FABREEKA®
VIBRATION & SHOCK CONTROL

Fabreeka® Pads

Reducing structure-borne noise & Impact shock and vibration

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Fabreeka® pads are comprised of organic materials, and properties may vary from lot to lot. All technical values contained in this literature are averages and can vary depending upon test procedures. Please consult Fabreeka's Engineering Department for design assistance at 1-800-322-7352 or 781-341-3655.

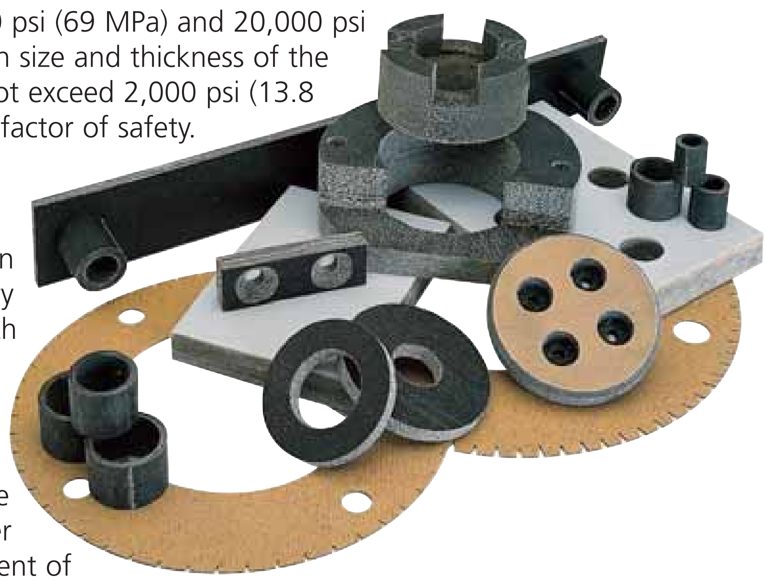
Fabreeka meets the following specifications:

Military:	MIL-C-882
Military Environmental:	MIL-E-5272A
D.O.T. Federal Administration:	Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (1985). FP85 paragraph 555.17, page 378, Preformed Fabric Pads and page 506, bedding of masonry plates in FP96.
AASHTO:	Standard Specifications for Highway Bridges. Preformed Fabric Pads: 16th Edition - 18.10.2 17th Edition - 18.4.9.1 2nd ED.LRFD - 18.10.2
PCI:	Prestressed Concrete Design Handbook 7th Edition (2010) Part 6, paragraph 6.10.3, Bearing Pad.

Fabreeka® resilient laminated fabric pad is a scientifically designed and manufactured material composed of layers of tightly twisted, closely woven lightweight duck. Each layer is impregnated with an elastomeric compound containing mold and mildew inhibiting agents. The properties of Fabreeka are exceptionally suited for the reduction of impact shock, vibration and structure-borne noise.

Strength in Compression

Fabreeka will withstand loads between 10,000 psi (69 MPa) and 20,000 psi (138 MPa) before breakdown, depending upon size and thickness of the pad. In general, compressive stresses should not exceed 2,000 psi (13.8 MPa) for long life, freedom from set and high factor of safety.



Compression

Fabreeka is compressible due to its composition and does not depend on flow to give necessary deflection. It substantially retains original length and width under compression and impact.

Set and Creep

One of the great advantages of Fabreeka is the fact that increased deflection due to creep over long periods of time is limited to about 5 percent of original thickness. When stresses are removed, permanent set of Fabreeka is also limited to about 5 percent of original thickness. This explains the continued high isolating efficiency of Fabreeka through long periods of continuous hard service.

Density - 74 lbs/ft^3 (1185 Kg/m^3)

Compressive Modulus

Fabreeka's load-deflection curve is nonlinear, therefore its modulus varies with load and is determined by:

$$M = 1.5 \times \frac{\text{stress}}{\text{strain}}$$

It approaches a maximum of 23,000 psi (158 MPa) at loads up to 2,000 psi (13.8 MPa).

As with compressive modulus, Fabreeka's static spring rate varies with loading. The formula is:

$$K = M \times \frac{A_f}{T_f}$$

or

$$K = 1.5 \times \frac{\text{Force}}{\text{Deflection}}$$

Damping

Fabreeka has a high damping value (damping constant is 0.14). Its ratio of successive amplitudes (2 to 1) is about 4 times that of natural rubber and 100 times that of steel. The log decrement is 0.69. Fabreeka's high damping is attributed to its large energy loss per cycle (Hysteresis) 25% to 45%.

Hardness and Stability

The Shore A Durometer hardness of Fabreeka is very high. This combined with a limited compressibility affords a greater degree of stability than is found in other types of vibration isolators.

Electrical Insulation

Fabreeka has a dielectric strength of 12,500 volts (210 volts/mil) and a resistivity of 8.5 x 10^9 ohm-cm. (Insulating material classification requires a resistivity greater than 10^5 ohm-cm.) Natural rubber has a resistivity value of 10^{15} ohm-cm. Dielectric Constant is 9.34 with a Power Factor of 0.201 and a Loss Index of 1.881. All the above values are for Fabreeka at standard room conditions of 73°F (23°C) and 50% relative humidity.

Service Life

The unusual strength of Fabreeka and its ability to withstand conditions of service commonly encountered both in and out of doors insures long life and constant efficient performance.

Fabrication

Fabreeka is furnished in the form of pads, washers, bushings and special molded shapes in accordance with customers' specifications and drawings. Special units with steel or plastic bonded to Fabreeka are also available.

Tolerances:

	English	Metric
Pad Length/Width	±1/16"	1.6 mm
Pad Thickness (avg)	±5%	5%
Washers OD/ID	±1/16"	1.6 mm
Bushings OD/ID	±1/32"	0.8 mm
Bushing Length	±1/32"	0.8 mm

Resistance to Water, Oil and Heat

Fabreeka is impervious to most oils and is resistant to the effects of steam, water, mildew and brine. Continuous temperature exposure limits for long life are 200°F (95°C) maximum and -65°F (-55°C) minimum.

Sizes

Fabreeka is manufactured in nominal thicknesses of:

English	Metric
1/16"	1.6 mm
3/32"	2.4 mm
1/8"	3.2 mm
5/32"	4.0 mm
3/16"	4.8 mm
15/64"	6.0 mm
9/32"	7.0 mm
11/32"	8.8 mm
1/2"	12.7 mm
5/8"	16.0 mm
3/4"	19.0 mm
1"	25.4 mm

Other thicknesses are available by simply combining and bonding the above standard thicknesses.

Thicknesses shown are nominal and tolerances average. Please contact Fabreeka International for actual thickness and tolerance values.

How Fabreeka Functions in Absorbing Impact Shock

Introduction

Impact shock and vibration problems encountered in industry, with their resulting losses in efficiency, repair costs and human discomfort, have been serious in the past and are intensified with the advent of heavier impact machinery and high speed machine tools.

Combining more than 65 years of field experience in virtually all phases of industry with sound engineering principles and knowledge of its product, Fabreeka International is well equipped to analyze these problems and make recommendations. This topic briefly illustrates the action and effectiveness of Fabreeka in reducing the transmission of impact shock.

Theory of Shock Isolation

A machine which transmits impact to its foundation initiates disturbances of varying intensities according to the work it performs. To illustrate the theory of impact shock reduction, consider such a machine (forging hammer, punch press, etc.) mounted rigidly on its foundation, a condition of maximum transmission of impact shock into the surrounding ground and structures. The ensuing disturbances are often so pronounced as to prohibit proper operation of adjacent equipment, in addition to reducing the operating life of the machine itself.

