Selection Procedure for Soft Absorbers

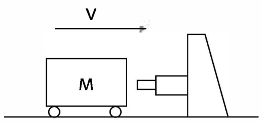
<Selection Procedure>

Item	Descriptions
1 Verification of the operating conditions	Verification of the types of motion: determine if it is a linear motion or a rotating motion, and whether thrust is present or not. Identify the specifications required for the selection.
⬇	Verification of the colliding object's mass: Determine the maximum mass M (kg) of the colliding object.
⬇	Verification of the impact rate: Determine the velocity V (m/s) just before it collides with the absorber. If the impact rate is not clear because the colliding object is cylindrical, the impact rate is determined by doubling the average velocity.
2 Calculation of the colliding object's kinetic energy	Based on the equation, calculate the kinetic energy, E1 $E_1 = \frac{1}{2} \times M \times V^2$
3 Verification of thrust	Verify if thrust F is present, and if so, refer to the sample selection equation to determine the thrust. Based on these, select a tentative soft absorber.
4 Tentative determination of the absorber's stroke	Based on the tentatively selected soft absorber, the tentative stroke St is determined.
5 Calculation of thrusting energy	Determine Energy E2 due to thrust. $E_2 = F \times St$
6 Calculation of the total energy E and selection of the soft absorbe	Determine the total energy E. $E = E_1 + E_2$
7 Checking the maximum absorption energy per minute	Based on the operating cycle C (times/min) and the total energy, determine the amount of energy per minute and confirm that it is within the specifications. $E_3 \geqq E \times C$
8 Checking the equivalent mass	When an impact is accompanied by thrust, always verify the equivalent mass, particularly for low-speed impacts (0.3m/s or slower).
⬇	Me must be smaller than the catalogue specifications. $Me = \frac{2 \times E}{V^2}$
⬇	Me = M (mass of the colliding object) in horizontal impact without thrust.
9 Checking the operating temperature	Operating temperature must be within an acceptable range.
10 Other	Model selection can also be done on a computer using automatic selection software. Please contact our sales department for inquiries. You can also download information from our homepage. http://www.fujilatex.co.jp/

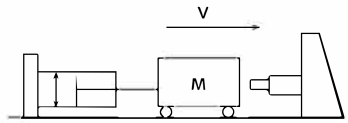
Selection Method for Soft Absorbers

1.Verifying the Type of Motion

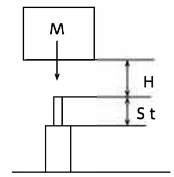
Impact conditions can be divided into following categories. When making a selection, it is necessary to calculate the energy for the relevant category and then consider the attachment method.



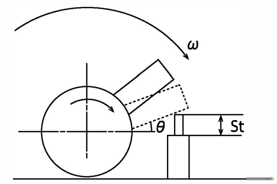
Horizontal motion without thrust



Thrusting motion



Falling motion



Rotating motion

2. Energy Calculation

2-1. Linear motion

<Specifications to be verified>

- ☐ Mass of the colliding object : M(kg)
- ☐ Impact rate : V(m/s)
- ☐ Thrust : F(N) (air cylinder, thrust of the motor, friction, gravity, etc.)
- ☐ Number of soft absorber receivers : N
- ☐ Falling height : H(m) (Only if a falling motion is applicable. The soft absorber's stroke is not included.)
- ☐ Soft absorber stroke : St(m)

<Equations>

Horizontal motion without thrust $E=\frac{1}{2}\times M\times V^2$

Thrusting motion $E=\frac{1}{2}\times M\times V^2+F\times St$

Falling motion $E= M\times g\times(H+St)$ (g : Acceleration due to gravity=9.8m/s^2)

2-2. Rotating motion

<Specifications to be verified>

- ☐ Mass of the colliding object : M(kg)
- ☐ Angular velocity of the impact : ω(rad/s)
- ☐ Torque : T(N·m)
- ☐ Moment of inertia : I(kg·m^2)
- ☐ Stopping angle : θ(rad)

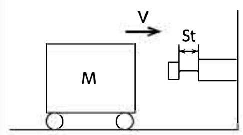
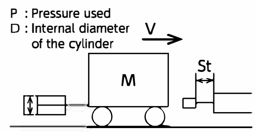
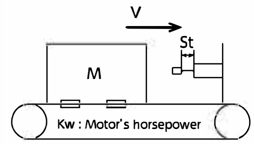
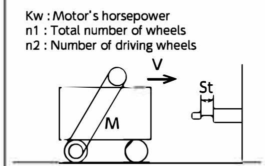
<Equations>

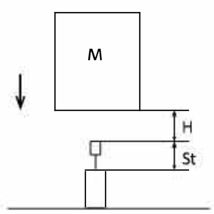
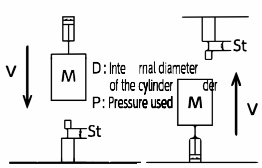
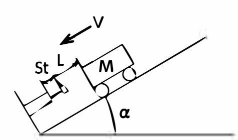
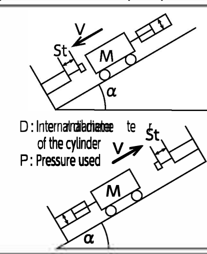
Thrusting motion $E=\frac{1}{2}\times I\times\omega^2+T\times\theta$

2-3. Other equations (the following equations indicate the minimum values; the actual values will be larger)

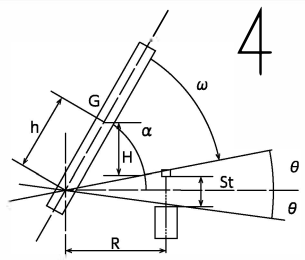
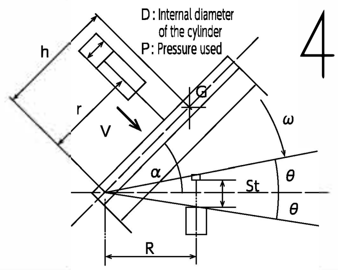
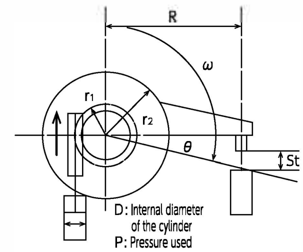
- ☐ Deceleration (G value) $G=\frac{0.051\times V^2}{St}$ This indicates the degree of impact at the time of collision. (Smaller value means smaller impact)
- ☐ Braking force $F=\frac{E}{St}$ This indicates the resistance that is generated in the soft absorber at the moment of collision. This value is required for confirming the strength of attachment parts.
- ☐ Braking time $t=\frac{2\times St}{V}$ This indicates the time it takes for the colliding object to come to a complete stop after colliding with a soft absorber.

