MAC / MAD Sizing formulas & Examples

SHOCK ABSORBERS

Four parameters are required to precisely determine the dimension of shock absorbers

- Mass to be decelerated m (kg)
- Impact velocity v (m/s)
- Propelling or driving force F (N)
- Number of impact cycles per hour C (/hr)

Some useful calculation formulas

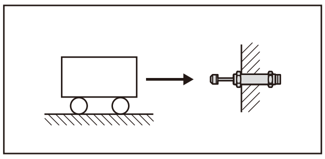
- Kinetic energy: $E_K = mv^2/2$
- Drive energy: $E_D = F \cdot S$
- Free fall velocity: $v = \sqrt{2g \cdot h}$
- Pneumatic or hydraulic cylinder driving forces: $F = 0.00785\ Pd^2$
- Maximum shock force (approximate): $Fm = 1.2\ E_T/S$
- Propelling force generated by electric motors: $F = 3000\ kW/v$
- Total energy absorbed per hour: $E_{TC} = E_T \cdot C$

Symbols	Unit	Description
μ		Coefficient of friction
α	(rad)	Angle of incline
θ	(rad)	Side load angle
ω	(rad/s)	Angular velocity
A	(m)	Width
B	(m)	Thickness
C	(/hr)	Impact cycles per hour
d	(mm)	Cylinder bore diameter
E_D	(Nm)	Drive energy per cycle
E_K	(Nm)	Kinetic energy per cycle
E_T	(Nm)	Total energy per cycle
E_{TC}	(Nm)	Total energy per hour
F	(N)	Propelling force
F_m	(N)	Maximum shock force
g	(m/s^2)	Acceleration due to gravity (9.81 m/s)
h	(m)	Height
HM		Arresting torque factor for motors (normally 2.5)
kW	(kW)	Electric motor power
m	(kg)	Mass to be decelerated
M_e	(kg)	Effective mass
P	(bar)	Operation pressure
R	(m)	Radius
R_s	(m)	Shock absorber mounting distance from rotation center
S	(m)	Stroke
T	(Nm)	Driving torque
t	(s)	Deceleration time
v	(m/s)	Velocity of impact mass
v_s	(m/s)	Impact velocity at shock absorber

Example 1: Horizontal impact

Application data

m = 300kg
v = 1.0m/s
S = 0.04m
C = 300/hr



Formulas and calculation

$$E_K = \frac{mv^2}{2} = \frac{300 \cdot 1.0^2}{2} = 150Nm$$

$$E_T = E_K = 150Nm$$

$$E_{TC} = E_T \cdot C = 150 \cdot 300 = 45000Nm/hr$$

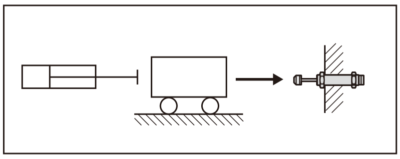
$$M_e = \frac{2E_T}{V^2} = \frac{2 \cdot 1.50}{1.0^2} = 300kg$$

Choose from sizing diagram: MAD3650 is adequate

Example 2: Horizontal impact with propelling force

Application data

m = 300kg
v = 1.2m/s
S = 0.05m
P = 40N/cm²
d = 100mm
C = 300/hr



Formulas and calculation

$$E_K = \frac{mv^2}{2} = \frac{300 \cdot 1.0^2}{2} = 216Nm$$

$$E_D = F \cdot S = 0.00785Pd^2 \cdot S$$

$$= 0.00785 \cdot 40 \cdot 100^2 \cdot 0.05 = 157Nm$$

$$E_T = E_K + E_D = 216 + 157 = 373Nm$$

$$E_{TC} = E_T \cdot C = 373 \cdot 300 = 111900Nm/hr$$

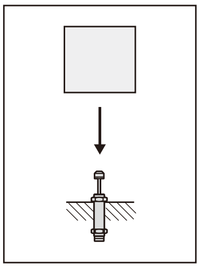
$$M_e = \frac{2E_T}{V^2} = \frac{2 \cdot 3.73}{1.2^2} = 518kg$$

Choose from sizing diagram: MAD4250 is adequate

Example 3: Free fall impact

Application data

m = 40kg
h = 0.4m
S = 0.06m
C = 200/hr



Formulas and calculation

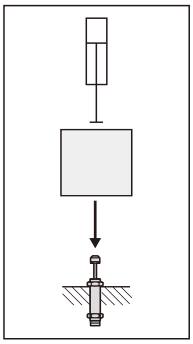
v	$=$	$\sqrt{2g \cdot h}$	$= \sqrt{2 \cdot 9.81 \cdot 0.4}$ =2.8m/sec
E_K	$=$	$\frac{mv^2}{2}$	$= \frac{40 \cdot 2.8^2}{2}$ =157Nm
E_D	$=$	$F \cdot S$	$= mg \cdot h$ $=40 \cdot 9.81 \cdot 0.06$ =23.5Nm
E_T	$=$	E_K+E_D	$=157+23.5$ =180.5Nm/hr
E_{TC}	$=$	$E_T \cdot C$	$=180.5 \cdot 200$=36100Nm/hr
M_e	$=$	$\frac{2E_T}{V^2}$	$= \frac{2 \cdot 180.5}{2.8^2}$ =46kg