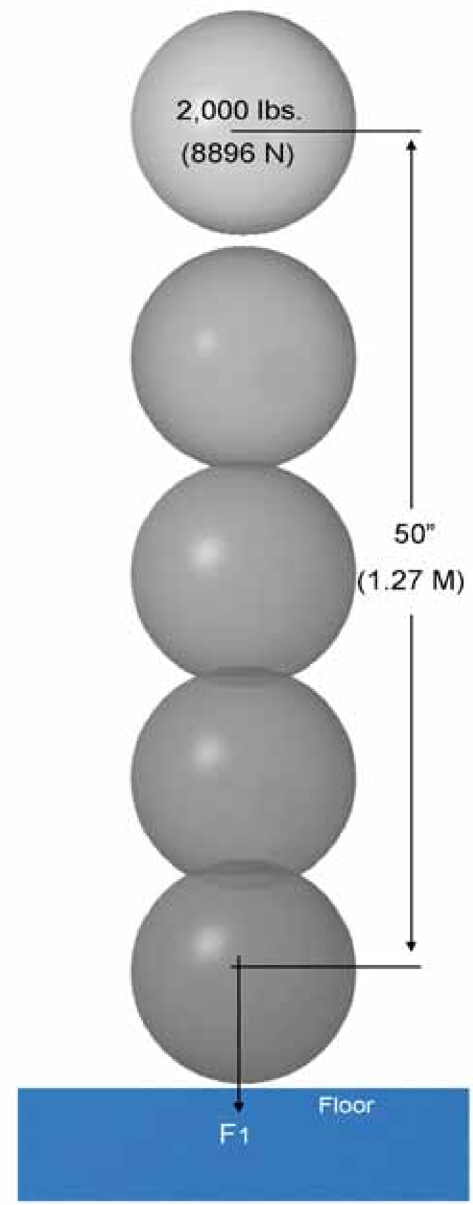


Figure 1A - Direct Impact on Floor

A simple example of an impact shock condition is a rigid object of given weight being dropped through a given vertical distance onto a floor. See Figure 1A. The maximum impact force that would be transmitted into the floor depends upon the deflection in the floor necessary to bring the object to rest. The smaller the deflection in the floor, the larger will be the maximum impact force (if the given weight and vertical drop are kept constant).

In order to determine this impact force, the kinetic energy of the object the instant before it contacts the floor must be calculated. This kinetic energy is equal to the weight of the object multiplied by the vertical distance through which it falls. The floor must absorb this kinetic energy in bringing the object to rest after impact.

For example:

Object Weight = 2000 lbs. (8896 N)
Vertical Falling Distance = 50 in. (1.27 m)
Kinetic Energy Developed = KE

ENGLISH	METRIC
KE = 2000 lbs. × 50 in.	KE = 8896 N × 1.27 m
KE = 100,000 in-lbs.	KE = 11 300 joules

Now assume the floor is a normally rigid concrete structure which will deflect 1/64" (0.0004 meters) before the object is brought to rest. We must analyze the load-deflection curve of the floor to determine the maximum impact force (F_1) transmitted.

It can safely be assumed the curve will be a straight line. In other words, any load (force) on the floor will be a linear function of the resulting deflection in the floor. See Figure 1B.

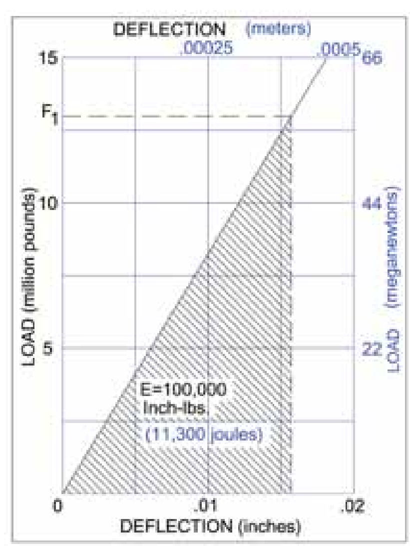


Figure 1B - Floor-Load vs. Deflection

The crosshatched area beneath the floor's load-deflection curve in Figure 1B represents the kinetic energy absorbed by the floor in bringing the object to rest. Since this area is a simple triangle, the relationship between (F_1) impact force transmitted, floor deflection and kinetic energy developed-and-absorbed is:

$$KE = \text{Curve Area} = \text{Area of a triangle}$$
$$KE = 1/2 \times F_1 \times \text{Deflection}$$

F_1 can be calculated as follows:

$$F_1 = \frac{2 \times KE}{Deflection}$$

ENGLISH	METRIC
$F_1 = \frac{2 \times 100{,}000}{1/64}$	$F_1 = \frac{2 \times 11\,300}{0.000397}$
$F_1 = 2 \times 100{,}000 \times 64$	$F_1 = 2 \times 11\,300 \times 2\,519$
$F_1 = 12{,}800{,}000$ lbs.	$F_1 = 56\,936\,960$ N

This means that when the object strikes the floor, the impact force transmitted into the floor builds up from a value of 0 to a maximum value of 12.8 x 10^6 lbs (56.94 x 10^6 newtons [N]) as the floor simultaneously deflects from 0 to 1/64" (0.0004 m) in absorbing the kinetic energy of the falling object.

Let's assume this magnitude of force is objectionable and must be reduced by 75 percent. To bring about such a drastic reduction, a Fabreeka pad will be placed on top of the floor to take the full impact of the falling object and absorb most of the kinetic energy. The amount of energy remaining for the floor to absorb will be what it takes to build up a maximum impact force of 25 percent of its previous value without the Fabreeka pad. In addition, the floor's deflection is greatly reduced.

$$F_2 = 0.25 \times F_1$$

ENGLISH	METRIC
$F_2 = 0.25 \times 12{,}800{,}000$	$F_2 = 0.25 \times 56\,936\,960$
$F_2 = 3{,}200{,}000$ lbs.	$F_2 = 14\,234\,240$ N

See Figure 2A, B & C

Note the crosshatched areas for the floor (E_S) in Figure 2B and Fabreeka pad (E_f) in Figure 2C, each representing the portion of the initial kinetic energy it absorbs.

It is evident that a state of equilibrium must exist between the forces developed in the floor and the Fabreeka pad as they absorb the kinetic energy of the falling object. This force is F_2 or 3,200,000 lbs (14.2 x 10^6 N).

We must now calculate what portion of the kinetic energy each absorbs; i.e. floor and Fabreeka pad respectively:

Floor:

$$E_S = \tfrac{1}{2} \times F_2 \times D_S$$

Where:

D_S = Floor deflection at 3,200,000 lbs. (14.2 × 10^6 N)

Since it is known that a load of 12.8 x 10^6 lbs (56.94 x 10^6 N) produces a deflection of 1/64" (0.0004 m) in the floor and the slope of the floor's load-deflection curve is constant, then by proportion we can calculate D_S as follows:

ENGLISH	METRIC
$\frac{12{,}800{,}000}{1/64} = \frac{3{,}200{,}000}{D_S}$	$\frac{56\,939\,960}{0.0004} = \frac{14\,234\,240}{D_S}$
$D_S = \frac{3{,}200{,}000}{12{,}800{,}000 \times 64}$	$D_S = \frac{14\,234\,240 \times 0.0004}{56\,936\,960}$
$D_S = 0.0039"$	$D_S = 0.0001$ m (0.10 mm)

Knowing (D_S), we can now compute E_S:

$E_S = \tfrac{1}{2} \times 3{,}200{,}000 \times D_S$	$E_S = \tfrac{1}{2} \times 14\,234\,240 \times D_S$
$E_S = 1{,}600{,}000 \times 0.0039$	$E_S = 7\,117\,120 \times 0.0001$
$E_S = 6250$ in-lbs.	$E_S = 712$ joules

Remembering:

$$KE = E_S + E_f$$

We can now find what portion of the original KE the Fabreeka pad absorbs.

FABREEKA

$$E_f = KE - E_S$$

ENGLISH	METRIC
$E_f = 100{,}000 - 6{,}250$	$E_f = 11\,300 - 712$
$E_f = 93{,}750$ in-lbs.	$E_f = 10\,588$ joules

Note: Fabreeka absorbs 93.75% of KE, while the floor only absorbs 6.25%.

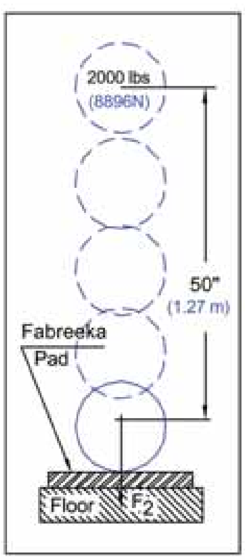


Figure 2A - With Fabreeka Isolator

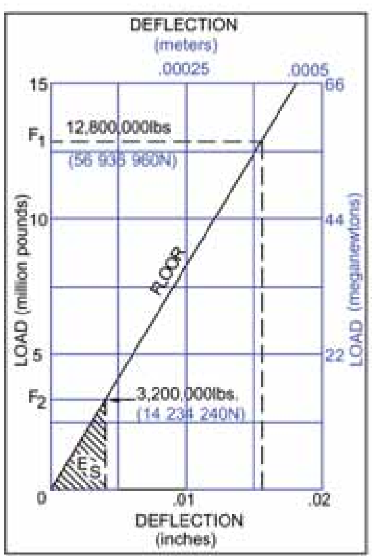


Figure 2B - Floor-Load vs. Deflection

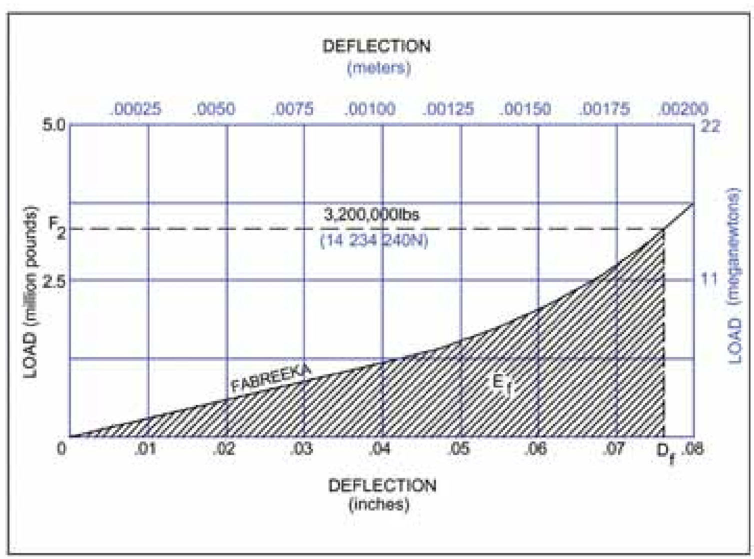


Figure 2C - Fabreeka Isolator-Load vs. Deflection

The next step is to determine the area and thickness of the Fabreeka pad to satisfy the established conditions.

