Shock Absorber Sizing Examples
Typical Shock Absorber Applications

SHOCK ABSORBER SIZING
Follow the next six steps to manually size ITT Enidine shock absorbers:

STEP 1: Identify the following parameters. These must be known for all energy absorption calculations. Variations or additional information may be required in some cases.

A. Weight of the load to be stopped (Kg).
B. Velocity of the load upon impact with the shock absorber (m/s).
C. External (propelling) forces acting on the load (N), if any.
D. Cyclic frequency at which the shock absorber will operate.
E. Orientation of the application's motion (i.e. horizontal, vertical up, vertical down, inclined, rotary horizontal, rotary vertical up, rotary vertical down).

NOTE: For rotary applications, it is necessary to determine both the radius of gyration (K) and the mass moment of inertia (I). both of these terms locate the mass of a rotating object with respect to the pivot point. It is also necessary to determine the angular velocity (ω) and the torque (T).

STEP 2: Calculate the kinetic energy of the moving object.

$$E_K = \frac{I}{2}\omega^2 \text{ (rotary) or } E_K = \frac{1}{2}MV^2 \text{ (linear)}$$

Utilizing the Product Locators for Shock Absorbers located at the beginning of each product family section, select a model, either adjustable or non-adjustable, with a greater energy per cycle capacity than the value just calculated.

STEP 3: Calculate the work energy input from any external (propelling) forces acting on the load, using the stroke of the model selected in Step 2.

$$E_W = F_D \times S \text{ (linear) or } E_W = \frac{T}{R_S} \times S \text{ (rotary)}$$

Caution: The propelling force must not exceed the maximum propelling force listed for the model chosen. If the propelling force is too high, select a larger model and recalculate the work energy.

STEP 4: Calculate the total energy per cycle $E_T = E_K + E_W$

The model selected must have at least this much energy capacity. If not, select a model with greater energy capacity and return to Step 3.

STEP 5: Calculate the energy that must be absorbed per hour. Even though the shock absorber can absorb the energy in a single impact, it may not be able to dissipate the heat generated if the cycle rate is too high.

$$E_TC = E_T \times C$$

The model selected must have an energy per hour capacity greater than this calculated figure. If it is not greater, there are two options:

1. Choose another model that has more energy per hour capacity (because of larger diameter or stroke). Keep in mind that if the stroke changes, you must return to Step 3.
2. Use an Air/Oil Tank. The increased surface area of the tank and piping will increase the energy per hour capacity by 20 percent.

STEP 6: If you have selected an TK or ECO Series model, refer to the sizing graph(s) in the appropriate series section to determine the required damping constant. If the point cannot be found in the sizing graph, you must select a larger model or choose a different series. Note that if the stroke changes, you must return to Step 3.

If you have selected an adjustable model (OEM or HDA Series), refer to the Useable Adjustment Setting Range graph for the chosen model. The impact velocity must fall within the limits shown on the graph.

RATE CONTROL SIZING
Follow the next five steps to manually size ITT Enidine rate controls:

STEP 1: Identify the following parameters. These must be known for all rate control calculations. Variations or additional information may be required in some cases.

A. Weight of the load to be controlled Kg
B. Desired velocity of the load m/s
C. External (propelling) force acting on the load N, if any.
D. Cyclic frequency at which the rate control will operate.
E. Orientation of the application's motion (i.e. horizontal, vertical up, vertical down, inclined, rotary horizontal, rotary vertical up, rotary vertical down.)
F. Damping direction (i.e., tension [T], compression [C] or both [T and C].
G. Required stroke mm

NOTE: For rotary applications, please submit the application worksheet on page 175 to ITT Enidine for sizing.

STEP 2: Calculate the propelling force at the rate control in each direction damping is required. (See sizing examples on page 6-15).

CAUTION: The propelling force in each direction must not exceed the maximum propelling force listed for the chosen model. If the propelling force is too high, select a larger model.

STEP 3: Calculate the total energy per cycle

$$E_T = E_W \text{ (tension)} + E_W \text{ (compression)}$$
$$E_W = F_D \times S$$

STEP 4: Calculate the total energy per hour

$$E_TC = E_T \times C$$

The model selected must have an energy per hour capacity greater than this calculated figure. If not, choose a model with a higher energy per hour capacity.

Compare the damping direction, stroke, propelling force, and total energy per hour to the values listed in the Rate Controls Engineering Data Charts (pages 99-104).

STEP 5: If you have selected a rate control, refer to the sizing graphs in the Rate Controls section to determine the required damping constant.

If you have selected an adjustable model (ADA), refer to the Useable Adjustment Setting Range graph for the chosen model. The desired velocity must fall within the limits shown on the graph.

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SYMBOLS

- a = Acceleration (m/s^2)
- A = Width (m)
- B = Thickness (m)
- C = Number of cycles per hour
- d = Cylinder bore diameter (mm)
- D = Distance (m)
- E_K = Kinetic energy (Nm)
- E_T = Total energy per cycle (Nm/c), $E_K + E_W$
- E_TC = Total energy to be absorbed per hour (Nm/hr)
- E_W = Work or drive energy (Nm)
- F_D = Propelling force (N)
- F_P = Shock force (N)
- H = Height (m)
- Hp = Motor rating (kw)
- I = Mass moment of inertia (kgm^2)
- K = Radius of gyration (m)
- L = Length (m)
- P = Operating pressure (bar)
- R_S = Mounting distance from pivot point (m)
- S = Stroke of shock absorber (m)
- t = Time (s)
- T = Torque (Nm)
- V = Impact velocity (m/s)
- M = Mass (kg)
- α = Angle of incline (degrees)
- θ = Start point from true vertical 0° (degrees)
- μ = Coefficient of friction
- Ø = Angle of rotation (degrees)
- ω = Angular velocity (rad/s)

USEFUL FORMULAS

1. To Determine Reaction Force

$$F_P = \frac{E_T}{S \times \mathbf{.85}}$$

For Non-Adjustable ECO Series only, use

$$F_P = \frac{E_T}{S \times \mathbf{.50}}$$

2. To Determine Impact Velocity

A. If there is no acceleration (V is constant) (e.g., load being pushed by hydraulic cylinder or motor driven.) $V = \frac{D}{t}$

B. If there is acceleration. (e.g., load being pushed by air cylinder) $V = \frac{\mathbf{2} \times D}{t}$

3. To Determine Propelling Force Generated by Electric Motor

$$F_D = \frac{\mathbf{3000} \times kw}{V}$$

4. To Determine Propelling Force of Pneumatic or Hydraulic Cylinders

$F_D = \mathbf{0{,}0785} \times d^2 \times P$

5. Free Fall Applications

A. Find Velocity for a Free Falling Weight:
$V = \sqrt{19{,}6 \times H}$

B. Kinetic Energy of Free Falling Weight:
$E_K = \mathbf{9{,}8} \times M \times H$

6. Deceleration

A. To Determine the Approximate Stroke

$$a = \frac{F_P - F_D}{M}$$

B. To Determine the Approximate Stroke (Conventional Damping Only)

$$S = \frac{E_K}{a \times M\ 0{,}85 - 0{,}15\ F_D}$$

*For ECO and TK Models:

$$S = \frac{E_K}{a \times M\ 0{,}5 - 0{,}5\ F_D}$$

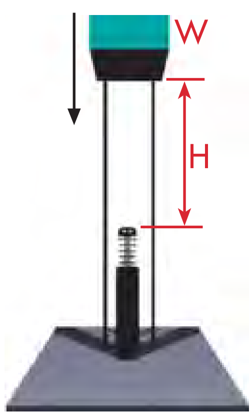
NOTE: Constants are printed in **bold**.