Choose from sizing diagram: MAC3660-1 is adequate

Example 4: Free fall impact with propelling

Application data

m = 40kg
h = 0.3m
S = 0.025m
P = 5bar
d = 50mm
C = 200/hr
v = 1.0m/sec



Formulas and calculation

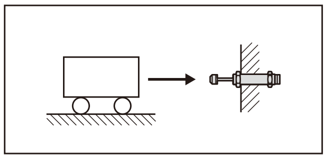
E_K	$=$	$\frac{mv^2}{2}$	$= \frac{40 \cdot 1.0^2}{2}$ =20Nm
E_D	$=$	$F \cdot S$	$=(mg+0.0785Pd^2) \cdot S$ $=(40 \cdot 9.81+0.0785 \cdot 5 \cdot 50^2) \cdot 0.025$ =33.5Nm
E_T	$=$	E_K+E_D	$=$ 20+33.5 =55.5Nm
E_{TC}	$=$	$E_T \cdot C$	$=55.5 \cdot 200$=11100Nm/hr
M_e	$=$	$\frac{2E_T}{V^2}$	$= \frac{2 \cdot 55.5}{1.0^2}$ =111kg

Choose from sizing diagram: MAD2525 is adequate

Example 5: Horizontal impact with motor driving

Application data

m = 400kg
v = 1.0m/s
kW = 1.5kW
HM = 2.5
S = 0.075m
C = 60/hr



Formulas and calculation

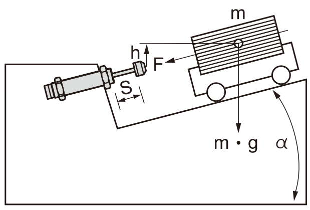
E_K	$=$	$\frac{mv^2}{2}$	$= \frac{400 \cdot 1.0^2}{2}$ =200Nm
E_D	$=$	$F \cdot S = \frac{kW \cdot HM}{v} \cdot S$	$= \frac{1500 \cdot 2.5}{1.0} \cdot 0.075$=281Nm
E_T	$=$	E_K+E_D	$=$ 200+281 =481Nm
E_{TC}	$=$	$E_T \cdot C$	$= 481 \cdot 60$ =25860Nm/hr
M_e	$=$	$\frac{2E_T}{V^2}$	$= \frac{2 \cdot 481}{1.0^2}$ =962kg

Choose from sizing diagram: MAD4275 is adequate

Example 6: Inclined impact

Application data

m = 150kg
h = 0.3m
S = 0.075m
α = 30°
C = 200/hr



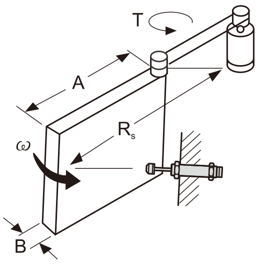
Formulas and calculation

v	$=$	$\sqrt{2g \cdot h}$	$= \sqrt{2 \cdot 9.81 \cdot 0.3}$ =2.43m/sec
E_K	$=$	$\frac{mv^2}{2}$	$= \frac{150 \cdot 2.43^2}{2}$ =443Nm
E_D	$=$	$F \cdot S$	$= m \cdot g \cdot S \cdot \sin\alpha$
	$=$	$150 \cdot 9.81 \cdot 0.075 \cdot \sin 30°$	=55.2Nm
E_T	$=$	E_K+E_D	$=433+55.2$ =498.2Nm/hr
E_{TC}	$=$	$E_T \cdot C$	$=498.2 \cdot 200$=99640Nm/hr
M_e	$=$	$\frac{2E_T}{V^2}$	$= \frac{2 \cdot 498.2}{2.43^2}$ =168.7kg

Choose from sizing diagram: MAD4275 is adequate

Example 7: Horizontal rotating door

Application data
m = 20kg
ω = 2.0rad/s
T = 20Nm
R_s = 0.8m
A = 1.0m
B = 0.05m
S = 0.016m
C = 100/hr