Equations for the Selection of Soft Absorbers (1)

	Inertial impact (horizontal)	Cylindrical thrust (horizontal)	Motor-driven dolly (horizontal)	Friction-driven dolly (horizontal)
Impact (examples)				
Mass of the colliding object (kg)	M	M	M	M
Impact rate (m/s)	V	V	V	V
Kinetic energy (J)	$E_1=\frac{1}{2}M\cdot V^2$	$E_1=\frac{1}{2}M\cdot V^2$	$E_1=\frac{1}{2}M\cdot V^2$	$E_1=\frac{1}{2}M\cdot V^2$
Thrust (N)	———	$F=\frac{\pi D^2}{4}\times P\times 10^6$ ※1	$F=\frac{kw\times 2.5}{V}\times 10^3$ ※2	$\left\{\begin{array}{l}F=0.25\cdot M\cdot g\cdot\frac{n1}{n2}\\F=\frac{kw\times 2.5}{V}\times 10^3\end{array}\right.$ ※3
Thrusting energy (J)	———	$E_2=F\cdot St$	$E_2=F\cdot St$	$E_2=F\cdot St$
Total energy (J)	$E=\frac{E_1}{N}$ (N : Number of soft absorber receivers)	$E=\frac{E_1+E_2}{N}$ (N : Number of soft absorber receivers)	$E=\frac{E_1+E_2}{N}$ (N : Number of soft absorber receivers)	$E=\frac{E_1+E_2}{N}$ (N : Number of soft absorber receivers)
Equivalent mass (kg)	$Me=\frac{M}{N}$	$Me=\frac{2\cdot E}{V^2}$	$Me=\frac{2\cdot E}{V^2}$	$Me=\frac{2\cdot E}{V^2}$

	Free-fall (vertical)	Cylindrical thrust (up and down)	Free-fall (slope)	Cylindrical thrust (slope; up and down)
Collision Models				
Collision Mass (kg)	M	M	M	M
Collision Speed (m/s)	$V=\sqrt{19.6H}$	V	$V=\sqrt{19.6L\cdot\sin\alpha}$	V
Kinetic Energy (J)	$E_1=M\cdot g\cdot H$	$E_1=\frac{1}{2}M\cdot V^2$	$E_1=M\cdot g\cdot L\cdot\sin\alpha$	$E_1=\frac{1}{2}M\cdot V^2$
Driving Force (N)	$F=M\cdot g$	$F=F_1+M\cdot g$ (Descending) $F=F_1-M\cdot g$ (Ascending) (F_1 : Cylindrical thrust)	$F=M\cdot g\cdot\sin\alpha$	$F=F_1+M\cdot g\cdot\sin\alpha$ (Descending) $F=F_1-M\cdot g\cdot\sin\alpha$ (Ascending) (F_1 : Cylindrical thrust)
Driving Force Energy (J)	$E_2=F\cdot St$	$E_2=F\cdot St$	$E_2=F\cdot St$	$E_2=F\cdot St$
Total Energy (J)	$E=\frac{E_1+E_2}{N}$ (N : Number of soft absorber receivers)	$E=\frac{E_1+E_2}{N}$ (N : Number of soft absorber receivers)	$E=\frac{E_1+E_2}{N}$ (N : Number of soft absorber receivers)	$E=\frac{E_1+E_2}{N}$ (N : Number of soft absorber receivers)
Equivalent Mass (kg)	$Me=\frac{2\cdot E}{V^2}$	$Me=\frac{2\cdot E}{V^2}$	$Me=\frac{2\cdot E}{V^2}$	$Me=\frac{2\cdot E}{V^2}$

Equations for the Selection of Soft Absorbers (2)

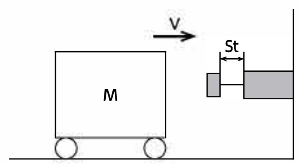
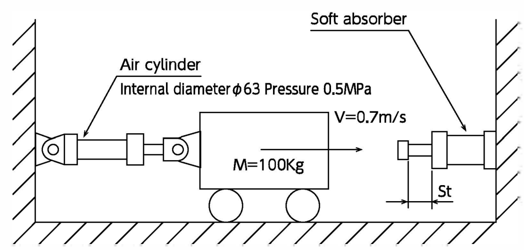
	Free-fall (rotating)	Cylindrical thrust (rotating)	Cylindrical thrust (horizontally rotating)
Collision Models			
Collision Mass (kg)	M	M	M
Collision Speed (m/s)	$V=\sqrt{\frac{2M\cdot g\cdot H}{I}\cdot R^2}$	$V=R\cdot\omega$	$V=R\cdot\omega$
Kinetic Energy (J)	$E_1=M\cdot g\cdot H$	$E_1=\frac{1}{2}I\cdot\omega^2$	$E_1=\frac{1}{2}I\cdot\omega^2$
Driving Force (N)	$F=\frac{M\cdot g\cdot h}{R}$	$F=\left(\frac{\pi D^2}{4}\times P\times 10^6+Mg\right)\times\frac{r}{R}$	$F=\frac{r_1}{R}\left(\frac{\pi D^2}{4}\right)\times P\times 10^6$
Driving Force Energy (J)	$E_2=F\cdot St$	$E_2=F\cdot St$	$E_2=F\cdot St$
Total Energy (J)	$E=\frac{E_1+E_2}{N}$ (N : Number of soft absorber receivers)	$E=\frac{E_1+E_2}{N}$ (N : Number of soft absorber receivers)	$E=\frac{E_1+E_2}{N}$ (N : Number of soft absorber receivers)
Equivalent Mass (kg)	$Me=\frac{2\cdot E}{V^2}$	$Me=\frac{2\cdot E}{V^2}$	$Me=\frac{2\cdot E}{V^2}$