Fabreeka has a safe working stress of up to 2,000 psi (13.9 MPa) if impacts are infrequent. Conversely, if impacts occur frequently (one per second), stress is limited to 500 psi (3.5 MPa). However, there is a safety factor of at least 5 to 1 because Fabreeka's compressive stress is in excess of 10,000 psi (69 MPa). In this example, we will assume the impacts are relatively frequent and will therefore limit the working stress to 1,000 psi (6.9 MPa). The minimum area (A_f) therefore is:

$$F_2 = \text{Working Stress} \times A_f$$

$$A_f = \frac{F_2}{\text{Working Stress}}$$

ENGLISH	METRIC
$A_f = \frac{3{,}200{,}000}{1000}$	$A_f = \frac{14\,234\,240}{6.9 \times 10^6}$
$A_f = 3200\ \text{in}^2$	$A_f = 2.063\ \text{m}^2$

We must now find the mathematical relationship between the stress developed in Fabreeka as a result of absorbing the kinetic energy. This relationship is derived from Fabreeka's stress vs. deflection curve. For convenience, we have plotted stress vs. deflection in percentage of original thickness. (See Figure 3.) This then allows us to determine deflection for any thickness of Fabreeka. The area under this curve gives us the energy stored per unit volume of Fabreeka having the following units:

$$\text{Curve Area Units} = F/A_f \times 100 \left(\frac{D_f}{T_f}\right)$$

Where:

A_f = Area of FABREEKA
T_f = Original thickness of FABREEKA
F = Force on FABREEKA
D_f = Deflection of FABREEKA

ENGLISH	METRIC
Curve Area Unit = C A U	Curve Area Unit = C A U
$\text{C A U} = \frac{\text{lbs}}{\text{in}^2} \times 100 \frac{\text{inches}}{\text{inch}}$	$\text{C A U} = \frac{\text{N}}{\text{m}^2} \times 100 \frac{\text{meters}}{\text{meter}}$
$\text{C A U} = 100 \times \frac{\text{in-lbs}}{\text{in}^3}$	$\text{C A U} = 100 \times \frac{\text{meter-N}}{\text{m}^3}$
$\frac{\text{C A U}}{100} = \frac{\text{in-lbs}}{\text{in}^3}$	$\frac{\text{C A U}}{100} = \text{joules}$
	Note: $\frac{\text{meter-N}}{\text{m}^3} = \text{joules}$

The area under the stress vs. strain curve has been determined mathematically and a new curve plotted relating stress vs. stored energy per unit volume of Fabreeka. (See Figure 4.)

We can now use Figure 4 to find the required thickness of the Fabreeka pad at a stress of 1,000 psi (6.9 MPa):

ENGLISH	METRIC
$\frac{E_f}{A_f \times T_f} = 36 \frac{\text{in-lbs}}{\text{in}^3}$	$\frac{E_f}{A_f \times T_f} = 24.84 \times 10^4\ \text{joules}$
$T_f = \frac{E_f}{36 \times A_f}$	$T_f = \frac{E_f}{24.84 \times 10^4 \times A_f}$
$T_f = \frac{93{,}750\ \text{in-lbs}}{36 \times 3{,}200}$	$T_f = \frac{10\,588\ \text{joules}}{24.84 \times 10^4 \times 2.063}$
$T_f = 0.814''$ (approx. 13/16")	$T_f = 0.02066$ m (approx. 21 mm)

The following Fabreeka pad is required to reduce the impact force to the floor by 75%.

ENGLISH	METRIC
$3200\ \text{in}^2 \times \frac{13''}{16}$ thick	$2.063\ \text{m}^2 \times 21$ mm thick

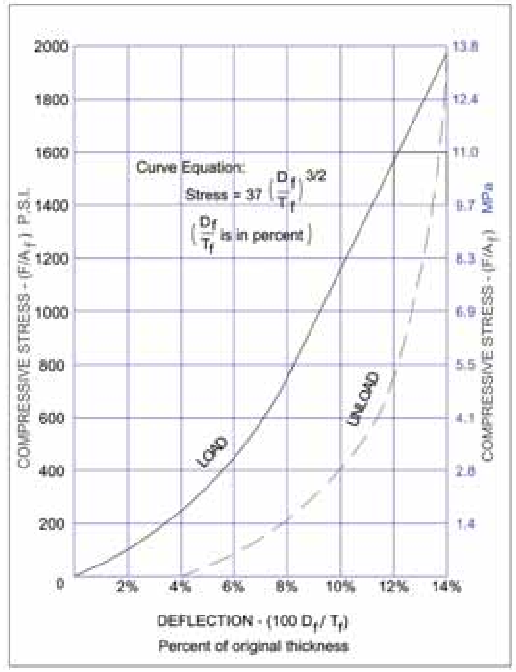


Figure 3 - Stress vs. Deflection for Fabreeka

AVERAGE DEFLECTION

Thickness in Inches and (mm)

Load PSI	14 ply 15/64" (6mm)	17 ply 9/32" (7mm)	21 ply 11/32" (9mm)	31 ply 1/2" (13mm)	39 ply 5/8" (16mm)	48 ply 3/4" (19mm)	64 ply 1" (25mm)	Load MPa
50	.003" (.08mm)	.004" (.10mm)	.005" (.13mm)	.006" (.15mm)	.008" (.20mm)	.010" (.25mm)	.013" (.33mm)	0.35
100	.005" (.13mm)	.006" (.15mm)	.007" (.18mm)	.010" (.25mm)	.013" (.33mm)	.015" (.38mm)	.021" (.53mm)	0.69
200	.008" (.20mm)	.009" (.23mm)	.012" (.30mm)	.017" (.43mm)	.021" (.53mm)	.025" (.64mm)	.034" (.86mm)	1.40
300	.010" (.25mm)	.012" (.36mm)	.015" (.38mm)	.022" (.56mm)	.028" (.71mm)	.033" (.84mm)	.044" (1.12mm)	2.10
400	.012" (.30mm)	.015" (.38mm)	.018" (.46mm)	.027" (.69mm)	.033" (.84mm)	.040" (1.02mm)	.053" (1.35mm)	2.80
500	.014" (.36mm)	.017" (.43mm)	.021" (.53mm)	.031" (.79mm)	.038" (.97mm)	.046" (1.17mm)	.061" (1.55mm)	3.40
600	.016" (.41mm)	.019" (.48mm)	.024" (.61mm)	.034" (.86mm)	.043" (1.10mm)	.052" (1.32mm)	.069" (1.75mm)	4.10
700	.018" (.46mm)	.021" (.53mm)	.026" (.66mm)	.038" (.97mm)	.048" (1.22mm)	.057" (1.45mm)	.076" (1.93mm)	4.80
800	.019" (.48mm)	.023" (.58mm)	.028" (.71mm)	.041" (1.05mm)	.051" (1.30mm)	.062" (1.57mm)	.082" (2.08mm)	5.50
900	.020" (.51mm)	.024" (.61mm)	.030" (.76mm)	.044" (1.12mm)	.054" (1.37mm)	.066" (1.68mm)	.087" (2.21mm)	6.20
1000	.022" (.56mm)	.026" (.66mm)	.032" (.81mm)	.047" (1.19mm)	.058" (1.47mm)	.070" (1.78mm)	.093" (2.36mm)	6.90
1200	.024" (.61mm)	.029" (.74mm)	.036" (.91mm)	.052" (1.32mm)	.065" (1.65mm)	.078" (1.98mm)	.104" (2.64mm)	8.30
1400	.027" (.69mm)	.032" (.81mm)	.039" (.99mm)	.057" (1.45mm)	.071" (1.80mm)	.085" (2.16mm)	.113" (2.87mm)	9.70
1600	.029" (.74mm)	.035" (.89mm)	.042" (1.07mm)	.062" (1.57mm)	.077" (1.96mm)	.092" (2.34mm)	.123" (3.12mm)	11.00
1800	.031" (.79mm)	.037" (.94mm)	.045" (1.14mm)	.066" (1.68mm)	.083" (2.11mm)	.100" (2.54mm)	.132" (3.35mm)	12.40
2000	.033" (.84mm)	.039" (.99mm)	.048" (1.22mm)	.070" (1.78mm)	.088" (2.23mm)	.105" (2.67mm)	.140" (3.56mm)	13.80