The following examples are shown using Metric formulas and units of measure.

Shock Absorbers

EXAMPLE 1:

Vertical Free Falling Weight



STEP 1: Application Data

(M) Mass = 1 550 kg
(H) Height = 0,5 m
(C) Cycles/Hr = 2

STEP 2: Calculate kinetic energy

E_K = **9,8** x M x H
E_K = **9,8** x 1 550 x 0,5
E_K = 7 595 Nm

Assume Model OEM 4.0M x 6 is adequate (Page 31).

STEP 3: Calculate work energy

E_W = **9,8** M x S
E_W = **9,8** x 1 550 x 0,15
E_W = 2 278,5 Nm

STEP 4: Calculate total energy per cycle

E_T = $E_K + E_W$
E_T = 7 595 + 2 278,5
E_T = 9 873,5 Nm/c

STEP 5: Calculate total energy per hour

E_TC = E_T x C
E_TC = 9 873,5 x 2
E_TC = 19 747 Nm/hr

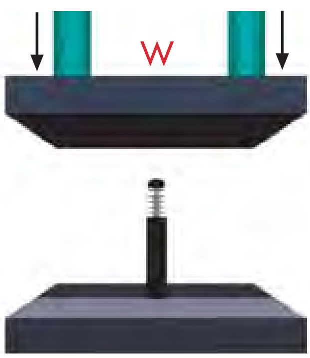
STEP 6: Calculate impact velocity and confirm selection

V = $\sqrt{\mathbf{19{,}6} \times H}$
V = $\sqrt{\mathbf{19{,}6} \times \mathbf{0{,}5}}$
V = 3,1 m/s

Model OEM 4.0M x 6 is adequate for this application.

EXAMPLE 2:

Vertical Moving Load with Propelling Force Downward



STEP 1: Application Data

(M) Mass = 1 550 kg
(V) Velocity = 2,0 m/s
(d) Cylinder bore dia. = 100mm
(P) Pressure = 5 bar
(C) Cycles/Hr = 200

STEP 2: Calculate kinetic energy

$E_K = \frac{M}{2} \times V^2 = \frac{1\,550}{2} \times 2^2$

E_K = 3 100 Nm

Assume Model OEM 4.0M x 4 is adequate (Page 31).

STEP 3: Calculate work energy

F_D = [**0,0785** x d^2 x P] + [**9,8** x M]
F_D = [**0,0785** x 100^2 x 5] + [**9,8** x 1 550]
F_D = 19 117 N
E_W = F_D x S
E_W = 19 117 x 0,1
E_W = 1 911,7 Nm

STEP 4: Calculate total energy per cycle

E_T = $E_K + E_W$
E_T = 3 100 + 1 911,7
E_T = 5 011,7 Nm/c

STEP 5: Calculate total energy per hour

E_TC = E_T x C
E_TC = 5 011,7 x 200
E_TC = 1 002 340 Nm/hr

Model OEM 4.0M x 4 is adequate.

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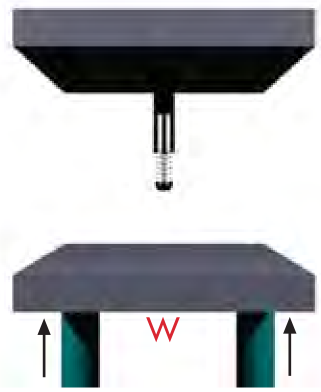
EXAMPLE 3:
Vertical Moving Load with Propelling Force Upward



STEP 1: Application Data
(M) Mass = 1 550 kg
(V) Velocity = 2 m/s
(d) 2 Cylinders bore dia. = 150mm
(P) Operating pressure = 5 bar
(C) Cycles/Hr = 200

STEP 2: Calculate kinetic energy

$E_K = \frac{M}{2} \times V^2 = \frac{1\,550}{2} \times 2^2$

$E_K = 3\,100$ Nm

Assume Model OEM 3.0M x 5 is adequate (Page 31).

STEP 3: Calculate work energy

$F_D = 2 \times [\mathbf{0{,}0785} \times d^2 \times P] - [\mathbf{9{,}8} \times M]$

$F_D = 2 \times [\mathbf{0{,}0785} \times 150^2 \times 5] - [\mathbf{9{,}8} \times 1\,550]$

$F_D = 2\,472{,}5$ N

$E_W = F_D \times S$

$E_W = 2\,472{,}5 \times 0{,}125$

$E_W = 309$ Nm

STEP 4: Calculate total energy per cycle

$E_T = E_K + E_W$

$E_T = 3\,100 + 309$

$E_T = 3\,409$ Nm/c

STEP 5: Calculate total energy per hour

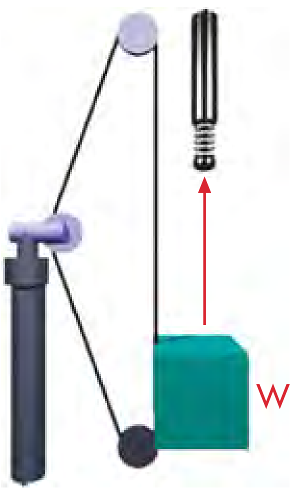
$E_TC = E_T \times C$

$E_TC = 3\,409 \times 200$

$E_TC = 681\,800$ Nm/hr

Model OEM 3.0M x 5 is adequate.

EXAMPLE 4:
Vertical Moving Load with Propelling Force from Motor



STEP 1: Application Data
(M) Mass = 90 kg
(V) Velocity = 1,5 m/s
(kW) Motor rating = 1 kW
(C) Cycles/Hr = 100

STEP 2: Calculate kinetic energy

$E_K = \frac{M}{2} \times V^2 = \frac{90}{2} \times 1{,}5^2$

$E_K = 101$ Nm

CASE A: UP

STEP 3: Calculate work energy

$F_D = \frac{\mathbf{3\,000} \times kW}{V} - \mathbf{9{,}8} \times M$

$F_D = \frac{\mathbf{3\,000} \times 1}{1{,}5} - 882$

$F_D = 1\,118$ N

Assume Model OEM 1.25 x 2 is adequate (Page 26).

$E_W = F_D \times S$

$E_W = 1\,118 \times 0{,}5$

$E_W = 56$ Nm

STEP 4: Calculate total energy per cycle

$E_T = E_K + E_W$

$E_T = 101 + 56$

$E_T = 157$ Nm/c

STEP 5: Calculate total energy per hour

$E_TC = E_T \times C$

$E_TC = 157 \times 100$

$E_TC = 15\,700$ Nm/hr

Model OEM 1.25M x 2 is adequate.

CASE B: DOWN

STEP 3: Calculate work energy

$F_D = \frac{\mathbf{3\,000} \times kW}{V} + \mathbf{9{,}8} \times M$

$F_D = \frac{\mathbf{3\,000} \times 1}{1{,}5} + 882$

$F_D = 2\,882$ N

Assume Model OEMXT 2.0M x 2 is adequate (Page 30).