Explanation of the symbols

Symbol	Unit	Explanation	Symbol	Unit	Explanation
E	J	Total energy (per soft absorber)	α	rad	Sloping angle
E_1	J	Kinetic energy	θ	rad	Vibrational angle within the soft absorber stroke
E_2	J	Thrusting energy	R	m	Distance between the centre of rotation and absorber
P	MPa	Pressure used by the driving cylinder	r_1	m	Pitch circle radius of pinion gear
D	m	Internal diameter of the driving cylinder	r_2	m	Radius of turntable
M	kg	Mass of the colliding object	h	m	Distance between the centre of rotation and centre of gravity
V	m/s	Impact rate	Tθ	N·m	Driving torque
F	N	Thrust	ω	rad/s	Angular velocity
F_1	N	Air cylinder' s thrust	I	$kg\cdot m^2$	Moment of inertia around the rotating shaft
St	m	Soft absorber stroke	N	Units	Number of soft absorber receivers
H	m	The distance an object falls until it hits the soft absorber	kw	kw	Motor capacity
L	m	Travelling distance on slope	n1		Total number of wheels
g	m/s^2	Acceleration due to gravity : $9.8m/s^2$	n2		Number of driving wheels
G		Centre of gravity			

*1 Includes empty weight and external force of a cylinder, etc.
*2 Includes torque due to empty weight and torque due to motor, etc.
*3 Use whichever value is smaller.

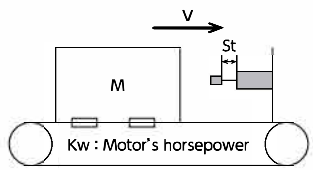
Sample Calculations for Selecting Soft Absorbers 1

	1. Inertial Impact (Horizontal)	2. Thrusting Motion due to Air Cylinder Thrust
Case Examples		
Specifications	☐ Mass of the colliding object M : 150kg ☐ Impact rate V : 1.5 m/s ☐ Operation frequency C : 1 time/min ☐ Ambient temperature t : 0～25° C ☐ Number of soft absorber receivers N : 1 unit	☐ Mass of the colliding object M : 100kg ☐ Impact rate V : 0.7m/s ☐ Operation frequency C : 1 time/min ☐ Ambient temperature t : 0～25° C ☐ Thrust F : Varies with the air cylinder D : Cylinder diameter···63mm P : Air pressure··0.5MPa ☐ Number of soft absorber receivers N : 1 unit
Sample Calculations	**1. Calculating kinetic energy** $E_1 = \frac{1}{2} M\cdot V^2 = \frac{1}{2} \times 150 \times 1.5^2 = 169\,(J)$ **2. Calculating total energy** $E = \frac{E_1}{N} = \frac{169}{1} = 169\,(J)$ According to Items 3 and 4 of the selection procedure on page 14, tentatively select FA-3625A3-C having the maximum absorption energy of 200(J) from the catalog. **3.Feasibility check** 3-1. Using equivalent mass to check $Me = \frac{M}{N} = \frac{150}{1} = 150\,(kg)$ As the equivalent mass of FA-3625A3-C is 700(kg), it does not pose a problem. Based on these, FA-3625A3-C is selected	**1. Calculating kinetic energy** $E_1 = \frac{1}{2} M\cdot V^2 = \frac{1}{2} \times 100 \times 0.7^2 = 24.5\,(J)$ **2. Calculating thrusting energy** Here, the soft absorber's stroke must be determined tentatively. In essence, because the absorber must have an absorption capacity larger than the calculated kinetic energy, tentatively select an absorber that has a capacity that is at least 24.5(J) higher than the catalogue specifications. Because the thrusting energy due to air cylinder must also be taken into consideration, tentatively select an absorber that has a capacity that is at least twice the kinetic energy. Here, FWM-2725FBD-* with a maximum absorption capacity of 79.4J is tentatively selected from the catalogue. Thrusting energy is determined as follows. $F = \frac{\pi\cdot D^2}{4} \times P$ $= \frac{3.14 \times 0.063^2}{4} \times 0.5 \times 10^6$ $= 1{,}557(N)$ $St = 25\ (mm) = 0.025(m)$ $E_2 = F \times St = 1{,}557 \times 0.025$ $= 38.9(J)$ **3. Determine the total energy.** $E = E_1 + E_2 = 24.5 + 38.9$ $= 63.4\,(J)$ **4. Feasibility check** 4-1. Using absorption energy to check As the absorption energy of FWM-2725FBD-* is 79.4(J), it does not pose a problem. 4-2. Using equivalent mass to check $Me = \frac{2E}{V^2} = \frac{2 \times 63.4}{0.7^2}$ $= 259(kg)$ As the equivalent mass of FWM-2725FBD-* is 450(kg), it does not pose a problem. Based on these, FWM-2725FBD-* is selected.

Sample Calculations for Selecting Soft Absorbers 2

3. Motor's horsepower

Case Examples



Specifications

☐Mass of the colliding object	M : 30kg
☐Impact rate	V : 0.7m/s
☐Motor's horsepower	kw : 1kw
☐Operation frequency	C : 1 time/min
☐Ambient temperature	t : 0~25° C
☐Number of soft absorber receivers	N : 1 unit

Sample Calculations

1. Calculating kinetic energy

$$E_1 = \frac{1}{2} M \cdot V^2 = \frac{1}{2} \times 30 \times 0.7^2 = 7.35\,(J)$$

2. Calculating thrust

$$F = \frac{kw \cdot 2.5}{V} \times 10^3 = \frac{1 \times 2.5}{0.7} \times 10^3 = 3{,}571\,(N)$$

3. Calculating thrusting energy

According to Items 3 and 4 of the selection procedure on page 14, tentatively select FA-3625A3-C having the maximum absorption energy of 200(J) from the catalog. The thrusting energy will be as follows.

St = 25 (mm) = 0.025 (m)

$E_2 = F \cdot St = 3{,}571 \times 0.025 = 89.3\,(J)$

4. Calculating total energy

$$E = \frac{E_1 + E_2}{N} = \frac{7.35 + 89.3}{1} = 96.6\,(J)$$

5. Feasibility check

5-1. Using absorption energy to check

As the absorption energy of FA-3625A3-C is 200(J), it does not pose a problem.