Note: 1 MPa = 1 MN/m^2 = 1N/mm^2 = 10 Kg/cm^2

A purely mathematical solution instead of the graphical solution is also possible. The equation for the curve in Figure 4 can be used as follows:

$$F/A_f = \left(\text{Constant} \times \frac{E_f}{A_f \times T_f}\right)^{3/5}$$

ENGLISH

$$F/A_f = \left(2693 \times \frac{E_f}{A_f \times T_f}\right)^{3/5}$$

METRIC

$$F/A_f = \left(985\,000 \times \frac{E_f}{A_f \times T_f}\right)^{3/5}$$

Rearranging terms and solving for T_f:

$$T_f = \frac{2693 \times E_f}{A_f \times (F/A_f)^{5/3}} \qquad T_f = \frac{985\,000 \times E_f}{A_f \times (F/A_f)^{5/3}}$$

$$T_f = \frac{2693 \times 93{,}750}{3200 \times (1000)^{5/3}} \qquad T_f = \frac{985\,000 \times 10\,588}{2.063 \times (6.9 \times 10^6)^{5/3}}$$

$$T_f = 0.79'' \qquad T_f = 0.0202 \text{ m}$$

Note: The graphical and mathematical answers will be within 5% of each other.

Solutions for Difficult Impact Shock Problems

The impact problem just analyzed is a simple one, but the energy theory used can also be applied to solve the more difficult problems encountered in industry. For example, in the Steel Mill, Fabreeka components have been designed and used in bumper assemblies for stopping the motion of hot ingots or to cushion the manipulating tables from the impacts of flipped ingots. In the Forge Shop, the same energy theory is used in conjunction with other basic engineering laws to design Fabreeka Anvil Pads for Forging Hammers.

In addition to cushioning the initial impacts, Fabreeka offers high inherent damping. This means that a smaller portion of the absorbed energy will be expelled in the form of rebound. Dynamic loading tests performed on a Roelig testing machine indicate the range of energy loss per cycle is 25 to 45 percent of the total mechanical energy stored by Fabreeka.

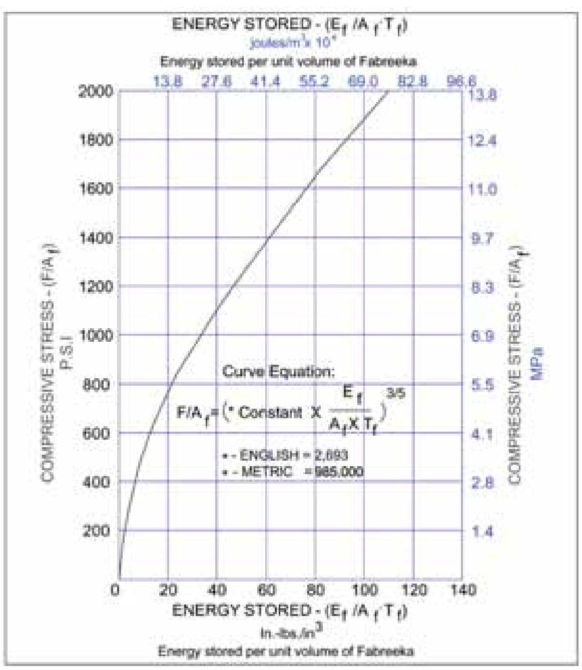


Figure 4 - Mechanical Energy Stored Per Unit Volume vs. Resultant Compressive Stress

An impact machine not only produces impact shock, but the impacts themselves produce internal vibrations that can be quite harmful if not quickly damped out. Fabreeka has this ability due to its high damping or internal hysteresis.

The Fabreeka pad performs a double function, that of impact shock (discussed in this section) and vibration isolation, which is discussed in the next section.

Case Study of Impact Shock - Bumper Application

This particular case study revolves around a steel mill requiring a bumper to cushion a bundle of steel plates being conveyed. The following calculations would apply to any type of bumper application.

Given:
Steel Plate Bundle Weight = 15,000 lbs (6803 Kg)
Bundle Strikes Bumper at = 120 ft/minute (36.6 m/minute)
Bumper Area Available = 9" x 9" (0.229 m x 0.229 m)

Step 1: Limit stress buildup in Fabreeka to 1,500 psi (10.35 MPa).

$$KE = \tfrac{1}{2} MV^2$$

ENGLISH

$$KE = \frac{1}{2} \times \frac{15{,}000 \text{ lbs}}{32.2 \frac{\text{ft.}}{\text{sec}^2}} \times \left(\frac{120}{60}\frac{\text{ft}}{\text{sec}}\right)^2$$

$$KE = 932 \text{ ft-lbs}$$

$$KE = 932 \times 12 = 11{,}180 \text{ in-lbs}$$

METRIC

$$KE = \frac{1}{2} \times 6803 \text{ kg} \times \left(\frac{36.6}{60}\frac{\text{m}}{\text{sec}}\right)^2$$

$$KE = 1265 \text{ joules}$$

Stress vs Energy Stored per Unit Volume of Fabreeka at 1500 psi (10.35 MPa) (Figure 4)

$$KE/\text{Volume} = 70 \frac{\text{in-lbs}}{\text{in}^3} \qquad KE/\text{Volume} = 48.3 \times 10^4 \frac{\text{joules}}{\text{m}^3}$$

Step 2: Divide the KE/Unit Volume into the total KE to get the Fabreeka pad volume required:

ENGLISH

$$\frac{11{,}180 \text{ in-lbs}}{70 \frac{\text{in-lbs}}{\text{in}^3}} = 160 \text{ in}^3$$

METRIC

$$\frac{1265 \text{ joules}}{48.3 \times 10^4 \frac{\text{joules}}{\text{m}^3}} = 0.0026 \text{ m}^3$$

Step 3: Divide the volume by the bumper area to get the proper Fabreeka pad thickness.

$$\text{Bumper Area} = 81 \text{ in}^2 \qquad \text{Bumper Area} = 0.052 \text{ m}^2$$

$$T_f = \frac{160 \text{ in}^3}{81 \text{ in}^2} = 2'' \text{ thick} \qquad T_f = \frac{0.0026 \text{ m}^3}{0.052 \text{ m}^2} = 0.05 \text{ m}$$

Referring to Figure 3

2" thick @ 1500 psi	50 mm @ 10.35 MPa
Deflection = 0.236" (approx. ¼")	Deflection = 6 mm

Hence the plate bundle is stopped in a 1/4" (6 mm) displacement (deflection) in lieu of otherwise instantaneous stop. Remembering that the impact force developed is in direct proportion to the stopping distance (deflection in this instance), a greater stopping distance means a smaller impact force, and vice versa.

Conclusion

Use the following Fabreeka pad size:

ENGLISH	METRIC
9" × 9" × 2" thick	229 mm × 229 mm × 50 mm thick

How Fabreeka Functions in Reducing the Transmission of Vibration and Structure-Borne Noise

Introduction

The analytical treatment of steady-state vibration is fundamentally different from the treatment of shock conditions. Vibration is a continuing disturbance in which an oscillating motion exists at a constant frequency or combination of frequencies. It is a steady-state condition when the pattern of vibration amplitude is repeated during each cycle. Damped vibration exists whenever the pattern is repeated with successively diminishing amplitudes.

Any mechanical system possessing mass and elasticity is capable of vibration. Systems capable of vibration are obviously varied in form and may often execute complex motions. The number of independent coordinates required to describe the motion of a system designates the number of degrees of freedom of the system. Vibration is thus classified as having "one", "two" or "many" degrees of freedom.

Shock, as contrasted to vibration, is a transient condition wherein the equilibrium of a system is disrupted by a suddenly applied force or by a sudden change in force direction. This disturbance and the ensuing reaction of the system in restoring equilibrium constitute a condition of shock. Isolation of vibration or shock is the temporary storage of energy and its subsequent release substantially in its entirety but in different time relation. Isolation is thus distinctly different from the absorption or dissipation of energy.