$E_W = F_D \times S$

$E_W = 2\,882 \times 0{,}05$

$E_W = 144$ Nm

STEP 4: Calculate total energy per cycle

$E_T = E_K + E_W$

$E_T = 101 + 144$

$E_T = 245$ Nm/c

STEP 5: Calculate total energy per hour

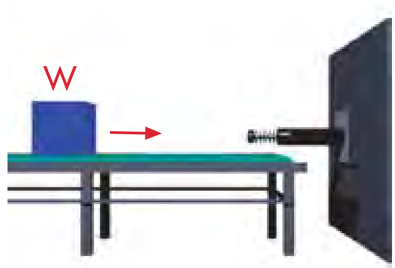
$E_TC = E_T \times C$

$E_TC = 245 \times 100$

$E_TC = 24\,500$ Nm/hr

Model OEMXT 2.0M x 2 is adequate.

EXAMPLE 5:
Horizontal Moving Load



STEP 1: Application Data
(M) Mass = 900 kg
(V) Velocity = 1,5 m/s
(C) Cycles/Hr = 200

STEP 2: Calculate kinetic energy

$E_K = \frac{M}{2} \times V^2$

$E_K = \frac{900}{2} \times 1{,}5^2$

$E_K = 1\,012{,}5$ Nm

Assume Model OEMXT 2.0M x 2 is adequate (Page 30).

STEP 3: Calculate work energy: N/A

STEP 4: Calculate total energy per cycle

$E_T = E_K = 1\,012{,}5$ Nm/c

STEP 5: Calculate total energy per hour

$E_TC = E_T \times C$

$E_TC = 1\,012{,}5 \times 200$

$E_TC = 202\,500$ Nm/hr

Model OEMXT 2.0M x 2 is adequate.

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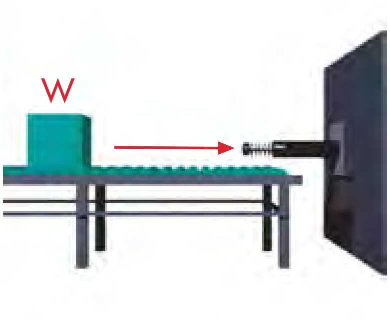
EXAMPLE 6:
Horizontal Moving Load with Propelling Force



STEP 1: Application Data

(M) Mass = 900 kg
(V) Velocity = 1,5 m/s
(d) Cylinder bore dia. = 75mm
(P) Operating pressure = 5 bar
(C) Cycles/Hr = 200

STEP 2: Calculate kinetic energy

$E_K = \frac{M}{2} \times V^2$

$E_K = \frac{900}{2} \times 1{,}5^2$

$E_K = 1\,012{,}5$ Nm

Assume Model OEMXT 2.0M x 2 is adequate (Page 30).

STEP 3: Calculate work energy

$F_D = \mathbf{0,0785} \times d^2 \times P$
$F_D = \mathbf{0,0785} \times 75^2 \times 5$
$F_D = 2\,208{,}9$ N
$E_W = F_D \times S$
$E_W = 2\,208{,}9 \times 0{,}05$
$E_W = 110$ Nm/c

STEP 4: Calculate total energy per cycle

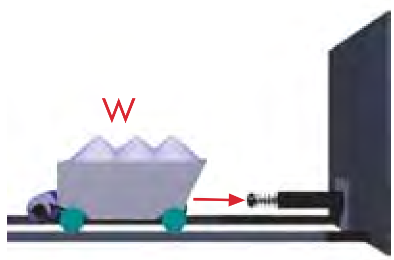
$E_T = E_K + E_W$
$E_T = 1\,012{,}5 + 110$
$E_T = 1\,122{,}5$ Nm/c

STEP 5: Calculate total energy per hour

$E_TC = E_T \times C$
$E_TC = 1\,122{,}5 \times 200$
$E_TC = 224\,500$ Nm/hr

Model OEMXT 2.0M x 2 is adequate.

EXAMPLE 7:
Horizontal Moving Load, Motor Driven



STEP 1: Application Data

(M) Mass = 1 000 kg
(V) Velocity = 1,5 m/s
(kW) Motor rating = 1 kW
(C) Cycles/Hr = 120

STEP 2: Calculate kinetic energy

$E_K = \frac{M}{2} \times V^2$

$E_K = \frac{1\,000}{2} \times 1{,}5^2$

$E_K = 1\,125$ Nm

Assume Model OEMXT 2.0M x 2 is adequate (Page 30).

STEP 3: Calculate work energy

$F_D = \frac{\mathbf{3\,000} \times kW}{V}$

$F_D = \frac{\mathbf{3\,000} \times 1}{1{,}5}$

$F_D = 2\,000$ N
$E_W = F_D \times S$
$E_W = 2\,000 \times 0{,}05$
$E_W = 100$ Nm

STEP 4: Calculate total energy per cycle

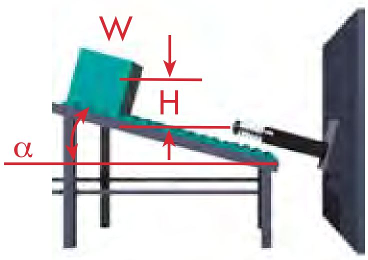
$E_T = E_K + E_W$
$E_T = 1\,125 + 100$
$E_T = 1\,225$ Nm/c

STEP 5: Calculate total energy per hour

$E_TC = E_T \times C$
$E_TC = 1\,225 \times 120$
$E_TC = 147\,000$ Nm/hr

Model OEMXT 2.0M x 2 is adequate.

EXAMPLE 8:
Free Moving Load Down an Inclined Plane



STEP 1: Application Data

(M) Mass = 250 kg
(H) Height = 0,2 m
(α) Angle of incline = 30°
(C) Cycles/Hr = 250

STEP 2: Calculate kinetic energy

$E_K = \mathbf{9,8} \times M \times H$
$E_K = \mathbf{9,8} \times 250 \times 0{,}2$
$E_K = 490$ Nm

Assume Model OEMXT 1.5M x 3 is adequate (Page 27).

STEP 3: Calculate work energy

$F_D = \mathbf{9,8} \times M \times \sin\alpha$
$F_D = \mathbf{9,8} \times 250 \times 0{,}5$
$F_D = 1\,225$ N
$E_W = F_D \times S$
$E_W = 1\,225 \times 0{,}075$
$E_W = 91{,}9$ Nm

STEP 4: Calculate total energy per cycle

$E_T = E_K + E_W$
$E_T = 490 + 91{,}9$
$E_T = 581{,}9$ Nm/c

STEP 5: Calculate total energy per hour

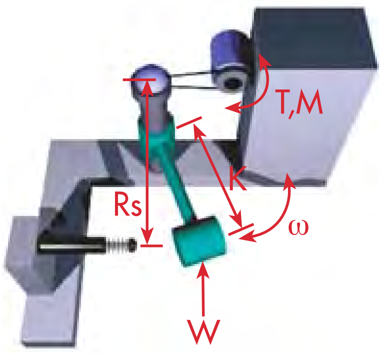
$E_TC = E_T \times C$
$E_TC = 581{,}9 \times 250$
$E_TC = 145\,475$ Nm/hr

STEP 6: Calculate impact velocity and confirm selection

$V = \sqrt{\mathbf{19,6} \times H}$
$V = \sqrt{\mathbf{19,6} \times 0{,}2} = 2{,}0$ m/s

Model OEMXT 1.5M x 3 is adequate.