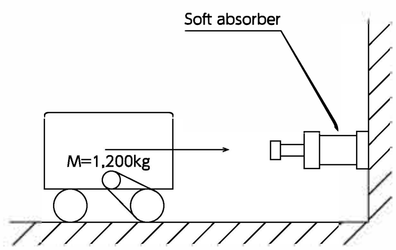
5-2. Using equivalent mass to check

$$Me = \frac{2 \cdot E}{V^2} = \frac{2 \times 96.6}{0.7^2} = 394\,(kg)$$

As the equivalent mass of FA-3625A3-C is 700(kg), it does not pose a problem.
Based on these, FA-3625A3-C is selected.

4. Thrusting Energy due to Motor-Driven Dolly

Case Examples



Specifications

☐ Mass of the colliding object	M : 1,200kg
☐ Impact rate	V : 0.5m/s
☐ Operation frequency	C : 1 time/min
☐ Ambient temperature	t : 0～25° C
☐ Thrust	F : Varies with the motor Motor output···3.7kw
☐ Number of soft absorber receivers	N : 1 unit

Sample Calculations

1. Calculating kinetic energy

$$E_1 = \frac{1}{2} M \cdot V^2 = \frac{1}{2} \times 1{,}200 \times 0.5^2 = 150\,(J)$$

2. Calculating thrusting energy

Here, the trust is first calculated. For a motor-driven dolly, the smaller calculated value based on the following two equations is used as thrust.

(1) $F = \frac{Kw \times 2.5}{V} \times 10^3 = \frac{3.7 \times 2.5}{0.5} \times 10^3 = 18{,}500(N)$

(2) $F = M \times g \times 0.25 \times \frac{n1}{n2}$ (n1: Number of driving wheels, n2: Total number of wheels)

$= 1{,}200 \times 9.8 \times 0.25 \times \frac{1}{2}$

$= 1{,}470(N)$

Therefore, 1,470N is used as thrust. At this point, a tentative absorber is selected.
FA-3650A2-C is selected as the tentative soft absorber based on the kinetic energy.
Thrusting energy is determined as follows:

St = 50 (mm) = 0.05 (m)

$E_2 = F \times St = 1{,}470 \times 0.05$

$= 73.5(J)$

3. Determine the total energy.

$E = E_1 + E_2 = 150 + 73.5 = 223.5(J)$

4. Feasibility check

4-1. Using absorption energy to check

As the absorption energy of FA-3650A2-C is 400 (J), it does not pose a problem.

4-2. Using equivalent mass to check

$$Me = \frac{2E}{V^2} = \frac{2 \times 223.5}{0.5^2}$$

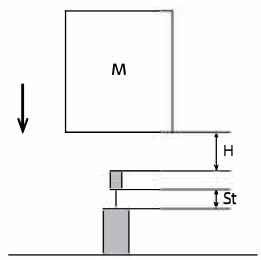
$= 1{,}788(kg)$

As the equivalent mass of FA-3650A2-C is 2,700 (kg), it does not pose a problem.
Based on these, FA-3650A2-C is selected.

Sample Calculation for Selecting Soft Absorbers 3

5. Free-Fall (vertical)

Case Examples



Specifications

□Mass of the colliding object	M : 300kg
□The distance of an object falls until it hits the shock absorber	H : 0.15m/s
□Operation frequency	C : 1 time/min
□Ambient temperature	t : 0～25℃
□Number of soft absorber receivers	N : 2 units

Sample Calculations

1. Calculating impact rate

$$V=\sqrt{2 \cdot g \cdot H}=\sqrt{2\times9.8\times0.15}=1.71\,(m/s)$$

2. Calculating kinetic energy

$$E_1=\frac{1}{2}\cdot M\cdot V^2=\frac{1}{2}\times 300\times 1.71^2=439(J)$$

3. Calculating thrust

3-1. Using equivalent mass to check

$F = M \cdot g = 300 \times 9.8 = 2{,}940\,(N)$

4. Calculating thrusting energy

According to Items 3 and 4 of the selection procedure on page 14, tentatively select FK-4250BH-C having the maximum absorption energy of 520(J) from the catalog.

* Since multiple absorbers are used, tentatively select the FK type (fixed type).

The thrusting energy will be as follows.

$St = 50\,(mm) = 0.05\,(m)$

$E_2 = F \cdot St = 2{,}940 \times 0.05 = 147(J)$

3. Calculating total energy

$$E=\frac{E_1+E_2}{N}=\frac{439+147}{2}=293(J)$$

6. Feasibility check

6-1. Using absorption energy to check

As the absorption energy of FK-4250BH-C is 520(J), it does not pose a problem.

6-2. Using equivalent mass to check

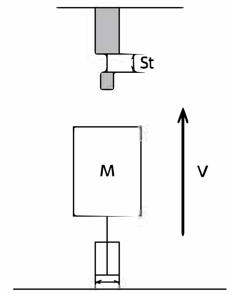
$$Me=\frac{2\cdot E}{V^2}=\frac{2\times293}{1.71^2}=200\,(kg)$$

As the equivalent mass of FK-4250BH-C is 450(kg), it does not pose a problem.

Based on these, two units of FK-4250BH-C are selected.

6. Cylindrical thrust (up)

Case Examples



Specifications

□Mass of the colliding object	M : 80kg
□Impact rate	V : 0.5m/s
□Operation frequency	C : 1 time/min
□Ambient temperature	t : 0～25℃
□Thrust	F : Air cylinder's thrust D : Internal diameter of the driving cylinder…80mm P : Pressure used by the driving Cylinder…0.5MPa
□Number of soft absorber receivers	N : 1 unit

Sample Calculations

1. Calculating kinetic energy

$$E_1=\frac{1}{2}M\cdot V^2=\frac{1}{2}\times 80\times 0.5^2=10\,(J)$$

2. Calculating thrust

$$F=\frac{\pi\cdot D^2}{4}\times P-M\cdot g$$

$$=\frac{\pi\times 80^2}{4}\times 0.5-80\times 9.8=1{,}729\,(N)$$

3. Calculating thrusting energy

According to Items 3 and 4 of the selection procedure on page 14, tentatively select FWM-2725FBD-* having the maximum absorption energy of 79.3(J) from the catalog.

The thrusting energy will be as follows.

$St = 25\,(mm) = 0.025\,(m)$

$E_2 = F \cdot St = 1{,}729 \times 0.025 = 43.2\,(J)$

4. Calculating total energy

$$E_2=\frac{E_1+E_2}{N}=\frac{10+43.2}{1}=53.2\,(J)$$

5. Feasibility check

5-1. Using absorption energy to check

As the absorption energy of FWM-2725FBD - * is 79.3(J), it does not pose a problem.