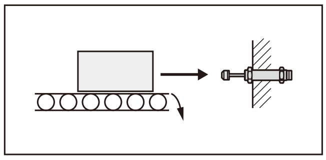
Formulas and calculation

I	=	$\frac{m(4A^2+B^2)}{12}$	= $\frac{20(4 \cdot 1.0^2+0.05^2)}{12}$	=6.67kg · m²
E_K	=	$\frac{I\omega^2}{2}$	= $\frac{6.67 \cdot 2.0^2}{2}$	=13.34Nm
θ	=	$\frac{s}{R_S}$	= $\frac{0.04}{0.8}$	=0.05rad
E_D	=	$T \cdot \theta$	= 20 · 0.05	=1.0Nm
E_T	=	E_K+E_D	= 13.34+1.0	=1434Nm
E_{TC}	=	$E_T \cdot C$	= 14.34 · 100	=1434Nm/hr
v	=	$\omega \cdot R_S$	= 2.0 · 0.8	=1.6m/s
M_e	=	$\frac{2E_T}{V^2}$	= $\frac{2 \cdot 14.34}{1.6^2}$	=11.20kg

Choose from sizing diagram: MAD2016 is adequate

Example 9: Horizontal mass on driven rollers

Application data
m = 150kg
v = 0.5m/s
μ = 0.25
S = 0.02m
C = 120/hr



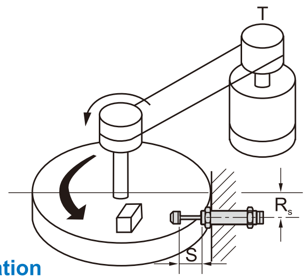
Formulas and calculation

E_K	=	$\frac{mv^2}{2}$	= $\frac{150 \cdot 0.5^2}{2}$	=18.75Nm
E_D	=	$F \cdot S = mg\mu \cdot S$	= 150 · 9.81 · 0.25 · 0.02	=7.35Nm
E_T	=	E_K+E_D	= 18.73+7.35	=26.1Nm
E_{TC}	=	$E_T \cdot C$	= 26.1 · 120	=3132Nm/hr
M_e	=	$\frac{2E_T}{V^2}$	= $\frac{2 \cdot 26.1}{0.5^2}$	=208.8kg

Choose from sizing diagram: MAC2020-3 is adequate

Example 8: Rotary index table with propelling force

Application data
m = 200kg
ω = 1.0rad/s
T = 100Nm
R = 0.5m
R_s = 0.4m
S = 0.04m
C = 100/hr



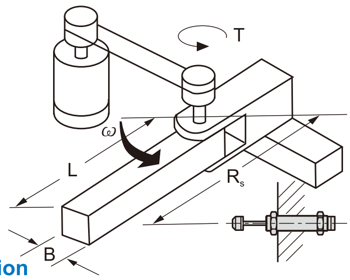
Formulas and calculation

I	=	$\frac{mR^2}{2}$	= $\frac{200 \cdot 0.5^2}{2}$	=25kg · m²
E_K	=	$\frac{I\omega^2}{2}$	= $\frac{25 \cdot 1.0^2}{2}$	=12.5Nm
θ	=	$\frac{s}{R_S}$	= $\frac{0.04}{0.4}$	=0.1rad
E_D	=	$T \cdot \theta$	= 100 · 0.1	=10Nm
E_T	=	E_K+E_D	= 12.5+10	=22.5Nm
E_{TC}	=	$E_T \cdot C$	= 22.5 · 50	=1125Nm/hr
v	=	$\omega \cdot R_S$	= 1.0 · 0.4	=0.4m/s
M_e	=	$\frac{2E_T}{V^2}$	= $\frac{2 \cdot 22.5}{0.4^2}$	=281kg

Choose from sizing diagram: MAD2540 is adequate

Example 10: Rotating beam with driving force

Application data
m = 40kg
A = 0.5m
B = 0.05m
ω = 2.0rad/s
T = 10Nm
R_s = 0.4m
S = 0.05m
C = 50/hr



Formulas and calculation

I	=	$\frac{m(4A^2+B^2)}{12}$	= $\frac{40(4 \cdot 0.5^2+0.05^2)}{12}$	=3.36kg · m²
E_K	=	$\frac{I\omega^2}{2}$	= $\frac{3.36 \cdot 2.0^2}{2}$	=6.8Nm
θ	=	$\frac{s}{R_S}$	= $\frac{0.05}{0.4}$	=0.125rad
E_D	=	$T \cdot \theta$	= 10 · 0.125	=1.25Nm
E_T	=	E_K+E_D	= 6.8+1.25	=8.05Nm
E_{TC}	=	$E_T \cdot C$	= 8.05 · 50	=402.5Nm/hr
v	=	$\omega \cdot R_S$	= 2.0 · 0.4	=0.8m/s
M_e	=	$\frac{2E_T}{V^2}$	= $\frac{2 \cdot 8.05}{0.8^2}$	=25.15kg

Choose from sizing diagram: MAD1416-2 is adequate