IN POSITION TECHNOLOGIES SMART SHEET

POWER AND ENERGY

ENERGY = ½mv²+mgΔy

HP = $\frac{\text{oz-in X RPM}}{1{,}008{,}000}$ HP = $\frac{\text{ft-lb X RPM}}{5{,}250}$ HP = $\frac{\text{lb-in X RPM}}{63{,}000}$

POWER = Force*Velocity

1 HP = 746 W = 550ft-lbs/s

1 kW = 1.34 HP

GRAVITY

$g = 386 in/s^2$

$g = 9.80 m/s^2$

$g = 32.2 ft/s^2$

DISTANCE

$d = ½ at^2 + v_0t$

1 in = 25.4mm; 1m = 39.37in; 1.0mm = 0.03937mils

VELOCITY

$v = at + v_0$; $v = 2d/t + v_0$

ACCELERATION

$a = 2d/t^2 + a_0 = \Delta v/t + a_0$

FORCE

f=ma *1 Kg = 2.20lb 1 N = 0.225 lb_f*

1 lb_f = 0.454Kg = 4.45 N

ROTARY INERTIA CONVERSION TABLE

Largest ⟶ Smallest (Largest ⟶ Smallest)

Kg-m-sec²	ft-lb- sec²	Kg-m²	lb-in-sec²	N- m²	oz-in-sec²	lb-in²	oz-in²	gm-cm-sec²	gm-cm²
1	7.23295	9.80665	86.796	96.17038	1388.74	33,510	536,173	10^5	9.80665×10^7

e.g. 0.1 Kg-m² = ? lb-in-sec² ; 0.1 Kg-m² x $\frac{86.796 \text{ lb-in-sec}^2}{9.80665 \text{ Kg-m}^2}$ = 0.885 lb-in-sec²

INERTIA

Solid Cylinder $I = WR^2/2$

Hollow Cylinder $I = ½W(R_1^2 + R_2^2)$

Gear Box System $I = I_{mtr/gearbox} + (I_{load}/N^2)$ N= Gear Ratio

Solid Pipe $I = MR^2/4 + ML^2/12$

Solid Rectangle $I = M(a^2 + b^2)$

DENSITIES OF MATERIALS (oz-in³)

Aluminum:	1.54	Steel:	4.48
Brass:	4.80	Plastic:	0.64
Copper:	5.14	Wood:	0.28-0.46

TORQUE CONVERSION TABLE

Largest ⟶ Smallest (Largest ⟶ Smallest)

Kg-m	lb-ft	Newton-m	lb-in	Kg-cm	N-cm	oz-in	gm-cm	dyn-cm
1	7.233	9.80665	86.796	100	980.665	1388.74	10^5	9.80665×10^7

e.g. 3 N-m = ? Kg-m ; 3 N-m x $\frac{1.0 \text{ Kg-m}}{9.80665 \text{ N-m}}$ = 0.3059 Kg-m

TORQUE

General Formula: $T = I\alpha + T_{friction} + T_{external}$ I = load inertia, α= rotational acceleration in radians

Leadscrew Formula: $T = (I_{load} + I_{screw} + I_{mtr/cplng})\alpha + F/2\pi pe + T_{ext} = ((W/2\pi p)^2 + \pi L\rho R^4/2 + I_{mtr/cplng})\alpha + W\mu_s/2\pi pe + T_{ext}$

F=friction force, p=screw pitch, e=efficiency, W=load weight, L = Screw Length, R=screw radius, μ_s=coeff. Friction

Belt & Pulley System: $T = (I_{load} + I_{pulleys} + I_{belt} + I_{motor})\alpha + T_{friction} + T_{external} = (W_L R^2 + W_p R^2/2 + W_B R^2/2 + I_m)\alpha + FR + T_{ext}$

Gear Drive System: $T = {}^1/_\eta (T_{gearbox} / N) + (I_{mtr/gearbox})\alpha$

$T_{gearbox}$ = Total Torque reflected at gearbox, N= Gear Ratio, η = Gear Efficiency, α= motor acceleration in radians

LEADSCREW / BALLSCREW DATA

Lead Screw Efficiency: Acme w/Bronze Nut = 35%; Acme w/Plastic Nut = 50-85%; Ball Nut = 85%

Torque to Drive Load: $T_{torque} = F_{load}L_{lead}/2\pi\eta^*$

Back Driving Load: $F_{load} = T_{torque}\ 2\pi / L_{lead}\eta^*$ *Rule of Thumb: The Lead Should be Less Than 1/3 the Diameter to Prevent Ball Screw Back Driving*

Screw Critical Speed: $C_s = (F_c \times 4.76 \times 10^6) \times (d/L^2)$; C_s = Critical Speed (RPM); d = Root Diameter; L = Length Between Supports

F_c = end support factor; Fixed-Free = 0.36; Simple-Simple = 1.00; Fixed-Simple = 1.47; Fixed-Fixed = 2.23

Life of Ballscrew: $L = (F_r / D \times f_w)^3 \times 10^6$ L = Life; F_r = Dynamic Load Rating; D = Design Load;

f_w = 1.2-1.5 Normal Operation; f_w = 1.5-3.0 Operation with Impact or Vibration

η* = Efficiency

COEFFICIENTS OF FRICTION OF COMMON BEARINGS AND BEARING MATERIALS

Teflon on Steel = 0.04	Steel on Steel = 0.54	Linear Guideway = 0.003	Cross Roller Bearing = 0.003
Teflon on Steel (lubricated) = 0.001	Steel on Steel (lubricated) = 0.15	Ball Bushing = 0.001	Brass on Steel = 0.19

LINEAR GUIDEWAY DATA

Nominal Life of Guideway: $L = (f_h f_t C / f_w L_C)^3 \times 50Km$ f_h = Hardness factor; f_t = Temp. Factor; f_w = Load factor,

L_C = Calculated Load; C = Basic Dynamic Load Rating

Service Life of Guideway: $L_S = L \times 10^3 / S \times 60Hr$ S = Distance Traveled per Minute; L = Nominal Life (Km)

f_h = 1.0@H_RC=60, =0.6@ H_RC=50, = 0.2@ H_RC=30; **f_h = 1.0 for Hiwin Linear Guides**

f_t = 1.0@T≤100°C, f_t = 0.93@T=150°C, f_t =0.77@T=200°C; f_t = 0.60@T=250°C

f_w = 1.0 No Vibration; f_w = 2.0 Light Impact and Vibration; f_w = 3.0 High Impact and Vibration

BASIC DC MOTOR EQUATIONS

$T_m = K_t I - T_{friction}$ or $I = (T_m + T_{friction})/K_t$ $RPM = (V_{in} - IR_m)/K_e$ or $V_{in} = K_e \times RPM + IR_m$

i.e. Calculate the minimum current and voltage required to drive a motor to 100oz-in @ 3000RPM

$T_{friction}$ = 10oz-in; K_t = 22oz-in/A; R_m = 5Ω; K_e = 40V/1000RPM

I = (100oz-in + 10oz-in)÷22oz-in/A = 4.82A V = (40V/1000RPM) x 3000RPM + (4.82Ax5 Ω) = 144VDC

877.478.3241 | www.iptech1.com