EXAMPLE 9:
Horizontal Rotating Mass



STEP 1: Application Data

(M) Mass = 90 kg
(ω) Angular velocity = 1,5 rad/s
(T) Torque = 120 Nm
(K) Radius of gyration = 0,4 m
(R_S) Mounting radius = 0,5 m
(C) Cycles/Hr = 120

STEP 2: Calculate kinetic energy

$I = M \times K^2$
$I = 90 \times 0,4^2$
$I = 14,4 \text{ kgm}^2$
$E_K = \frac{I \times \omega^2}{2}$
$E_K = \frac{14,4 \times 1,5^2}{2}$
$E_K = 16,2 \text{ Nm}$

Assume Model STH 0.5M is adequate (Page 41).

STEP 3: Calculate work energy

$F_D = \frac{T}{R_S}$
$F_D = \frac{120}{0,5}$
$F_D = 240 \text{ N}$
$E_W = F_D \times S$
$E_W = 240 \times 0,013$
$E_W = 3 \text{ Nm}$

STEP 4: Calculate total energy per cycle

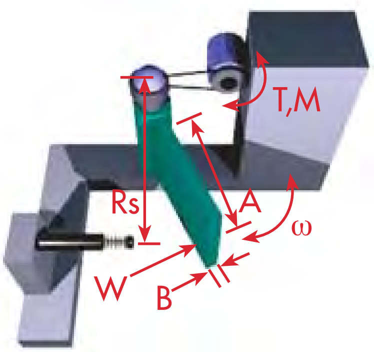
$E_T = E_K + E_W$
$E_T = 16,2 + 3$
$E_T = 19,2 \text{ Nm/c}$

STEP 5: Calculate total energy per hour

$E_TC = E_T \times C$
$E_TC = 19,2 \times 120$
$E_TC = 2\,304 \text{ Nm/hr}$

Model STH 0.5M is adequate.

EXAMPLE 10:
Horizontal Rotating Door



STEP 1: Application Data

(M) Mass = 25 kg
(ω) Angular velocity = 2,5 rad/s
(T) Torque = 10 Nm
(R_S) Mounting radius = 0,5 m
(A) Width = 1,0 m
(B) Thickness = 0,1 m
(C) Cycles/Hr = 250

STEP 2: Calculate kinetic energy

$K = 0,289 \times \sqrt{\mathbf{4} \times A^2 + B^2}$
$K = 0,289 \times \sqrt{\mathbf{4} \times 1,0^2 + 0,1^2}$
$K = 0,58 \text{ m}$
$I = M \times K^2$
$I = 25 \times 0,58^2$
$I = 8,4 \text{ kgm}^2$

$E_K = \frac{I \times \omega^2}{2}$
$E_K = \frac{8,4 \times 2,5^2}{2}$
$E_K = 26,3 \text{ Nm}$

Assume Model OEM .5M is adequate (Page 19).

STEP 3: Calculate work energy

$F_D = \frac{T}{R_S}$
$F_D = \frac{10}{0,5}$
$F_D = 20 \text{ N}$
$E_W = F_D \times S$
$E_W = 20 \times 0,025$
$E_W = 0,5 \text{ Nm}$

STEP 4: Calculate total energy per cycle

$E_T = E_K + E_W$
$E_T = 26,3 + 0,5$
$E_T = 26,8 \text{ Nm/c}$

STEP 5: Calculate total energy per hour

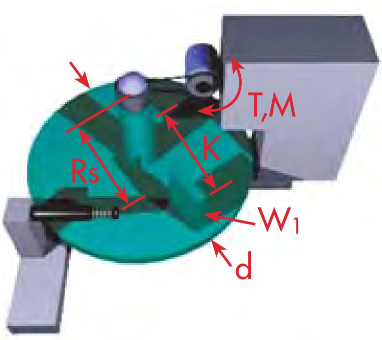
$E_TC = E_T \times C$
$E_TC = 26,8 \times 250$
$E_TC = 6\,700 \text{ Nm/hr}$

STEP 6: Calculate impact velocity and confirm selection

$V = R_S \times \omega$
$V = 0,5 \times 2,5$
$V = 1,25 \text{ m/s}$

Model OEM 0.5M is adequate.

EXAMPLE 11:
Horizontal Moving Load, Rotary Table Motor Driven with Additional Load Installed



STEP 1: Application Data

(M) Mass = 200 kg
(M_1) Installed load = 50 kg
Rotational speed = 10 RPM
(T) Torque = 250 Nm
Rotary table dia. = 0,5 m
(K_{Load}) Radius of gyration = 0,2 m
(R_S) Mounting radius = 0,225 m
(C) Cycles/Hr = 1

Step 2: Calculate kinetic energy

To convert RPM to rad/s, multiply by **0,1047**

$\omega = \text{RPM} \times \mathbf{0,1047}$
$\omega = 10 \times \mathbf{0,1047}$
$\omega = \mathbf{1,047} \text{ rad/s}$
$I = M \times K$

In this case, the mass moment of inertia of the table and the mass moment of inertia of the load on the table must be calculated.

$K_{Table} = \text{Table Radius} \times \mathbf{0,707}$
$K_{Table} = 0,25 \times \mathbf{0,707} = 0,176 \text{ m}$
$I_{Table} = M \times K^2_{Table}$
$I_{Table} = 200 \times 0,176^2$
$I_{Table} = 6,2 \text{ kgm}^2$
$I_{Load} = M_1 \times K^2_{Load}$
$I_{Load} = 50 \times (0,20)^2 = 2 \text{ kgm}^2$
$E_K = \frac{(I_{Table} + I_{Load}) \times \omega^2}{2}$
$E_K = \frac{(6,2 + 2) \times 1,047^2}{2}$
$E_K = 4,5 \text{ Nm}$

Assume model ECO 50M-4 is adequate (Page 47).

STEP 3: Calculate work energy

$F_D = \frac{T}{R_S} = \frac{250}{0,225} = 1\,111,1 \text{ N}$
$E_W = F_D \times S = 1\,111,1 \times 0,022$
$E_W = 24,4 \text{ Nm}$

STEP 4: Calculate total energy per cycle

$E_T = E_K + E_W$
$E_T = 4,5 + 24,4$
$E_T = 28,9 \text{ Nm/c}$

STEP 5: Calculate total energy per hour: not applicable, C=1

STEP 6: Calculate impact velocity and confirm selection

$V = R_S \times \omega$
$V = 0,225 \times 1,047$
$V = 0,24 \text{ m/s}$

From ECO Sizing Graph.
Model ECO 50M-4 is adequate.

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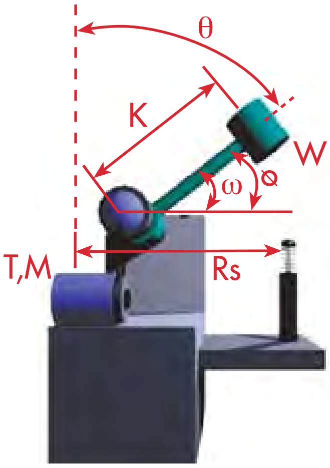
EXAMPLE 12:
Vertical Motor Driven Rotating Arm with Attached Load
CASE A–Load Aided by Gravity



STEP 1: Application Data
(M) Mass = 50 kg
(ω) Angular velocity = 2 rad/s
(T) Torque = 350 Nm
(Ø) Angle of rotation = 30°
(K_{Load}) Radius of gyration = 0,6 m
(R_S) Mounting radius = 0,4 m
(C) Cycles/Hr = 1

STEP 2: Calculate kinetic energy
$I = M \times K^2 = 50 \times 0{,}6^2$
$I = 18 \text{ kgm}^2$
$E_K = \frac{I \times \omega^2}{2}$
$E_K = \frac{18 \times 2^2}{2}$
$E_K = 36$ Nm

Assume Model OEM 1.0 is adequate (Page 21).