The two aspects to the principle of isolation are:

1) **ISOLATION OF MOTION** - the reduction of stresses and deflections in members whose support experiences motion resulting from shock or vibration.
2) **ISOLATION OF FORCES** - the reduction of forces created by the operation of machinery.

An isolator is a resilient element with controlled elasticity and damping, which when properly installed in a mechanical system, will control the dynamic forces and motions of that system.

The function of a Fabreeka isolator may be best understood by first reducing it to its simplest form. See Figure 5. The system includes a rigid mass (m) supported by a mass-less spring (k) having viscous damping (c). The mounted equipment is represented by the mass, while the spring and dampener together simulate the elasticity and damping of a Fabreeka isolator. Isolation is attained through proper frequency relations; that is, comparing the frequency of the disturbing vibration with the natural frequency of the mass (equipment) on its isolator.

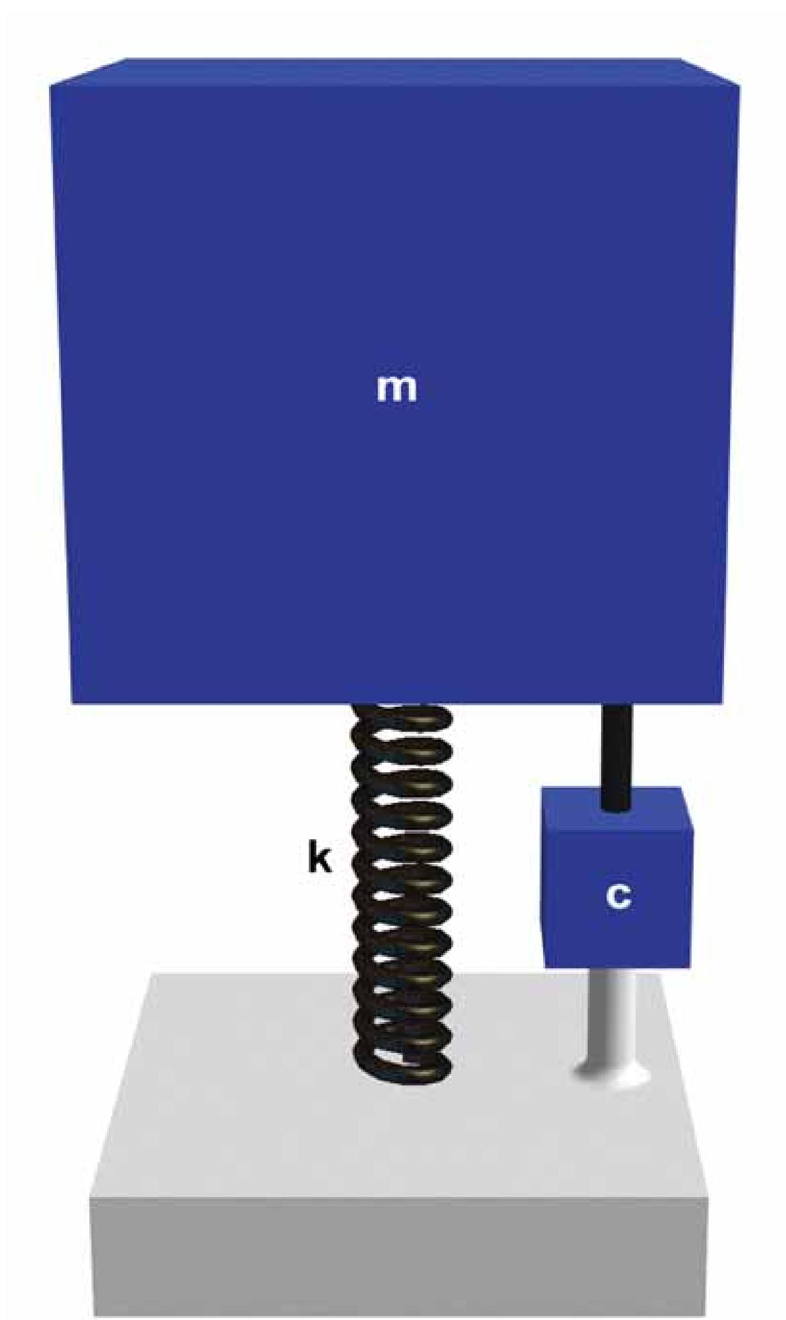


Figure 5

Natural Frequency

In a steady-state, single-degree-of-freedom system, the natural frequency is the number of cycles of vertical oscillations that a mounted system will carry out in a unit of time when displaced from its equilibrium and permitted to vibrate freely.

Whenever a weight (mass) is mounted on a resilient material and is subjected to an external force which is suddenly removed, it will oscillate freely up and down on its mounting a definite number of times until the oscillation dies out. See Figure 5A. One complete cycle of this free vibration involves movement of the weight from the equilibrium position (M), up through the uppermost position (N), down through the lower-most position (O), and finally back up to the equilibrium position again (P). The amplitude of this cycle is the distance (A) between the uppermost position (N) and the equilibrium position. The amplitudes of any of the succeeding cycles are similarly measured. The repeatability or rate of this free oscillation is measured in cycles per second (Hertz).

There are only two parameters that affect the natural frequency of a system. These are mass (weight) and stiffness (spring rate) as seen in the natural frequency (N_f) formula.

Increasing the weight (mass) or reducing the spring rate will produce a lower natural frequency, and conversely reducing the weight or increasing the spring rate will result in a higher natural frequency.

With a Fabreeka pad, the above relates as follows: An increase or decrease in weight produces a corresponding stress change in Fabreeka. An increase or decrease in thickness results in a spring rate change; i.e. a thinner Fabreeka pad increases the spring rate, while a thicker pad decreases the rate. This is readily seen in Figure 6. It is also interesting to observe that Fabreeka's natural frequency decreases as load is increased up to a level of 400 psi (2.8 MPa), where it is then essentially independent of loading.

Tests were conducted to determine Fabreeka's actual resonant (natural) frequency for various thicknesses at various loadings. Forced vibrations were applied and the amplitude monitored electronically to determine the frequency at which peak amplitude or resonance occurred for the various loads and thicknesses of Fabreeka.

The results of these extensive tests are shown in Figure 6, where static-load (stress) and thickness are plotted against natural (resonant) frequency. This curve is the result of dynamic testing and is therefore more reliable than natural frequencies obtained from static information.

$$N_f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

ENGLISH	METRIC
$N_f = 3.13\sqrt{\frac{k}{w}}$	$N_f = 0.159\sqrt{\frac{k}{m}}$
Where:	Where:
N_f = C.P.S.	N_f = Hertz
k = Spring rate (lbs/in)	k = Spring rate (N/m)
w = Weight (lbs).	m = mass (kg)

If the weight referred to represents a machine, it would have a definite natural frequency on its mounting. Furthermore, it may generate disturbing vibrations of its own while in operation. These latter vibrations are caused by either unbalanced moving parts within the machine or an unbalanced condition arising from the work being performed. These vibrations are referred to as forced vibrations, and their frequencies are called forcing frequencies. The major forcing (disturbing) frequency is generally the operating speed of the heaviest parts of the machine. However, higher secondary frequencies can sometimes create more of a disturbance than those created by the operating speed itself, thus requiring that these secondary frequencies also be isolated. Instrumentation may be required in some cases to determine the disturbing frequencies.