5-2. Using equivalent mass to check

$$Me=\frac{2\cdot E}{V^2}=\frac{2\times53.2}{0.5^2}=426\,(kg)$$

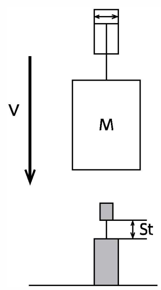
As the equivalent mass of FWM-2725FBD- * is 450(kg), it does not pose a problem.

Based on these, FWM-2725FBD- * is selected.

Sample Calculation for Selecting Soft Absorbers 4

7. Cylindrical thrust (down)

Case Examples



Specifications

- ☐ Mass of the colliding object M : 80kg
- ☐ Impact rate V : 0.5m/s
- ☐ Operation frequency C : 1 time/min
- ☐ Ambient temperature t : 0～25℃
- ☐ Thrust F : Air cylinder's thrust
  - D : Internal diameter of the driving cylinder…80mm
  - P : Pressure used by the driving Cylinder…0.5MPa
- ☐ Number of the soft absorber receivers N : 1 unit

Sample Calculations

1. Calculating kinetic energy

$$E_1 = \frac{1}{2} M \cdot V^2 = \frac{1}{2} \times 80 \times 0.5^2 = 10\,(J)$$

2. Calculating thrust

$$F = \frac{\pi \cdot D^2}{4} \times P + M \cdot g$$

$$= \frac{\pi \times 80^2}{4} \times 0.5 + 80 \times 9.8 = 3{,}297\,(N)$$

3. Calculating thrusting energy

According to Items 3 and 4 of the selection procedure on page 14, tentatively select FWM-3035TBD-* having the maximum absorption energy of 196(J) from the catalog.
The thrusting energy will be as follows.
$St = 35\,(mm) = 0.035\,(m)$
$E_2 = F \cdot St = 3{,}297 \times 0.035 = 115\,(J)$

4. Calculating total energy

$$E = \frac{E_1 + E_2}{N} = \frac{10 + 115}{1} = 125\,(J)$$

5. Feasibility check

5-1. Using absorption energy to check
As the absorption energy of FWM-3035TBD - * is 196(J), it does not pose a problem.

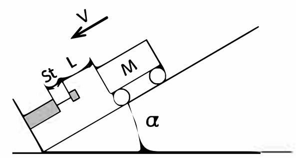
5-2. Using equivalent mass to check

$$Me = \frac{2 \cdot E}{V^2} = \frac{2 \times 125}{0.5^2} = 1{,}000\,(kg)$$

As the equivalent mass of FWM-3035TBD - * is 1,300(kg), it does not pose a problem.
Based on these, FWM-3035TBD - * is selected.

8. Free-Fall (slope)

Case Examples



Specifications

- ☐ Mass of the colliding object M : 70kg
- ☐ Travelling distance on slope L : 0.7m
- ☐ Sloping angle α : 3°
- ☐ Ambient temperature t : 0～25℃
- ☐ Number of the soft absorber receivers N : 1 unit

Sample Calculations

1. Calculating impact rate

$$V = \sqrt{2 \cdot g \cdot L \cdot \sin\alpha}$$

$$= \sqrt{2 \times 9.8 \times 0.7 \times \sin 3^\circ} = 0.85\,(m/s)$$

2. Calculating kinetic energy

$E_1 = M \cdot g \cdot L \cdot \sin\alpha$
$= 70 \times 9.8 \times 0.7 \times \sin 3^\circ = 25.1\,(J)$

3. Calculating thrusting energy

According to Items 3 and 4 of the selection procedure on page 14, tentatively select FA-2016E3-* having the maximum absorption energy of 35.7(J) from the catalog.
The thrusting energy will be as follows.
$St = 16\,(mm) = 0.016\,(m)$
$E_2 = M \cdot g \cdot \sin\alpha \cdot St$
$= 70 \times 9.8 \times \sin 3^\circ \times 0.016 = 0.57\,(J)$

4. Calculating total energy

$$E = \frac{E_1 + E_2}{N} = \frac{25.1 + 0.57}{1} = 25.7\,(J)$$

5. Feasibility check

5-1. Using absorption energy to check
As the absorption energy of FA-2016E3 - * is 35(J), it does not pose a problem.

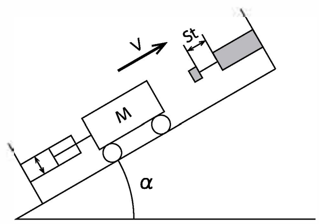
5-2. Using equivalent mass to check

$$Me = \frac{2 \cdot E}{V^2} = \frac{2 \times 25.7}{0.85^2} = 71.1\,(kg)$$

As the equivalent mass of FA-2016E3 - * is 120(kg), it does not pose a problem.
Based on these, FA-2016E3 - * is selected.

Sample Calculation for Selecting Soft Absorbers 5

9. Cylindrical thrust (slope ; up)



仕様

- ☐ Mass of the colliding object M : 70kg
- ☐ Impact rate V : 0.5m/s
- ☐ Thrust F : Air cylinder's thrust
  D : Internal diameter of the driving cylinder···80mm
  P : Pressure used by the driving Cylinder···0.4MPa
- ☐ Sloping angle α : 30°
- ☐ Ambient temperature t : 0∼25°C
- ☐ Number of the soft absorber receivers N : 1unit

1. Calculating kinetic energy

$$E_1 = \frac{1}{2} \cdot M \cdot V^2 = \frac{1}{2} \times 70 \times 0.4^2 = 5.6\,(J)$$

2. Calculating thrust

$$F = \frac{\pi \cdot D^2}{4} \cdot P - M \cdot g \cdot \sin\alpha$$

$$= \frac{\pi \times 80^2}{4} \times 0.4 - 70 \times 9.8 \times \sin 30^\circ$$

$$= 1{,}667\,(N)$$

3. Calculating thrusting energy

According to Items 3 and 4 of the selection procedure on page 14, tentatively select FA-2725FB-* having the maximum absorption energy of 79.3(J) from the catalog.
The thrusting energy will be as follows.
St = 25 (mm) = 0.025 (m)

$E_2 = F \cdot St = 1{,}667 \times 0.025 = 41.7(J)$

4. Calculating total energy

$$E = \frac{E_1 + E_2}{N} = \frac{5.6 + 41.7}{1} = 47.3\,(J)$$

5. Feasibility check

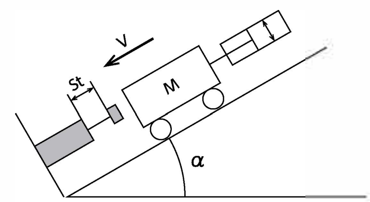
5-1. Using absorption energy to check
As the absorption energy of FA-2725FB - ∗ is 79.3(J), it does not pose a problem.