CASE A
STEP 3: Calculate work energy
$F_D = \frac{T + (\mathbf{9{,}8} \times M \times K \times \sin\theta)}{R_S}$
$F_D = \frac{350 + (\mathbf{9{,}8} \times 50 \times 0{,}6 \times 0{,}5)}{0{,}4}$
$F_D = 1\,242{,}5$ N
$E_W = F_D \times S$
$E_W = 1\,242{,}5 \times 0{,}025$
$E_W = 31{,}1$ N

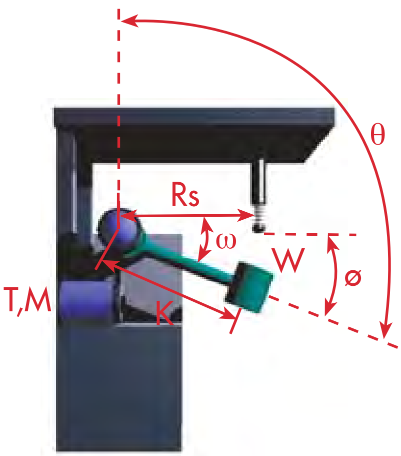
STEP 4: Calculate total energy per cycle
$E_T = E_K + E_W$
$E_T = 36 + 31{,}1$
$E_T = 67{,}1$ Nm/c

STEP 5: Calculate total energy per hour: not applicable, C=1

STEP 6: Calculate impact velocity and confirm selection.
$V = R_S \times \omega$
$V = 0{,}4 \times 2$
$V = 0{,}8$ m/s

Model LROEM 1.0M is adequate. Needed for higher calculated propelling force.

EXAMPLE 13:
Vertical Motor Driven Rotating Arm with Attached Load
CASE B–Load Opposing Gravity



STEP 1: Application Data
(M) Mass = 50 kg
(ω) Angular velocity = 2 rad/s
(T) Torque = 350 Nm
(Ø) Angle of rotation = 30°
(K_{Load}) Radius of gyration = 0,6 m
(R_S) Mounting radius = 0,4 m
(C) Cycles/Hr = 1

STEP 2: Calculate kinetic energy
$I = M \times K^2 = 50 \times 0{,}6^2$
$I = 18 \text{ kgm}^2$
$E_K = \frac{I \times \omega^2}{2}$
$E_K = \frac{18 \times 2^2}{2}$
$E_K = 36$ Nm

Assume Model OEM 1.0M is adequate (Page 21).

CASE B
STEP 3: Calculate work energy
$F_D = \frac{T - (\mathbf{9{,}8} \times M \times K \times \sin\theta)}{R_S}$
$F_D = \frac{350 - (\mathbf{9{,}8} \times 50 \times 0{,}6 \times 0{,}5)}{0{,}4}$
$F_D = 507{,}5$ N
$E_W = F_D \times S$
$E_W = 507{,}5 \times 0{,}025$
$E_W = 12{,}7$ Nm

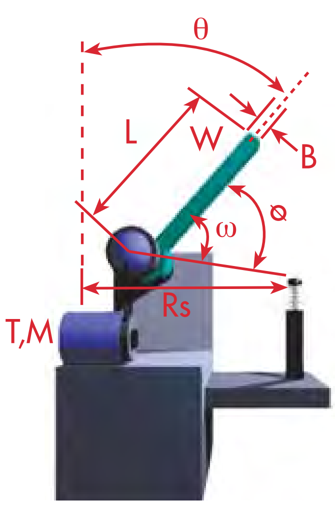
STEP 4: Calculate total energy per cycle
$E_T = E_K + E_W$
$E_T = 36 + 12{,}7$
$E_T = 48{,}7$ Nm/c

STEP 5: Calculate total energy per hour: not applicable, C=1

STEP 6: Calculate impact velocity and confirm selection
$V = R_S \times \omega$
$V = 0{,}4 \times 2$
$V = 0{,}8$ m/s

Model OEM 1.0M is adequate.

EXAMPLE 14:
Vertical Rotating Beam



STEP 1: Application Data
(M) Mass= 245 kg
(ω) Angular velocity = 3,5 rad/s
(T) Torque = 30 Nm
(θ) Starting point from true vertical = 20°
(Ø) Angle of rotation = 50°
(R_S) Mounting radius = 0,5 m
(B) Thickness = 0,06 m
(L) Length = 0,6 m
(C) Cycles/Hr = 1

STEP 2: Calculate kinetic energy
$K = \mathbf{0{,}289} \times \sqrt{\mathbf{4} \times L^2 + B^2}$
$K = \mathbf{0{,}289} \times \sqrt{\mathbf{4} \times 0{,}6^2 + 0{,}06^2}$
$K = 0{,}35$ m
$I = M \times K^2 = 245 \times 0{,}35^2$
$I = 30 \text{ kgm}^2$
$E_K = \frac{I \times \omega^2}{2} = \frac{30 \times 3{,}5^2}{2} = 184$ Nm

Assume Model OEM 1.5M x 2 is adequate (Page 27).

STEP 3:
$F_D = \frac{T + [\mathbf{9{,}8} \times M \times K \times \sin(\theta + Ø)]}{R_S}$
$F_D = \frac{30 + [\mathbf{9{,}8} \times 245 \times 0{,}35 \times \sin(20° + 50°)]}{0{,}5}$
$F_D = 1\,640$ N

$E_W = F_D \times S$
$E_W = 1\,640 \times 0{,}05$
$E_W = 82$ Nm

STEP 4: Calculate total energy per cycle
$E_T = E_K + E_W$
$E_T = 184 + 82$
$E_T = 266$ Nm/c

STEP 5: Calculate total energy per hour: not applicable, C=1

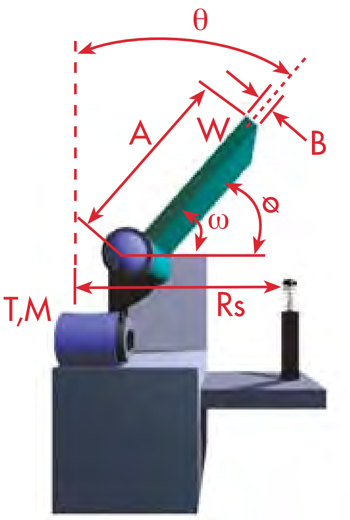
STEP 6: Calculate impact velocity and confirm selection
$V = R_S \times \omega$
$V = 0{,}5 \times 3{,}5$
$V = 1{,}75$ m/s

Model OEMXT 1.5M x 2 is adequate.