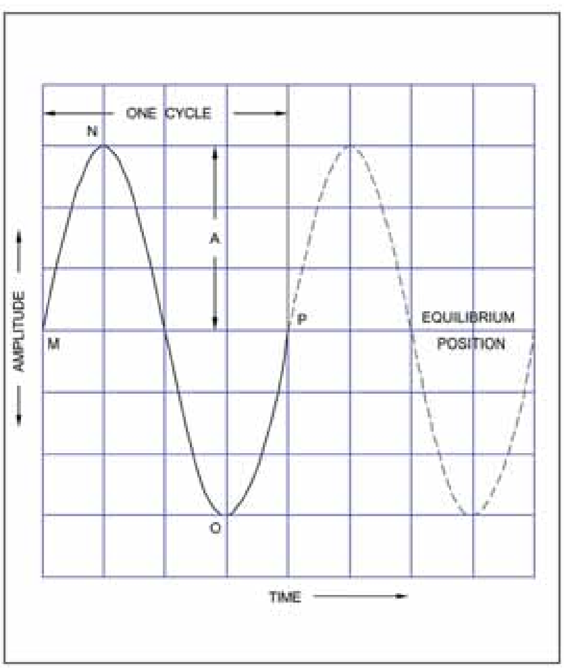


Figure 5A - Amplitude vs. Time

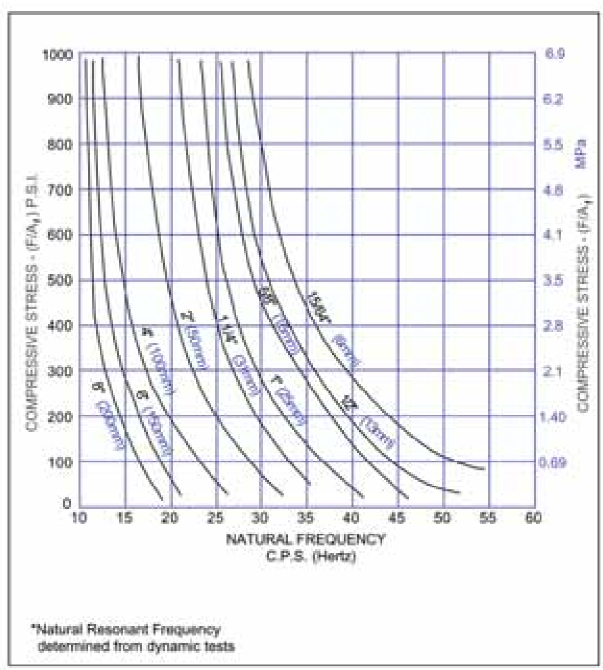


Figure 6 - Natural Frequency vs. Compressive Stress and Thickness

Frequency Ratio

The forcing frequency divided by the natural frequency is the ratio that indicates the effectiveness of a vibration isolator. See Figure 7.

$$\text{Frequency Ratio} = \frac{F_f}{N_f}$$

Where:

F_f = Forcing Frequency in C.P.S. (Hertz)

N_f = Natural Frequency in C.P.S. (Hertz)

Transmissibility is the percentage of disturbance being transmitted through the isolator (mounting). It is expressed by the ratio of vibration amplitudes or forces; i.e., it is the ratio of amplitude or force transmitted to amplitude or force generated.

For example: If the purpose of an isolator is to reduce the force transmitted to the support, then:

$$T = \frac{F_t}{F_d}$$

Where:

T = Transmissibility

F_t = Force Transmitted

F_d = Disturbing Force

If on the other hand, support motion must be reduced, then:

$$T = \frac{X_t}{X_d}$$

Where:

T = Transmissibility

X_t = Amplitude Transmitted to system

X_d = Disturbing Amplitude of support

Please note in both instances, reduction only occurs when the transmissibility is less than 1.

Fabreeka isolators (pads) are designed so that the force transmitted to the foundation is only a small fraction of the unbalanced force generated and acting on the system. This is accomplished by designing a Fabreeka isolator with a lower natural frequency than that of the disturbing frequency or frequencies (harmonics).

The measure of isolation thus obtained is called transmissibility. If the machine were mounted rigidly to its support or foundation (no isolators), the transmissibility would be unity because the amplitude or force transmitted would be equal to that generated by the unbalanced machine. This condition is represented by line AB in Figure 7.

A transmissibility of zero is necessary for theoretically perfect isolation; however, it is evident from the transmissibility curve that the frequency ratio would have to be infinitely large.

Alternatively, an infinitely large transmissibility is obtained when an isolator has no damping (dotted curve in Figure 7) and the frequency ratio is unity. This latter condition exists when the natural frequency equals the forcing frequency and is called resonance. It is apparent that a resonant condition must be avoided at all costs because it magnifies the initial disturbance many times its original value. It is further evident that the introduction of damping as in a Fabreeka isolator (solid curve) greatly reduces this magnification.

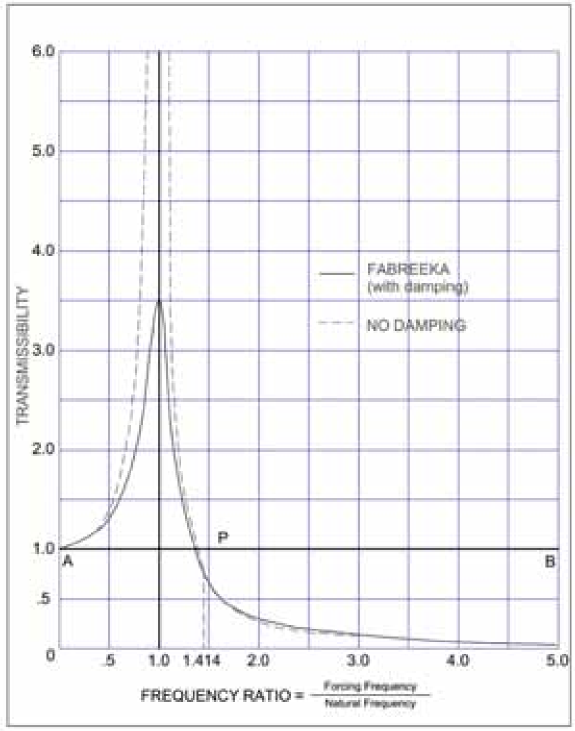


Figure 7 - Transmissibility vs. Frequency Ratio

Reduction of disturbances do not occur until the frequency ratio exceeds the value 1.414 and all values below that will result in magnification. It is desirable to have as low a natural frequency as practical. However, it is not always possible to obtain the low natural frequency desired without creating a very soft, and therefore, unstable mount. In these instances, effective compromise mountings can be used to advantage. This will be discussed more fully later under the heading "Reconciliation of Theory and Practice".

Damping

The time required for the vibration to die out depends upon the damping characteristics of the isolator. This inherent property of an isolator resists motion and thereby causes the free oscillation to diminish quickly. Fabreeka has a large internal resistance to motion called *hysteresis* (internal friction). It is this hysteresis property that converts mechanical energy of motion into heat which is then dissipated. In free vibration, a large percentage of the energy is dissipated in the form of heat during each cycle causing the vibration to quickly dampen out.

One term used to indicate the amount of damping in a system is the damping ratio:

$$\frac{C}{C_c}$$

Where:

C = damping in the system

C_c = damping in a "critically-damped-system"

A critically damped system when displaced from its equilibrium position will immediately return to equilibrium without vibrating.

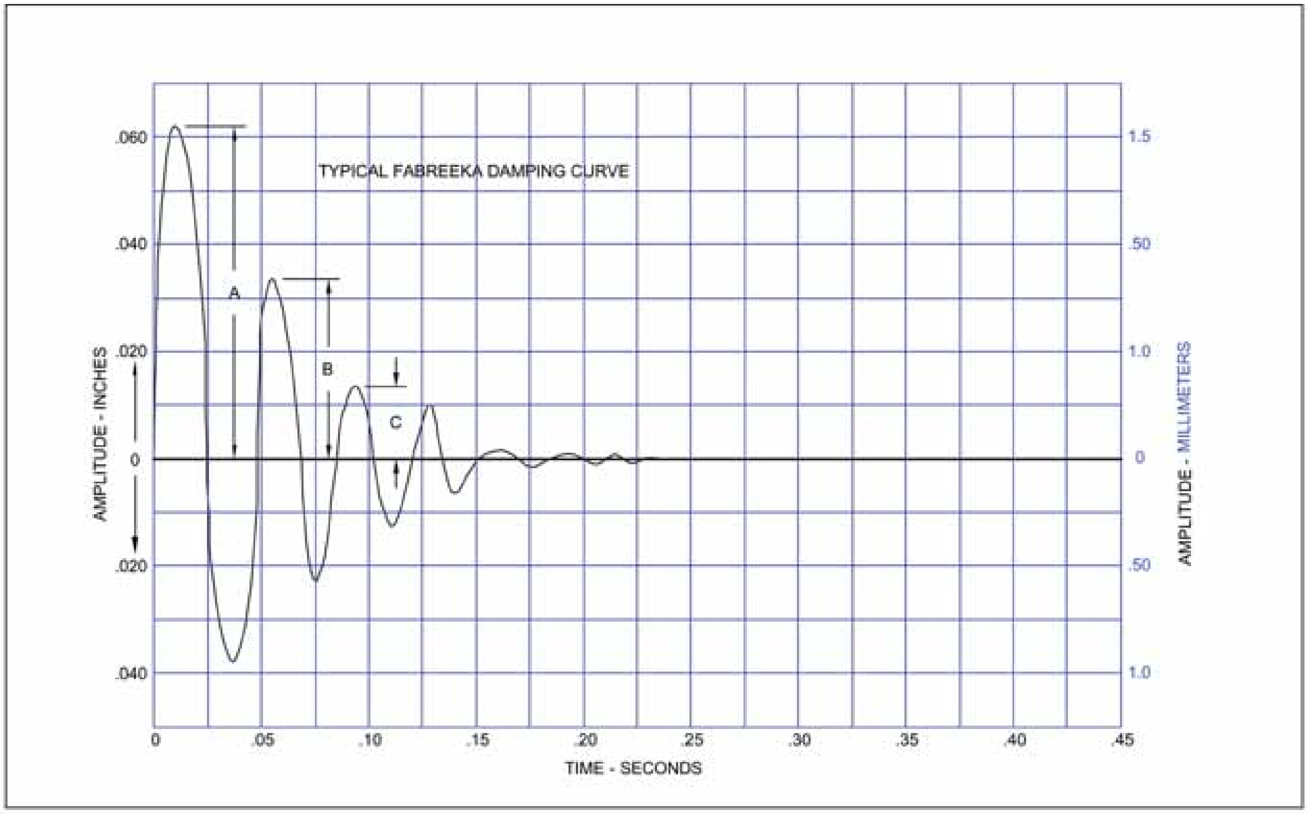


Figure 8 - Amplitude vs. Time

The damping coefficient for Fabreeka is 14.3 percent of critical or:

$$C = 0.143\ C_C$$

Another term used is logarithmic decrement, which is the natural logarithm of the ratio of two successive amplitude cycles in a free oscillation.

