

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:

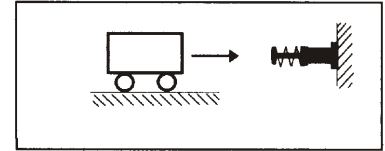
- Kinetic energy: $E_k = mv^2/2$
- Drive energy: $E_d = F \cdot S$
- Free fall velocity: $v = \sqrt{2g \cdot h}$
- Pneumatic or hydraulic cylinder driving forces:
 $F = 0.00785 Pd^2$
- Maximum shock force (approximate):
 $F_m = 1.2 E_T/S$
- Propelling force generated by electric motors:
 $F = 3000 \text{ kW}/v$
- 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 ²) |
| h | (m) | Height |
| HM | | Arresting torque factor for motors (normally 2.5) |
| kW | (kW) | Electric motor power |
| m | (kg) | Mass to be decelerated |
| M_m | (kg) | Effective mass |
| P | (bar) | Operation pressure |
| R_s | (m) | Radius |
| R | (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:

$m = 300\text{kg}$
 $v = 1.0\text{m/s}$
 $S = 0.04\text{m}$
 $C = 300/\text{hr}$



Formulas and calculation:

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

$$E_T = E_k = 150\text{Nm}$$

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

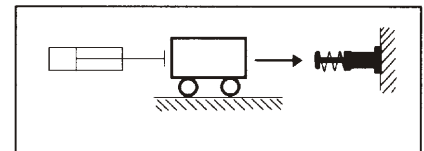
$$M_e = \frac{2E_T}{v^2} = \frac{2 \cdot 150}{1.0^2} = 300\text{kg}$$

Choose from sizing diagram: MAD3650 is adequate

Example 2: Horizontal impact with propelling force

Application data:

$m = 300\text{kg}$
 $v = 1.2\text{m/s}$
 $S = 0.05\text{m}$
 $P = 40\text{N/cm}^2$
 $d = 100\text{mm}$
 $C = 300/\text{hr}$



Formulas and calculation:

$$E_k = \frac{mv^2}{2} = \frac{300 \cdot 1.2^2}{2} = 216\text{Nm}$$

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

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

$$E_T = E_k + E_d = 216 + 157 = 373\text{Nm}$$

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

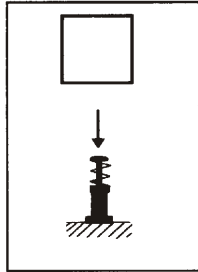
$$M_e = \frac{2E_T}{v^2} = \frac{2 \cdot 373}{1.2^2} = 518\text{kg}$$

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:

$$v = \sqrt{2g \cdot h} = \sqrt{2 \cdot 9.81 \cdot 0.4} = 2.8\text{m/sec}$$

$$E_k = \frac{mv^2}{2} = \frac{40 \cdot 2.8^2}{2} = 157\text{Nm}$$

$$E_D = F \cdot S = mg \cdot h = 40 \cdot 9.81 \cdot 0.06 = 23.5\text{Nm}$$

$$E_T = E_k + E_D = 157 + 23.5 = 180.5\text{Nm/hr}$$

$$E_{TC} = E_T \cdot C = 180.5 \cdot 200 = 36100\text{Nm/hr}$$

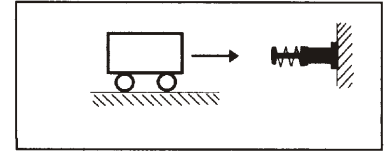
$$M_e = \frac{2E_T}{V^2} = \frac{2 \cdot 180.5}{2.8^2} = 46\text{kg}$$

Choose from sizing diagram: MAC3660-1 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:

$$E_k = \frac{mv^2}{2} = \frac{400 \cdot 1.0^2}{2} = 200\text{Nm}$$

$$E_D = F \cdot S = \frac{\text{kW} \cdot \text{HM}}{v} \cdot S = \frac{1500 \cdot 2.5}{1.0} \cdot 0.075 = 281\text{Nm}$$

$$E_T = E_k + E_D = 200 + 281 = 481\text{Nm}$$

$$E_{TC} = E_T \cdot C = 481 \cdot 60 = 25860\text{Nm/hr}$$

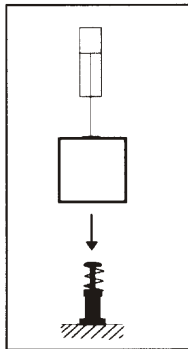
$$M_e = \frac{2E_T}{V^2} = \frac{2 \cdot 481}{1.0^2} = 962\text{kg}$$

Choose from sizing diagram: MAD4275 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:

$$E_k = \frac{mv^2}{2} = \frac{40 \cdot 1.0^2}{2} = 20\text{Nm}$$

$$E_D = F \cdot S = (mg + 0.0785Pd^2) \cdot S = (40 \cdot 9.81 + 0.0785 \cdot 5 \cdot 50^2) \cdot 0.025 = 33.5\text{Nm}$$

$$E_T = E_k + E_D = 20 + 33.5 = 55.5\text{Nm}$$

$$E_{TC} = E_T \cdot C = 55.5 \cdot 200 = 11100\text{Nm/hr}$$

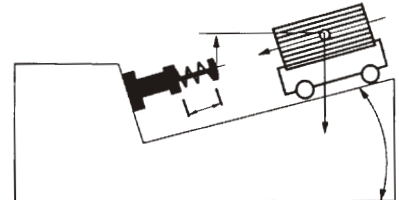
$$M_e = \frac{2E_T}{V^2} = \frac{2 \cdot 55.5}{1.0^2} = 111\text{kg}$$

