^3}\varepsilon$$

$$\sigma_{fm} = \frac{K}{\varepsilon}\left[\frac{\varepsilon^{n+1}}{n+1}\right] \qquad \sigma_{fm} = C \cdot \dot{\varepsilon}^m$$

$$\sigma_e = \sigma_{fm} \cdot \ln R \qquad \textit{without friction}$$

$$\sigma_e = \sigma_{fm}\left(1.7 \ln R + \frac{2L}{D_0}\right) \qquad \textit{with friction}$$

$$F = \sigma_e \cdot A_0$$

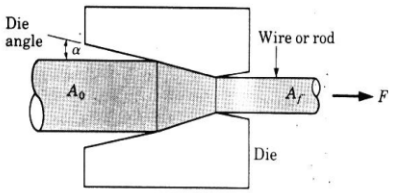
Drawing Stress

$$\sigma_d = \sigma_{fm}\, \ell n\left(\frac{A_o}{A_n}\right) = \sigma_{fm}\, \ell n\, R \quad : ideal$$

$$\sigma_{fm} = \frac{K}{\varepsilon}\left[\frac{\varepsilon^{n+1}}{n+1}\right] \quad : cold$$

$$\sigma_{fm} = c \cdot \dot{\varepsilon}^m \quad : hot$$

$$\dot{\varepsilon}_m = \frac{6V_0}{D_0} \ln\left(\frac{A_0}{A_f}\right)$$



$$\sigma_d = \sigma_{fm}\left[(1 + \frac{\mu}{\alpha})\ell n\left(\frac{A_o}{A_1}\right) + \frac{2}{3}\alpha\right]$$

$$F = \sigma_d \cdot A_1$$

$$HP = \frac{F \cdot V\ (ft \cdot lb/\min)}{33{,}000} \qquad KW = \frac{F \cdot V\ (N \cdot m/\min)}{60{,}000}$$

Designation and Composition, %	Liquidus/ Solidus, °C	Hot Working: Usual Temp., °C	Hot Working: Flow Stress,[b] MPa at °C	Hot Working: Flow Stress,[b] MPa C	Hot Working: Flow Stress,[b] MPa m	Hot Working: Work-ability[f]	Cold Working: Flow stress[c] MPa K	Cold Working: Flow stress[c] MPa n	Cold Working: $\sigma_{0.2}$, MPa	Cold Working: TS,[d] MPa	Cold Working: Elongation,[d] %	Cold Working: q RA, %	Annealing Temp.,[e] °C
Light Metals:													
1100 Al (99%)	657/643	250–550	300	60	0.08	A	140	0.25	35	90	35		340
			500	14	0.22								
~3003 Al (1Mn)	649/648	290–540	400	35	0.13	A			40	110	30		370
~2017 Al (3.5Cu, 0.5Mg, 0.5Mn)	635/510	260–480	400	90	0.12	B	380	0.15	70	180	20		415 (F)
			500	36	0.12								
5052 Al(2.5Mg)	650/590	260–510	480	35	0.13	A	210	0.13	90	190	25		340
6061-0(1Mg, 0.6Si, 0.3Cu)	652/582	300–550	400	50	0.16	A	220	0.16	55	125	25	65	415 (F)
			500	37	0.17								
6061-T6	NA[g]	NA	NA	NA	NA	NA	450	0.03	275	310	8	45	
~7075 Al(6Zn, 2Mg, 1Cu)	640/475	260–455	450	40	0.13	B	400	0.17	100	230	16		415
Low-Melting Metals:													
Sn (99.8%)	232	100–200				A				15	45	100	150
Pb (99.7%)	327	20–200	100	10	0.1	A				12	35	100	20–200
Zn (0.08% Pb)	417	120–275	75	260	0.1	A				130/170	65/50		100
			225	40	0.1								
High-Temperature Alloys:													
Ni (99.4Ni + Co)	1446/1435	650–1250				A			140	440	45	65	650–760
Hastelloy X (47Ni, 9Mo, 22Cr, 18Fe, 1.5Co, 0.6W)	1290	980–1200	1150~	140	0.2	C			360	770	42		1175
Ti (99%)	1660	750–1000	600	200	0.11	C			480	620	20		590–730
			900	38	0.25	A							
Ti–6Al–4V	1660/1600	790–1000	600	550	0.08	C			900	950	12		700–825
			900	140	0.4	A							
Zirconium	1852	600–1000	900	50	0.25	A			210	340	35		500–800
Uranium (99.8%)	1132	~700	700	110	0.1				190	380	4	10	
Steels:													
1008 (0.08C), sheet		<1250	1000	100	0.1	A	600	0.25	180	320	40	70	850–900 (F)
1015 (0.15C), bar		<1250	800	150	0.1	A	620	0.18	300	450	35	70	850–900 (F)
			1000	120	0.1								
			1200	50	0.17								
1045 (0.45C)		<1150	800	180	0.07	A	950	0.12	410	700	22	45	790–870 (F)
			1000	120	0.13								
~8620 (0.2C, 1Mn, 0.4Ni, 0.5Cr, 0.4Mo)			1000	120	0.1	A			350	620	30	60	
D2 tool steel (1.5C, 12Cr, 1Mo)		900–1080	1000	190	0.13	B	1300	0.3					880 (F)
H13 tool steel (0.4C, 5Cr 1.5Mo, 1V)			1000	80	0.26	B							
302 SS (18Cr, 9Ni) (austenitic)	1420/1400	930–1200	1000	170	0.1	B	1300	0.3	250	600	55	65	1010–1120 (Q)
410 SS (13Cr) (martensitic)	1530/1480	870–1150	1000	140	0.08	C	960	0.1	280	520	30	65	650–800
Copper-Base Alloys:													
Cu (99.94%)	1083/1065	750–950	600	130	0.06	A	450	0.33	70	220	50	78	375–650
				(48)	(0.17)								
			900	41	0.2								
Cartridge brass (30Zn)	955/915	725–850	600	100	0.24	A	500	0.41	100	310	65	75	425–750
			800	48	0.15								
Muntz metal (40Zn)	905/900	625–800	600	38	0.3	A	800	0.5	120	380	45	70	425–600
			800	20	0.24								
Leaded brass (1Pb, 39Zn)	900/855	625–800	600	58	0.14	A	800	0.33	130	340	50	55	425–600
			800	14	0.20								
Phosphor bronze (5Sn)	1050/950		700	160	0.35	C	720	0.46	150	340	57		480–675
Aluminum bronze (5Al)	1060/1050	815–870				A			170	400	65		425–750