Laboratory tests have been conducted to determine the rate-of-decay of free oscillation on Fabreeka. A heavy mass (weight) was placed on Fabreeka (producing a static deflection), after which a large external force was applied to this mass-Fabreeka system, so that the induced dynamic deflection was greater than the static deflection. The force was released and the weight allowed to oscillate freely on Fabreeka. An amplitude-vs-time recording was made. (See Figure 8.) The conditions of weight, externally applied force and Fabreeka thicknesses were used simulate the actual in-service conditions. The average ratio of successive amplitude A/B or B/C etc. is 2.

Fabreeka's Logarithmic Decrement = 0.69

This high ratio of successive amplitudes explains why, for example, the free motion of a forging hammer anvil on a Fabreeka isolator is quickly damped out. It is important that the anvil be motionless before the next blow is struck.

The time necessary to dampen out a free oscillation on Fabreeka depends upon the natural frequency and initial amplitude of the oscillation. Low frequency and high initial amplitude require more time to die out than the reverse conditions of high frequency and low initial amplitude. In Figure 8, it took one-quarter of a second (0.25 seconds) for a typical oscillation on Fabreeka to die out. In general, the maximum time to dampen out a typical application with Fabreeka would be about one-half second.

There are many instances where a machine, while running up to or slowing down from operating speed, will pass through resonance with its isolators. The motion of a machine can build up to such a point that damage occurs if its isolators are undamped. On the other hand, damped isolators prevent excessive motion, thus damping prevents excessive movement of the mounted machine.

It is interesting to note (in Figure 7) that at frequency ratios above 1.414, the undamped (dashed) curve shows slightly less transmissibility than the damped (solid) curve. A slight loss in efficiency occurs when using a highly damped material, such as Fabreeka, but this is greatly offset by the much-improved conditions at resonance.

Damping is necessary in an isolator to prevent excessive motion at resonance and to quickly dampen motion associated with shock and impact. Fabreeka is such an isolator.

Isolating Machinery from Outside Disturbances

It is necessary at times to isolate a particular machine or piece of equipment from incoming disturbance that could not be isolated at its source. For example, a large grinder performing precision work must be isolated from disturbances generated by a forging hammer (source) operating nearby. If the shock impulses and vibration were left unabated, they could cause flaws in the work piece being ground. It is more practical in this case to isolate the offended unit rather than the offending unit. However, whenever possible, isolating at the source should be the first consideration. Sometimes it becomes necessary to isolate both the disturbance receiver and transmitter. The same vibration theory used for reducing transmitted vibrations is used to isolate against incoming disturbances. In other words, the isolator's natural frequency must be lower than that of the incoming disturbing frequency.

Reconciliation of Theory and Practice

Usually more than one disturbing frequency is present in a machine. As a general rule, an attempt should be made to isolate the frequency producing the largest vibration amplitude, while avoiding resonance with the other disturbing frequencies.

There are also instances where unfavorable human response to particular frequencies (usually high) becomes a major consideration. For example, a single phase electric motor has two predominant disturbing frequencies. One is at the operating speed and the other is at twice the current frequency. If the operating speed of the motor is 1200 RPM and the current frequency is 60 cycles per second, there are two forcing frequencies, namely, 1200 divided by 60, or 20 cycles per second operating frequency, and 2 times 60 or 120 cycles per second, secondary forcing frequency. It is this latter secondary frequency that can be more disturbing because of the unfavorable human response. A Fabreeka isolator can be designed to isolate the higher secondary frequency while avoiding resonance with the lower frequency or operating speed of the motor.

If the isolator selected has a natural frequency of 40 cps, a frequency ratio of 3 exists between it and the secondary frequency resulting in an 84% reduction in the transmission of this disturbance. See Figure 7. On the other hand, the frequency ratio between the operating speed and isolator is 0.50, which indicates a small magnification. Although more of the lower frequency amplitude is transmitted, we have achieved reduction of the most troublesome disturbance. Practical experience has shown a need for such compromise isolation. High frequency vibration of a secondary nature very often transmits objectionable structure-borne noise that affects personal comfort.

Fabreeka can be applied to effectively isolate these disturbances. An example of this is in the Marine industry, where Fabreeka is used to isolate marine propulsion engines from transmitting (harmonic frequencies) structure-borne noise throughout the vessel.

Practical Considerations

In solving vibration problems, it is possible to design an ideal isolator using accepted theory and end up with unsatisfactory performance from a practical standpoint. A case in point is stability. It is seldom possible to design an isolator without considering the stability requirement.

Fabreeka, with its limited resilience, minimal deflection and high strength, often serves as a more practical isolator than softer materials. For instance, an isolator for a diesel engine on board a ship can be designed in accordance with accepted vibration theory and yet create greater problems than it solved. At high speeds or rough seas, the strength and stability of an isolator are vital to maintain proper alignment of shafting and to avoid excessive motion which can cause broken bolts and connections.

Fabreeka, with its limited deflection, has proven to be the ideal solution in many instances where alignment must be maintained between driver and driven; i.e., where the relative deflection between isolators must be minimal.

Satisfactory isolation, therefore, is often a compromise between theory and practical application. A material having the limited resilience, minimal deflection, great strength and high damping of Fabreeka, often yields a better solution than would a softer material selected on the basis of theoretical considerations only. Fabreeka therefore is a practical material for the reduction of shock and vibration.

Structure-Borne Noise Isolation

The problem of noise has become acute as witnessed by the introduction of noise exposure limits set by Government regulations.

Fabreeka's part in isolating noise is one of reducing structure-borne noise. Fabreeka reduces mechanical vibrations which can be converted to air-borne noise. For example, the operation of a machine sets up vibrations within a building structure. These vibrations travel throughout the structure causing a wall, panel, ceiling or other surfaces to pulsate. The movements (pulsations) of these surfaces are transferred into the air as audible vibrations or noise. This is called "drum head" or sounding-board effect.

When isolating structure-borne noise, it is essential that all conductive paths of vibration be blocked. Fabreeka's multi-layered construction gives a multitude of interfaces which offer a high acoustical mismatch of impedances, thus reducing the transfer of acoustical energy or sound transmission. Therefore, Fabreeka pads, washers and bushings are required to completely break the metal-to-metal contact between the isolated unit and its support. All connections to the unit such as pipes, cables, ventilating ducts must be isolated as well with flexible connections and the like.

Air-borne noise radiating directly from the machine (equipment) can be contained by employing an acoustically treated enclosure. This is isolating at the source. It may be more practical in some cases to acoustically isolate (insulate) a room, office or complaint area from the offending noise.

In summary, Fabreeka reduces mechanical vibrations and blocks the transmission of acoustical energy, both of which act to isolate structure-borne noise.

Low Frequency Vibration

If a vibration disturbance is of low frequency, special consideration must be given in selecting and applying the isolation system.

In certain situations, it may prove impractical to place isolators directly beneath the offending unit. For example, a very soft and therefore unstable mount may be required, in which case, an inertia block can be placed beneath the unit to be isolated. This adds resisting mass to the unit as well as stability. A suitable number of isolators can then be placed between the inertia block and its supporting foundation.

A more effective and stable isolation system is thus obtained by employing the inertia block. Inertia blocks are generally made from reinforced concrete; however, some have used steel slabs. Others have attached the offending machine to a unitizing structural steel base and then poured concrete into this steel framework thus forming the inertia block.