5-2. Using equivalent mass to check

$$Me = \frac{2 \cdot E}{V^2} = \frac{2 \times 47.3}{0.4^2} = 591\,(kg)$$

As the equivalent mass of FA-2725FB - ∗ is 650 (kg), it does not pose a problem.
Based on these, FA-2725FB- ∗ is selected.

10. Cylindrical thrust (slope ; down)



仕様

- ☐ Mass of the colliding object M: 70kg
- ☐ Impact rate V : 1m/s
- ☐ Thrust F : Air cylinder's thrust
  D : Internal diameter of the driving cylinder···80mm
  P : Pressure used by the driving Cylinder···0.4MPa
- ☐ Sloping angle α:30°
- ☐ Ambient temperature t : 0∼25°C
- ☐ Number of the soft absorber receivers N: 1 unit

1. Calculating kinetic energy

$$E_1 = \frac{1}{2} \cdot M \cdot V^2 = \frac{1}{2} \times 70 \times 1^2 = 35\,(J)$$

2. Calculating thrust

$$F = \frac{\pi \cdot D^2}{4} \cdot P + M \cdot g \cdot \sin\alpha$$

$$= \frac{\pi \times 80^2}{4} \times 0.4 + 70 \times 9.8 \times \sin 30^\circ$$

$$= 2{,}354\,(N)$$

3. Calculating thrusting energy

According to Items 3 and 4 of the selection procedure on page 14, tentatively select FK-3035M-* having the maximum absorption energy of 196(J) from the catalog.
The thrusting energy will be as follows.
St = 35 (mm) = 0.035 (m)

$E_2 = F \cdot St = 2{,}354 \times 0.035 = 82.4\,(J)$

4. Calculating total energy

$$E = \frac{E_1 + E_2}{N} = \frac{35 + 82.4}{1} = 117.4\,(J)$$

5. Feasibility check

5-1. Using absorption energy to check
As the absorption energy of FK-3035M- ∗ is 196 (J), it does not pose a problem.

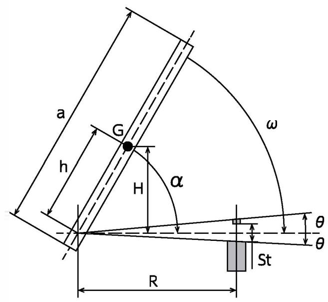
5-2. Using equivalent mass to check

$$Me = \frac{2 \cdot E}{V^2} = \frac{2 \times 117.4}{1^2} = 234.8\,(kg)$$

As the equivalent mass of FK-3035M - ∗ is 390 (kg), it does not pose a problem.
Based on these, FK-3035M- ∗ is selected

Sample Calculation for Selecting Soft Absorbers 6

11. Free-Fall (rotating)



☐ Mass of the colliding object	M	: 15kg
☐ Overall length of a colliding object	a	: 0.12m
☐ Distance between the center of rotation and center of gravity	h	: 0.06m
☐ Distance between the center of rotation and absorber	R	: 0.1m
☐ Angle of fall of a colliding object	α	: 60˚
☐ Number of the soft absorber receivers	N	: 1 unit
☐ Operation frequency	C	: 1 time/min
☐ Ambient temperature	t	: 0～25˚C

1. Calculating kinetic energy

Obtain the distance that an object falls from the angle of fall.

$H = h \cdot \sin\alpha = 0.06 \times \sin 60^\circ = 0.051$ (m)

$E_1 = M \cdot g \cdot H = 15 \times 9.8 \times 0.051 = 7.5$ (J)

2. Calculating thrust

$$F = \frac{h}{R} \cdot M \cdot g = \frac{0.06}{0.1} \times 15 \times 9.8 = 88.2\,(\mathrm{N})$$

3. Calculating thrusting energy

According to Items 3 and 4 of the selection procedure on page 14, tentatively select FA-1612X3-* having the maximum absorption energy of 14.7(J) from the catalog. The thrusting energy will be as follows.

St = 12 (mm) = 0.012 (m)

$E_2 = F \cdot St = 88.2 \times 0.012 = 1.06$ (J)

4. Calculating total energy

$$E = \frac{E_1+E_2}{N} = \frac{7.5+1.06}{1} = 8.56\,(\mathrm{J})$$

5. Feasibility check

5-1. Confirmation based on the absorbed energy

There is no problem because the maximum absorption energy of FA-1612X3-* is 14.7(J).

5-2. Confirmation based on the equivalent mass

Obtain the impact rate from the moment of inertia.

For the equation for obtaining the moment of inertia, refer to the Quick Reference for Moment of Inertia on page 32.

$$I = M \cdot \frac{a^2}{3} = 15 \times \frac{0.12^2}{3} = 0.072\,(\mathrm{kg \cdot m^2})$$

$$V = \sqrt{\frac{2 \cdot M \cdot g \cdot H}{I} \cdot R^2}$$

$$= \sqrt{\frac{2 \times 15 \times 9.8 \times 0.051}{0.072} \cdot 0.1^2} = 1.44\,(\mathrm{m/s})$$

$$Me = \frac{2 \cdot E_3}{V^2} = \frac{2 \times 8.56}{1.44^2} = 8.26\,(\mathrm{kg})$$

As the equivalent mass of FA-1612X3 - * is 35(kg), it does not pose a problem.
Based on these, FA-1612X3- * is selected.

5-3. Confirmation based on the eccentric angle

$$\theta = \tan^{-1}\left(\frac{St}{R}\right) = \tan^{-1}\left(\frac{0.012}{0.1}\right) = 6.8\,(^\circ)$$

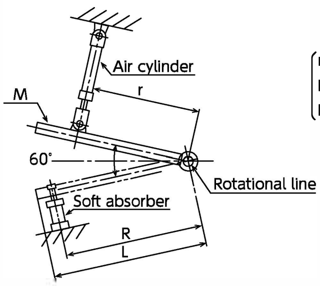
Since the eccentric angle of FA-1612X3-* is ± 2.5(˚), the eccentric angle adaptor needs to be used.