Shock Absorber Sizing Examples
Typical Shock Absorber Applications

Overview

EXAMPLE 15:
Vertical Rotating Lid



STEP 1: Application Data
(M) Mass = 910 kg
(ω) Angular velocity = 2 rad/s
(kW) Motor rating = 0,20 kW
(θ) Starting point from true vertical = 30°
(Ø) Angle of rotation = 60°
(R_S) Mounting radius = 0,8 m
(A) Width = 1,5 m
(B) Thickness = 0,03 m
(C) Cycle/Hr = 1

STEP 2: Calculate kinetic energy
$K = \mathbf{0{,}289} \times \sqrt{\mathbf{4} \times A^2 + B^2}$
$K = \mathbf{0{,}289} \times \sqrt{\mathbf{4} \times 1{,}50^2 + 0{,}03^2}$
$K = 0{,}87$ m

$I = M \times K^2 = 910 \times 0{,}87^2$
$I = 688{,}8$ kgm²
$E_K = \frac{I \times \omega^2}{2} = \frac{688{,}8 \times 2^2}{2}$
$E_K = 1\,377{,}6$ Nm
Assume Model OEM 3.0M x 2 is adequate (Page 21).

STEP 3: Calculate work energy
$T = \frac{\mathbf{3\,000} \times kW}{\omega}$
$T = \frac{\mathbf{3\,000} \times 0{,}20}{2} = 300$ Nm
$F_D = \frac{T + (\mathbf{9{,}8} \times M \times K \times \sin(\theta + Ø))}{R_S}$
$F_D = \frac{300 + (\mathbf{9{,}8} \times 910 \times 0{,}87 \times \sin(60° + 30°))}{0{,}8}$
$F_D = 10\,073$ N
$E_W = F_D \times S$
$E_W = 10\,073 \text{ N} \times 0{,}05$
$E_W = 503{,}7$ Nm

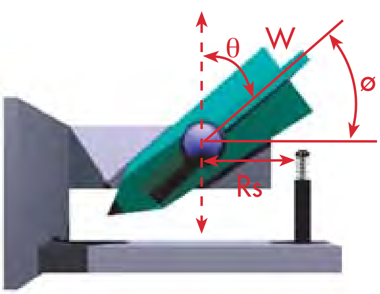
STEP 4: Calculate total energy per cycle
$E_T = E_K + E_W$
$E_T = 1\,377{,}6 + 503{,}7$
$E_T = 1\,881{,}3$ Nm/c

STEP 5: Calculate total energy per hour: not applicable, C=1

STEP 6: Calculate impact velocity and confirm selection
$V = R_S \times \omega$
$V = 0{,}8 \times 2$
$V = 1{,}6$ m/s

Model OEM 3.0M x 2 is adequate.

EXAMPLE 16:
Vertical Rotation with Known Intertia Aided by Gravity



STEP 1: Application Data
(M) Mass = 100 kg
(I) Known Intertia = 100 kgm²
(C/G) Center-of-Gravity = 305 mm
(θ) Starting point from true vertical = 60°
(Ø) Angle of rotation at impact = 30°
(R_S) Mounting radius = 254 mm
(C) Cycles/Hr = 1

STEP 2: Calculate kinetic energy
$H = C/G \times [\cos(\theta) - \cos(Ø + \theta)]$
$H = 0{,}305 \times [\cos(60°) - \cos(30° + 60°)]$
$E_K = \mathbf{9{,}8} \times M \times H$
$E_K = \mathbf{9{,}8} \times 100 \times 0{,}5$
$E_K = 149{,}5$ Nm

STEP 3: Calculate work energy
$F_D = (\mathbf{9{,}8} \times M \times C/G \times \sin(\theta + Ø))/R_S$
$F_D = (\mathbf{9{,}8} \times 100 \times 0{,}305 \times \sin(60° + 30°))/0{,}254$
$F_D = 1176{,}8$ N
$E_W = F_D \times S = 1176{,}8 \times 0{,}025 = 29{,}4$ Nm

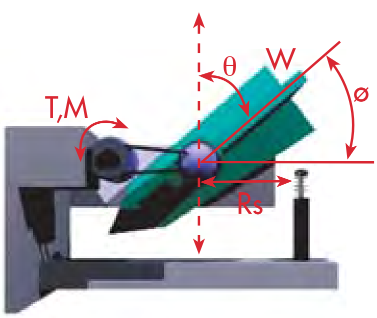
STEP 4: Calculate total energy per cycle
$E_T = E_K + E_W = 149{,}5 + 29{,}4$
$E_T = 178{,}9$ Nm/c

STEP 5: Calculate total energy per hour: not applicable, C=1
$E_TC = E_T \times C$
$E_TC = 178{,}9 \times 1$
$E_TC = 178{,}9$ Nm/hr

STEP 6: Calculate impact velocity and confirm selection
$\omega = \sqrt{(2 \times E_K)/I}$
$\omega = \sqrt{(2 \times 149{,}5)/100)} = 1{,}7$ rad/s
$V = R_S \times \omega = 0{,}254 \times 1{,}7 = 0{,}44$ m/s

Model OEM 1.15M x 1 is adequate (Page 24).

EXAMPLE 17:
Vertical Rotation with Known Intertia Aided by Gravity (w/Torque)



STEP 1: Application Data
(M) Mass = 100 kg
(ω) Angular Velocity = 2 rad/s
(T) Torque = 310 Nm
(I) Known Intertia = 100 kgm²
(C/G) Center-of-Gravity = 305 mm
(θ) Starting point from true vertical = 60°
(Ø) Angle of rotation at impact = 30°
(R_S) Mounting radius = 254 mm
(C) Cycles/Hr = 100

STEP 2: Calculate kinetic energy
$E_K = (I \times \omega^2)/2$
$E_K = (100 \times 2^2)/2$
$E_K = 200$ Nm

STEP 3: Calculate work energy
$F_D = [T + (\mathbf{9{,}8} \times M \times C/G \times \sin(\theta + Ø)]/R_S$
$F_D = [310 + (\mathbf{9{,}8} \times 100 \times 0{,}305 \times \sin(60° + 30°)]/0{,}254$
$F_D = 2\,397{,}2$ N
$E_W = F_D \times S = 2\,397 \times 0{,}025 = 59{,}9$ Nm

STEP 4: Calculate total energy per cycle
$E_T = E_K + E_W = 200 + 59{,}9$
$E_T = 259{,}9$ Nm/c

STEP 5: Calculate total energy per hour: not applicable, C=1
$E_TC = E_T \times C$
$E_TC = 259{,}9 \times 100$
$E_TC = 25\,990$ Nm/hr

STEP 6: Calculate impact velocity and confirm selection
$V = R_S \times \omega = 0{,}254 \times 2 = 0{,}51$ m/s

Model OEMXT 1.5M x 1 is adequate (Page 27).