Choose from sizing diagram: MAD2525 is adequate

Example 6: Inclined impact

Application data:

m = 150kg
h = 0.3m
S = 0.075m
 $\alpha = 30^\circ$
C = 200/hr



Formulas and calculation:

$$v = \sqrt{2g \cdot h} = \sqrt{2 \cdot 9.81 \cdot 0.3} = 2.43\text{m/sec}$$

$$E_k = \frac{mv^2}{2} = \frac{150 \cdot 2.43^2}{2} = 443\text{Nm}$$

$$E_D = F \cdot S = m \cdot g \cdot S \cdot \sin \alpha = 150 \cdot 9.81 \cdot 0.075 \cdot \sin 30^\circ = 55.2\text{Nm}$$

$$E_T = E_k + E_D = 443 + 55.2 = 498.2\text{Nm/hr}$$

$$E_{TC} = E_T \cdot C = 498.2 \cdot 200 = 99640\text{Nm/hr}$$

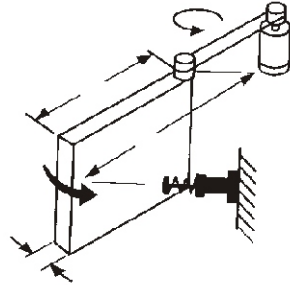
$$M_e = \frac{2E_T}{V^2} = \frac{2 \cdot 498.2}{2.43^2} = 168.7\text{kg}$$

Choose from sizing diagram: MAD4275 is adequate

Example 7: Horizontal rotating door

Application data:

$m = 20\text{kg}$
 $\omega = 2.0\text{rad/s}$
 $T = 20\text{Nm}$
 $R_s = 0.8\text{m}$
 $A = 1.0\text{m}$
 $B = 0.05\text{m}$
 $S = 0.016\text{m}$
 $C = 100/\text{hr}$



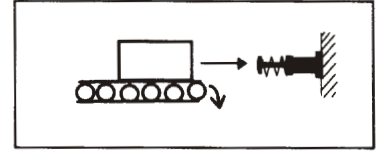
| | | |
|----------|----------------------------|--|
| I | $= \frac{m(4A^2+B^2)}{12}$ | $= \frac{20(4 \cdot 1.0^2+0.05^2)}{12} = 6.67\text{kg} \cdot \text{m}^2$ |
| E_k | $= \frac{I\omega^2}{2}$ | $= \frac{6.67 \cdot 2.0^2}{2} = 13.34\text{Nm}$ |
| θ | $= \frac{s}{R_s}$ | $= \frac{0.04}{0.8} = 0.05\text{rad}$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

Choose from sizing diagram: MAD2016 is adequate

Example 9: Horizontal mass on driven rollers

Application data:

$m = 150\text{kg}$
 $v = 0.5\text{m/s}$
 $\mu = 0.25$
 $S = 0.02\text{m}$
 $C = 120/\text{hr}$



Formulas and calculation:

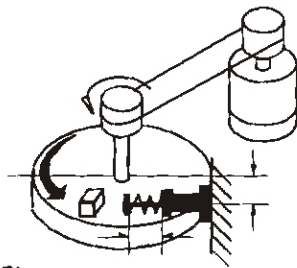
| | | |
|----------|-------------------------------|--|
| E_k | $= \frac{mv^2}{2}$ | $= \frac{150 \cdot 0.5^2}{2} = 18.75\text{Nm}$ |
| E_b | $= F \cdot S = mg\mu \cdot S$ | $= 150 \cdot 9.81 \cdot 0.25 \cdot 0.02 = 7.35\text{Nm}$ |
| E_T | $= E_k + E_b$ | $= 18.75 + 7.35 = 26.1\text{Nm}$ |
| E_{TC}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

Choose from sizing diagram: MAC2020-3 is adequate

Example 8: Rotary index table with propelling force

Application data:

$m = 200\text{kg}$
 $\omega = 1.0\text{rad/s}$
 $T = 100\text{Nm}$
 $R = 0.5\text{m}$
 $R_s = 0.4\text{m}$
 $S = 0.04\text{m}$
 $C = 100/\text{hr}$



Formulas and calculation:

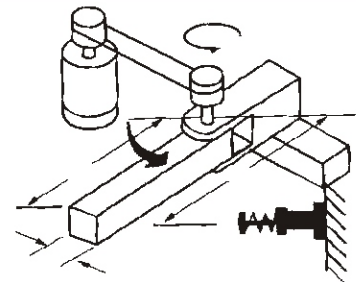
| | | |
|----------|-------------------------|--|
| I | $= \frac{mR^2}{2}$ | $= \frac{200 \cdot 0.5^2}{2} = 25\text{kg} \cdot \text{m}^2$ |
| E_k | $= \frac{I\omega^2}{2}$ | $= \frac{25 \cdot 1.0^2}{2} = 12.5\text{Nm}$ |
| θ | $= \frac{s}{R_s}$ | $= \frac{0.04}{0.4} = 0.1\text{rad}$ |
| E_b | $= T \cdot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

Choose from sizing diagram: MAD2540 is adequate

Example 10: Rotating beam with driving force

Application data:

$m = 40\text{kg}$
 $A = 0.5\text{m}$
 $B = 0.05\text{m}$
 $\omega = 2.0\text{rad/s}$
 $T = 10\text{Nm}$
 $R_s = 0.4\text{m}$
 $S = 0.05\text{m}$
 $C = 50/\text{hr}$



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

Choose from sizing diagram: MAD1416-2 is adequate