In view of the foregoing, FA-1612X3-S and the eccentric angle adaptor OP-1010XB are selected.

Sample Calculation for Selecting Soft Absorbers 7

12. Up-and-Down Motion due to Air Cylinder Thrust

Case Examples



r=0.5m
R=0.6m
L=0.7m

Specifications

☐ Mass of the colliding object	M :	260kg
☐ Air Cylinder rate	v :	0.5m/s
☐ Operation frequency	C :	1 time/min
☐ Ambient temperature	t :	0～25° C
☐ Thrust	F :	Varies with the air cylinder
	D :	Cylinder diameter···50mm
	P :	Air pressure···0.5MPa
☐ Number of soft absorber receivers	N :	1 unit

Sample Calculations

1. Calculating kinetic energy

$$E_1 = \frac{1}{2}I\omega^2 = \frac{1}{2}\times M\times\frac{L^2}{3}\times\left(\frac{v}{r}\right)^2$$

$$= \frac{1}{2}\times 260\times\frac{0.7^2}{3}\times\left(\frac{0.5}{0.5}\right)^2 = 21.2(J)$$

Impact rate $V = v\times\left(\frac{R}{r}\right) = 0.5\times\frac{0.6}{0.5} = 0.6(m/s)$

2. Calculating thrusting energy

$$E_2 = T\theta = \left(\frac{\pi\cdot D^2}{4}\times P\times 10^6\times r + Mg\times\frac{L}{2}\right)\times\frac{St}{R}$$

$$= \left(\frac{3.14\times 0.05^2}{4}\times 0.5\times 10^6\times 0.5 + 260\times 9.8\times\frac{0.7}{2}\right)\times\frac{St}{0.6}$$

As in previous examples, the soft absorber's stroke is tentatively determined. Here, FWM 3035TBD-*with a maximum absorption capacity of 196(J) is tentatively selected from the catalogue. Thrusting energy is determined as follows.

$$E_2 = \left(\frac{3.14\times 0.05^2}{4}\times 0.5\times 10^6\times 0.5 + 260\times 9.8\times\frac{0.7}{2}\right)\times\frac{0.035}{0.6} = 80.6(J)$$

3. Determine the total energy.

$E = E_1 + E_2 = 21.2 + 80.6 = 101.8\ (J)$

4. Feasibility check

4-1. Using absorption energy to check

As the absorption energy of FWM-3035TBD-*is 196(J), it does not pose a problem.

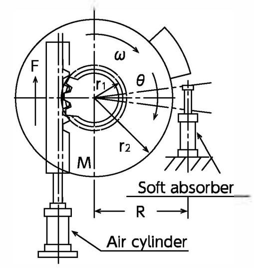
4-2. Using equivalent mass to check

$$Me = \frac{2E}{V^2} = \frac{2\times 101.8}{0.6^2} = 565.6\ (kg)$$

As the equivalent mass of FWM-3035TBD-* is 1300(kg), itdoes not pose a problem. Based on these, FWM-3035TBD-*is selected.

13. Rotating Motion due to Air Cylinder Thrust

Case Examples



r_1=0.1m
r_2=0.5m
R=0.6m

Specifications

☐ Mass of the colliding object	M :	200kg
☐ Air Cylinder rate	v :	0.5m/s
☐ Operation frequency	C :	1 time/min
☐ Ambient temperature	t :	0～25° C
☐ Thrust	F :	Varies with the air cylinder
	D :	Cylinder diameter···80mm
	P :	Air pressure···0.5MPa
☐ Number of soft absorber receivers	N :	1 unit

Sample Calculations

1. Calculating kinetic energy

$$E_1 = \frac{1}{2}I\omega^2 = \frac{1}{2}\times M\times\frac{r_2^2}{2}\times\left(\frac{v}{r_1}\right)^2$$

$$= \frac{1}{2}\times 200\times\frac{0.5^2}{2}\times\left(\frac{0.5}{0.1}\right)^2 = 312.5(J)$$

Impact rate $V = v\times\left(\frac{R}{r_1}\right) = 0.5\times\left(\frac{0.6}{0.1}\right) = 3(m/s)$

2. Calculating thrusting energy

$$E_2 = T\theta = F\times r\times\frac{St}{R}$$

$$= \frac{3.14\times 0.08^2}{4}\times 0.5\times 10^6\times 0.1\times\frac{St}{0.6}$$

At this point, the soft absorber' s stroke must be determined tentatively. FA-4250B3-C with a maximum absorption capacity of 520(J) is tentatively selected from the catalogue. Thrusting energy is determined as follows.

$$E_2 = \frac{3.14\times 0.08^2}{4}\times 0.5\times 10^6\times 0.1\times\frac{0.05}{0.6} = 20.9(J)$$

3. Determine the total energy.

$E = E_1 + E_2 = 312.5 + 20.9 = 333.4\ (J)$

4. Feasibility check

4-1. Using absorption energy to check

As the absorption energy of FA-4250B3-C is 520 (J), it does not pose a problem.

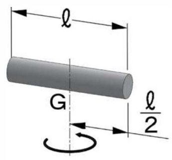
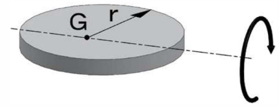
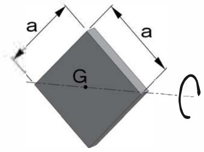
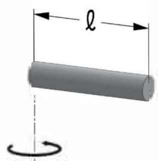
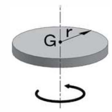
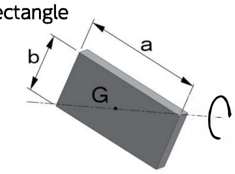
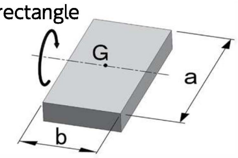
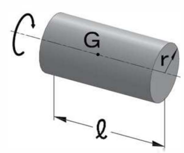
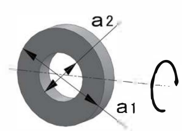
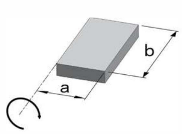
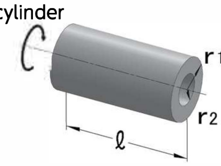
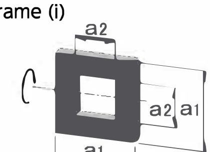
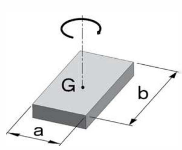
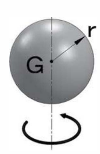
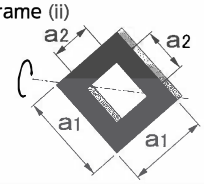
4-2. Using equivalent mass to check

$$Me = \frac{2E}{V^2} = \frac{2\times 333.4}{3^2} = 74\ (kg)$$

As the equivalent mass of FA-4250B3-C is 6,500 (kg), it does not pose a problem. Based on these, FA-4250B3-C is selected