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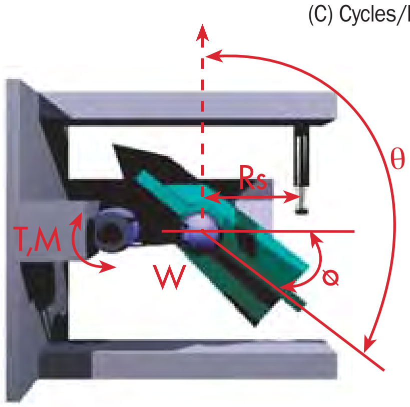
EXAMPLE 18:
Vertical Rotation with Known Intertia Opposing Gravity (w/Torque)

STEP 1: Application Data
(M) Mass = 100 kg
(ω) Angular Velocity = 2 rad/s
(T) Torque = 310 Nm
(I) Known Intertia = 100 kgm²
(C/G) Center-of-Gravity = 305 mm
(θ) Starting point from true vertical = 120°
(Ø) Angle of rotation at impact = 30°
(R_S) Mounting radius = 254 mm
(C) Cycles/Hr = 100



STEP 2: Calculate kinetic energy
$E_K = (I \times \omega^2)/2$
$E_K = (100x\ 2^2)/2$
$E_K = 200$ Nm

STEP 3: Calculate work energy
$F_D = [T - (\mathbf{9{,}8} \times M \times C/G \times \sin(\theta - Ø))]/R_S$
$F_D = [310 - (\mathbf{9{,}8} \times 100 \times 0{,}305 \times \sin(120° - 30°))]/0{,}254$
$F_D = 43{,}7$ N
$E_W = F_D \times S = 43{,}7 \times 0{,}025 = 1{,}1$ Nm

STEP 4: Calculate total energy per cycle
$E_T = E_K + E_W = 200 + 1{,}1$
$E_T = 201{,}1$ Nm/c

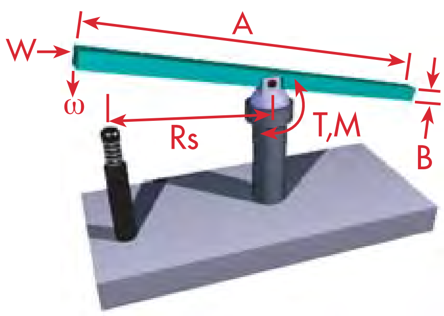
STEP 5: Calculate total energy per hour: not applicable, C = 1
$E_TC = E_T \times C$
$E_TC = 201{,}1 \times 100$
$E_TC = 20\,110$ Nm/hr

STEP 6: Calculate impact velocity and confirm selection
$V = R_S \times \omega = 0{,}254 \times 2 = 0{,}51$ m/s

Model OEMXT 1.5M x 1 is adequate (Page 27).

EXAMPLE 19:
Vertical Rotation Pinned at Center (w/Torque)

STEP 1: Application Data
(M) Mass = 100 kg
(ω) Angular velocity = 2 rad./s
(T) Torque = 310 Nm
(A) Length = 1,016 mm
(R_S) Mounting radius = 254 mm
(B) Thickness = 50,8 mm
(C) Cycles/Hr = 100



STEP 2: Calculate kinetic energy
$K = \mathbf{0{,}289} \times \sqrt{A^2 + B^2}$
$K = \mathbf{0{,}289} \times \sqrt{1{,}016^2 + 0{,}0508^2}$
$= 0{,}29$ m
$I = M \times K^2$
$I = 100 \times 0{,}29^2 = 8{,}6$ kgm²
$E_K = (I \times \omega^2)/2$
$E_K = (8{,}6 \times 2^2)/2$
$E_K = 17{,}2$ Nm

Assume Model OEM 1.0 is adequate (Page 21).

STEP 3: Calculate work energy
$F_D = T/R_S$
$F_D = 310/0{,}254$
$F_D = 1\,220{,}5$ N
$E_W = F_D \times S = 1\,220{,}5 \times 0{,}025$
$= 30{,}5$ Nm

STEP 4: Calculate total energy per cycle
$E_T = E_K + E_W = 17{,}2 + 30{,}5$
$E_T = 47{,}7$ Nm/c

STEP 5: Calculate total energy per hour
$E_TC = E_T \times C$
$E_TC = 47{,}7 \times 100$
$E_TC = 4\,770$ Nm/hr

STEP 6: Calculate impact velocity and confirm selection
$V = R_S \times \omega = 0{,}254 \times 2 = 0{,}51$ m/s

Model OEM 1.0M is adequate.

Shock Absorber Sizing Examples
Typical Shock Absorber and Crane Applications

Overview

Calculaions assume worst case scenario of 90% trolley weight over one rail.

Crane A		Per Buffer
Propelling Force Crane	kN	
Propelling Force Trolley	kN	
Weight of Crane (W_a)	t	
Weight of Trolley (W_{ta})	t	
Crane Velocity (V_a)	m/s	
Trolley Velocity (V_{ta})	m/s	

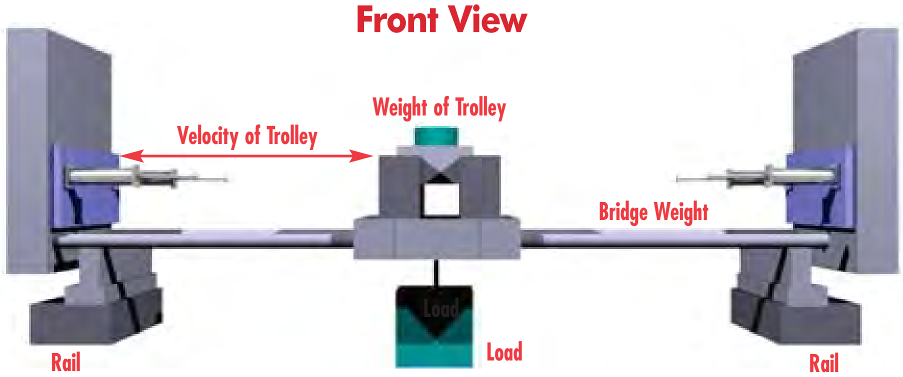
Crane B		Per Buffer
Propelling Force Crane	kN	
Propelling Force Trolley	kN	
Weight of Crane (W_a)	t	
Weight of Trolley (W_{ta})	t	
Crane Velocity (V_a)	m/s	
Trolley Velocity (V_{ta})	m/s	

Crane C		Per Buffer
Propelling Force Crane	kN	
Propelling Force Trolley	kN	
Weight of Crane (W_a)	t	
Weight of Trolley (W_{ta})	t	
Crane Velocity (V_a)	m/s	
Trolley Velocity (V_{ta})	m/s	

Please note:
Unless instructed otherwise, ITT Enidine will always calculate with:

- 100% velocity v, and
- 100% propelling force F_D

Front View



Plan Views

Application 1

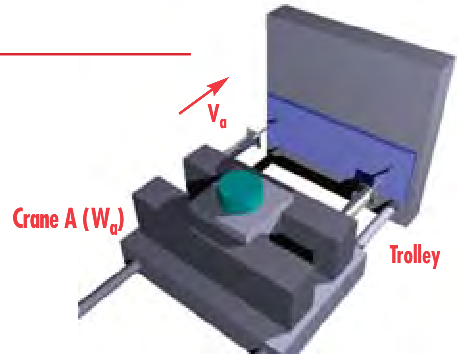
Crane A against Solid Stop

Velocity:

$V_r = V_a$

Impact weight per buffer:

$$W_d = \frac{Wa + (1{,}8)\ Wta}{\text{Total Number of Shocks}}$$



Application 2

Crane A against Crane B

Velocity:

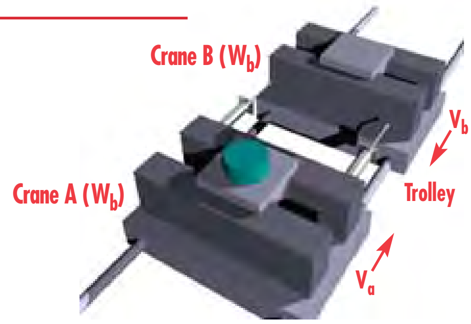
$V_r = V_a + V_b$

Impact weight per buffer:

