Formulas for the Final Exam of ME363

<u>Cutting mechanics:</u>

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

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

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

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

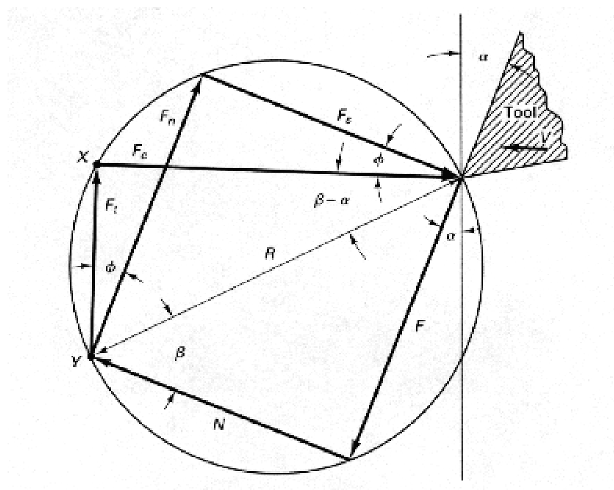
$$N = F_c \cos\alpha - F_T \sin\alpha$$

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

$$V_f = V_c \cdot r_t \qquad : \textit{chip velocity}$$

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

$$A_s = \frac{A_0}{\sin\phi} \qquad : \textit{shear plane area}$$



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

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

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

$$1\,KW = 1.34\,HP$$

<u>Mean chip temp. rise across the shear plane</u>

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

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

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

CuttingSpeed $$V = \frac{\pi DN}{12}\,(\text{fpm})$$

Material Removal Rate: $12Vf_rt$

Milling

Cutting Time: $(\ell_c + \ell)/f_m = slab\ or\ peripheral$

$(2\ell_c + \ell)/f_m = end\ and\ face$

$\ell_c = \sqrt{w(D-w)}\ \ for\ w < D/2$

Material Removal Rate: $\ell_c = D/2\ \ for\ w > D/2$

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

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)

$Total\ Machining\ Cost = C_1 + C_2 + C_3 + C_4$

$C_1 = CT \times C_o$

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

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

$C_4 = handling\ cost$

Punching and blanking

$$F_s = 0.7(UTS)(t)(L)$$

$$F = F_s(shearing) + F_R(Vee - ring) + F_G(counter)$$

Bending

$$\frac{R_i}{R_f} = 4\left(\frac{R_i Y}{ET}\right)^3 - 3\left(\frac{R_i Y}{ET}\right) + 1$$

Y : *yield stress*

Bend Allowance

$$A_b = 2\pi\frac{\alpha}{360}\left(R + K_{ba}t\right)$$

where

A_b : *bend allowance* (length of neural axis in the bend)

α : *bend angle*

R : *bend radius*

t : *stock thickness*

K_{ba} : *correciton factor*$(if\ R < 2t, K_{ba} = 0.33\ and\ if\ R > 2t,\ K_{ba} = 0.50)$

Deep Drawing

drawing force

$$F_{\max} = \pi D_p t_0 (UTS)\left(\frac{D_0}{D_p} - 0.7\right)$$

holding force

$$F_h = 0.015Y\pi\left\{D_0^2 - \left(D_p + 2.2t_0 + 2R_d\right)^2\right\}$$

Plastics and Composites

$$\eta = \eta_0 e^{E/kT}$$

η_0 : *material constant*

E : activation energy

k : *Boltzman's constant* $= 13.8 \times 10^{-24}\ J/K$

empirical relationship

$$\log \eta = 12 - \frac{17.5\Delta T}{52 + \Delta T}$$

$\Delta T = T - T_g \quad in\ °K$

Composite modulus

$$P_c = P_m + P_f$$

$$\sigma_c A_c = \sigma_f A_f + \sigma_m A_m$$

$$A_c = A_f + A_m$$

$$\sigma_c = x\sigma_f + (1-x)\sigma_m \qquad x = \frac{A_f}{A_c}$$

$$e = \frac{\sigma}{E} = \frac{P}{AE} \quad and \quad e_f = e_m$$

$$E_c = xE_f + (1-x)E_m$$

Powder Metallurgy

Tensile strength $UTS = UTS_0 e^{-nP}$

P: volume fraction of pores, UTS0: tensile strength at zero porosity, $n = 4 \sim 7$

Modulus of elasticity

$$E = E_0(1 - 1.9P + 0.9P^2)$$

Thermal conductivity $k = k_0(1-P)$

Designation and Composition, %	Liquidus/ Solidus, °C	Hot Working					Cold Working							Annealing Temp., [e] °C
		Usual Temp., °C	Flow Stress, [b] MPa			Work-ability[f]	Flow stress[c] MPa		$\sigma_{0.2}$, MPa	TS,[d] MPa	Elonga-tion,[d] %	[q] RA, %	
			at °C	C	m		K	n					
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								
			1000	120	0.1	A			350	620	30	60	
~8620 (0.2C, 1Mn, 0.4Ni, 0.5Cr, 0.4Mo)													
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