Calculation Reference for Selecting Soft Absorbers 1

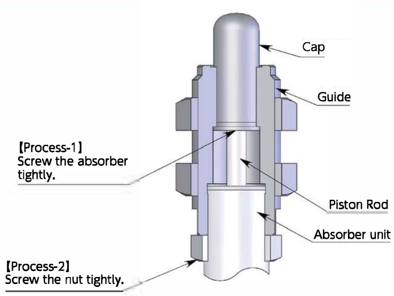
Quick Reference for Moment of Inertia

Shape	Slim rod 	Thin disc 	Thin square 
Rotating shaft	It is perpendicular to the rod and passes through the centre of gravity	It is parallel to the plain and passes through the centre of gravity	The axis passes through the centre of gravity and the opposing corner
Moment of inertia	$M \cdot \frac{\ell^2}{12}$	$M \cdot \frac{r^2}{4}$	$M \cdot \frac{a^2}{12}$
Shape	Slim rod 	Thin disc 	Thin rectangle 
Rotating shaft	It is perpendicular to the rod at one of the ends	It is perpendicular to the plain and passes through the centre of gravity	It is an axis that is parallel to the plain and passes through thecentre of gravity
Moment of inertia	$M \cdot \frac{\ell^2}{3}$	$M \cdot \frac{r^2}{2}$	$M \cdot \frac{b^2a^2}{6(b^2+a^2)}$
Shape	Thin rectangle 	Cylinder 	Thin donut shape 
Rotating shaft	It is parallel to side b and passes through the centre of gravity	It is a central axis that passes through the centre of gravity	It is an axis that is parallel to the plain and passes through the central axis
Moment of inertia	$M \cdot \frac{a^2}{12}$	$M \cdot \frac{r^2}{2}$	$M \cdot \frac{(a_1^2+a_2^2)}{16}$
Shape	Thin rectangle 	Hollow cylinder 	Square frame (i) 
Rotating shaft	It is parallel to side b and is on one side	It is a central axis that passes through the mutual center	It is an axis that is parallel to the plain and passes through the central axis
Moment of inertia	$M \cdot \frac{a^2}{3}$	$M \cdot \frac{r_1^2+r_2^2}{2}$	$M \cdot \frac{(a_1^2+a_2^2)}{12}$
Shape	Rectangle 	Sphere (filled) 	Square frame (ii) 
Rotating shaft	It is perpendicular to the plain and passes through the centre of gravity	It is an axis that passes through the centre of gravity	It is parallel to the plain and passes through the opposing corner
Moment of inertia	$M \cdot \frac{a^2+b^2}{12}$	$M \cdot \frac{2r^2}{5}$	$M \cdot \frac{(a_1^2+a_2^2)}{12}$

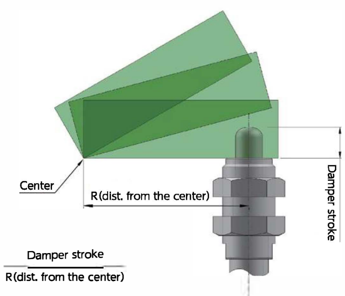
Unit : $kg \cdot m^2$

Calculation Reference for Selecting Soft Absorbers 2

How to mount the eccentric angle adopter



1. For a small eccentric angle



$$\text{Polarizational angle} = \tan^{-1}\frac{\text{Damper stroke}}{\text{R(dist. from the center)}}$$

Easy placing absorber for a relatively small eccentric angle

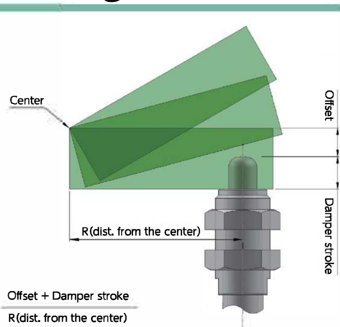
Example of calculation

R=100mm

Damber stroke=16mm

$$\theta=\tan^{-1}\frac{16}{100}=9^{\circ}$$

2. For a large eccentric angle



$$\text{Polarizational angle} = \tan^{-1}\frac{\text{Offset + Damper stroke}}{\text{R(dist. from the center)}}$$

Easy placing absorber but the case that eccentric angle is large

Example of calculation

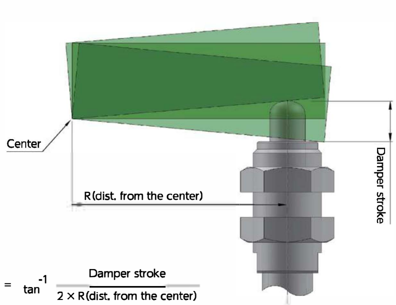
R=100mm

Damber stroke=16mm

Offset=15mm

$$\theta=\tan^{-1}\frac{16+15}{100}=17^{\circ}$$

3. For the smallest eccentric angle



$$\text{Polarizational angle} = \tan^{-1}\frac{\text{Damper stroke}}{2\times\text{R(dist. from the center)}}$$

Collision object does not stop perpendicular to the absorber at the end of stroke but the case that the eccentric angle is the smallest

Example of calculation

R=100mm

Damber stroke=16mm

$$\theta=\tan^{-1}\frac{16}{2\times100}=4.5^{\circ}$$

As above, depending on the mounting way, eccentric angle shall be differed even if the R(distance from the center) and damper stroke is same. Please confirm the maximum usable eccentric angle and use the eccentric angle adaptor within the allowance.