$W_1 = Wa + (1{,}8)\ Wta$

$W_2 = Wb + (1{,}8)\ Wtb$

$$W_d = \frac{W_1\ W_2}{(W_1 + W_2)(\text{Total Number of Shocks})}$$



Application 3

Crane B against Crane C

Velocity:

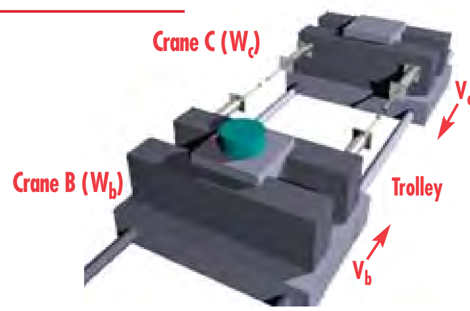
$$V_r = \frac{V_b + V_c}{2}$$

Impact weight per buffer:

$W_1 = Wb + (1{,}8)\ Wtb$

$W_2 = Wc + (1{,}8)\ Wtc$

$$W_d = \frac{2\ W_1\ W_2}{(W_1 + W_2)(\text{Number of Shocks Per Rail})}$$



Application 4

Crane C against Solid Stop with Buffer

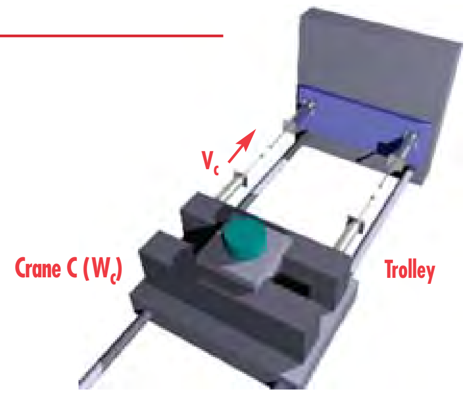
Velocity:

$$V_r = \frac{V_c}{2}$$

Impact weight per buffer:

$W_1 = W_c + 1{,}8\ (W_{tc})$

$$W_d = \frac{2\ W_1}{\text{Number of Shocks Per Rail}}$$



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Overview

Please note that this example is not based on any particular standard. The slung load can swing freely, and is therefore not taken into account in the calculation.

Calculation Example for Harbor Cranes as Application 1

Given Values

Total Weight of Bridge:	**380 t**
Weight of Trolley:	**45 t**
Crane Velocity:	**1,5 m/s**
Required Stroke:	**600 mm**
Trolley Velocity:	**4,0 m/s**
Required Stroke:	**1 000 m**

Determination of the Maximum Impact Mass W_d per Buffer

$$W_d = \frac{Wa + 1{,}8\ W{+}a}{\text{Total Number of Shocks}}$$

$$W_d = \frac{380\ t + (1{,}8)45\ t}{2}$$

$$\mathbf{W_d = 230.5\ t}$$

Determine Size of Shock Absorber for Crane

$$E_K = \frac{W_d}{2} \bullet V_r^2$$

$$E_K = \frac{230.5}{2} \bullet (1{,}5\ m/s)^2$$

$$\mathbf{E_K = 259\ kN}$$

$V_r = V_A$ (Application 1)

E_K = Kinetic Energy

η = Efficiency

Selecting for required 600mm stroke:
HD 5.0 x 24, maximum shock force ca. 460 kN = $F_s = \frac{E_K}{s \bullet \eta}$

Determine Size of Shock Absorber for Trolley

M_D = Trolley Mass per Shock Absorber

$$M_D = \frac{45\ t}{2}$$

$$\mathbf{M_D = 22{,}5\ t}$$

$V_r = V_A$ Application 1

$$E_K = \frac{M_D}{2} \bullet V_r^2$$

$$E_K = \frac{22{,}5\ t}{2} \bullet (4\ m/s)^2$$

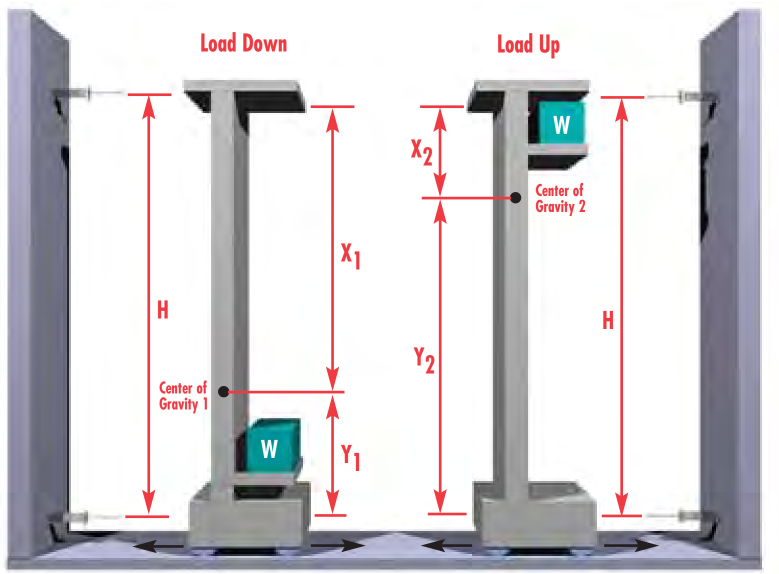
$$\mathbf{E_K = 180\ kNm}$$

Selecting for required 1 000 mm stroke:
HDN 4.0 x 40, maximum shock force ca. 212 kN = $F_s = \frac{E_K}{s \bullet \eta}$

Shock Absorber Sizing Examples
Typical Shock Absorber and Crane Applications

Overview

Application 1	Value
Buffer Distance H	m
Distance X_1	m
Distance Y_1	m
Distance X_2	m
Distance Y_2	m
Total Weight	t
$W_{max\ d}$	t
$W_{min\ d}$	t
$W_{max\ u}$	t
$W_{min\ u}$	t



Calculation Example Stacker Cranes

Please note that this example shows how to calculate the maximum impact weight on the upper and lower shock absorbers for a stacker crane.

Given Values

Distance Between Buffers:	H = 20 m
Distance to C of G1 - Upper:	X_1 = 15 m
Distance to C of G1 - Lower:	Y_1 = 5 m
Distance to C of G2 - Upper:	X_2 = 7 m
Distance to C of G1 - Lower:	Y_2 = 13 m
Total Weight:	W = 20 t

Calculation for Lower Shock Absorbers

$$W_{max\ d} = \frac{X_1}{H} \bullet W \qquad W_{max\ d} = \frac{X_2}{H} \bullet W$$

$$W_{max\ d} = \frac{15\ m}{20\ m} \bullet 20\ t \qquad W_{max\ d} = \frac{7\ m}{20\ m} \bullet 20\ t$$

$$W_{max\ d} = 15\ t \qquad W_{max\ d} = 7\ t$$

Calculation for Upper Shock Absorbers

$$W_{max\ d} = \frac{Y_1}{H} \bullet W \qquad W_{max\ d} = \frac{Y_2}{H} \bullet W$$

$$W_{max\ d} = \frac{5\ m}{20\ m} \bullet 20\ t \qquad W_{max\ d} = \frac{13\ m}{20\ m} \bullet 20\ t$$

$$W_{max\ d} = 5\ t \qquad W_{max\ d} = 13\ t$$

Shock Absorber Selection

Using the value for W_{max} obtained above, the kinetic energy can be calculated, and a shock absorber selected.

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