There are times when Fabreeka is not practical for low frequency vibrations and a softer material is required, such as our Fabcel® pad. Please contact us to receive a copy of the Fabcel engineering guide.

Determining the Proper Fabreeka Isolator

Fabreeka isolators are very simple to design. The following example illustrates the procedure used:

Example: Use Figures 6 and 7. A machine creates a major disturbance at operating speed of 3600 RPM.

$$\text{Forcing Frequency} = \frac{3600}{60}$$

$$\text{Forcing Frequency} = 60 \text{ cps (Hertz)}$$

The weight and bearing area of the machine are such that a stress of 200 psi (1.40 MPa) is placed on the Fabreeka isolator. *Note:* The bearing area of Fabreeka is the same as the machine's. We want an isolator whose natural frequency is less than half the disturbing frequency:

$$N_f = \frac{F_f}{2}$$

$$N_f = \frac{60 \text{ cps}}{2}$$

$$N_f = 30 \text{ cps (Hertz)}$$

In Figure 6, we see that at a loading of 200 psi (1.40MPa) and a thickness of 1-1/4" (31 mm) we get a natural frequency of 30 cps (Hz). In Figure 7, a transmissibility of 0.40 is shown for a frequency ratio of 2. This means 40% of the original disturbance is being transmitted, therefore a 60% reduction has been achieved. A greater reduction can be obtained by lowering Fabreeka's natural frequency. This is accomplished by either of the following:

1) Increase Fabreeka's thickness.
2) Increase the stress on Fabreeka by reducing the Fabreeka pad area.

The following frequency ratios and their respective transmissibility and reduction values are listed for convenience:

Ratio	Transmissibility	Percent Reduction
1.414	1.0	0
1.75	0.48	52%
2	0.33	67%
3	0.13	87%
4	0.07	93%

Only the free floating weight on Fabreeka (or any isolator) is used to determine the natural frequency. Nuts on anchor bolts should only be tightened until a slight bulge in the Fabreeka washer is observed. Over-tightening bolts will decrease the efficiency of Fabreeka by increasing its natural frequency.

DO NOT MAKE THE MISTAKE OF THINKING THAT ADDITIONAL BOLT LOAD, WHICH INCREASES THE STRESS ON THE FABREEKA, WILL DECREASE THE NATURAL FREQUENCY. THIS IS ERRONEOUS BECAUSE YOU ARE ACTUALLY STIFFENING OR INCREASING THE SPRING RATE OF FABREEKA WHILE THE FREE STATIC WEIGHT REMAINS THE SAME. SEE THE Nf FORMULA ON PAGE 9.

Fabreeka's Engineering Department is available for Engineering, Design Assistance and Consultation. To make proper recommendations they must know:

1) Nature of your vibration problem.
2) Operating speed of machine and disturbing frequencies to be isolated.
3) General description of machine, including weight distribution.
4) Where and how machine is mounted and of what the supporting construction consists.
5) Details on size and shape of machine base, including size and location of all foundation bolts.
6) Environmental conditions such as temperature, acids, oils, solvents, radiation, etc.

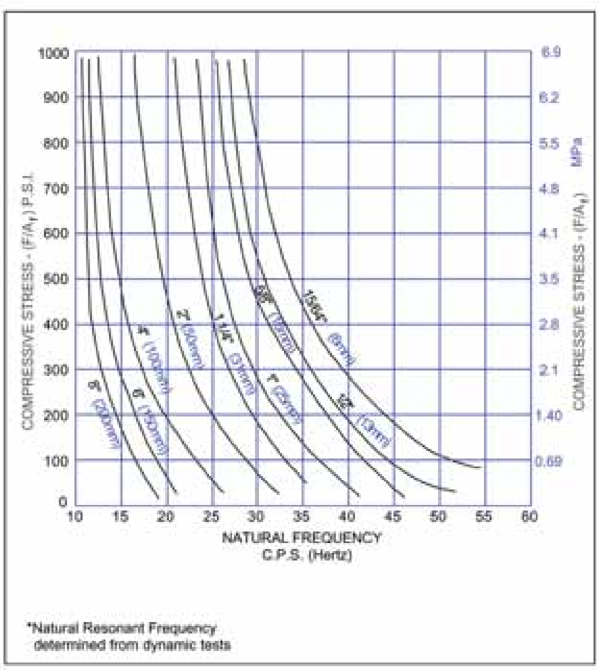


Figure 6 - Natural Frequency vs. Compressive Stress and Thickness

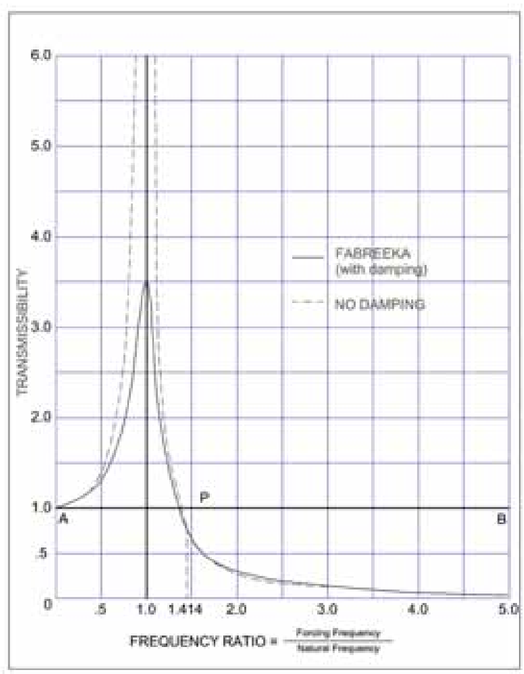


Figure 7 - Transmissibility vs. Frequency Ratio

Steps in Properly Applying Fabreeka to Isolate Vibration

1) Determine the most troublesome disturbing (forcing) frequency.
2) Select the frequency ratio that offers the desired degree of isolation. See Figure 7 on page 13.
3) Determine the natural frequency that will produce the selected frequency ratio.
4) Determine the minimum total area of Fabreeka necessary to insure stable support for the machine. In doing so, arrange the total Fabreeka area into as many pads as are necessary to give proper support and to avoid base distortion. The area of each pad should be in proportion to the load carried by it, so that the unit loading or stress on all pads will be approximately the same.
5) Divide the machine weight, including work load, by the minimum total area to find the static stress on Fabreeka. (If concrete or steel sub-base is used, the weight of this should be included in the total weight to be mounted.)
6) Obtain the thickness of Fabreeka required to yield the desired natural frequency. See Figure 6 on page 13.
7) If foundation bolts are used, provide a Fabreeka washer covered by a steel washer, and if warranted, a Fabreeka bushing around every bolt. (See Figure 8.)
8) Provide flexibility in all piping, shafting and other connections to the mounted unit.
9) When two or more units are rigidly coupled or geared together (i.e., motor-generator sets), they should be bolted rigidly to a common metal or concrete sub-base to preserve their alignment. The sub-base is then isolated on Fabreeka.
10) Fabreeka must be given firm support (a solid foundation) to function properly. It is important that the isolator and not its support deflect under dynamic conditions. A soft, flexible support will greatly reduce Fabreeka's effectiveness to isolate.
11) If the foundation of an isolated unit is directly on rock (ledge) or on a ground water pocket and the intent is to reduce transmitted disturbances, then a greater degree of isolation is required. Stone and water are extremely good conductors of vibration and shock waves.

Figure 8 - Typical Fabreeka pad, washer, bushing arrangement.

These tables can be used to select the desired Fabreeka pad thickness when forcing frequency and load are known.

Percent Reduction in Transmitted Vibration

Fabreeka 15/64" (6 mm) Thick

Forcing Freq.	Load - P.S.I. (MPa)							
C.P.S. (Hz)	50 (0.35)	100 (0.69)	150 (1.04)	200 (1.40)	400 (2.80)	600 (4.10)	800 (5.50)	1000 (6.90)
50	-	-	-	-	-	28	37	41
60	-	-	-	-	40	55	61	62
70	-	-	12	27	59	68	71	72
80	15	29	40	49	69	76	78	79
90	38	48	56	61	76	82	84	85
100	53	60	64	69	81	86	88	88
120	69	73	76	79	88	92	93	93
140	78	80	84	86	93	94	94	95
160	84	86	88	90	94	95	96	96
180	88	90	92	93	95	97	97	97
200	91	93	93	94	97	97	98	98
240	94	94	95	96	97	98	98	98
280	95	96	97	97	98	98	98	98
320	97	97	98	98	98	99	99	99

Fabreeka 1/2" (13 mm) Thick

Forcing Freq.	Load - P.S.I. (MPa)							
C.P.S. (Hz)	50 (0.35)	100 (0.69)	150 (1.04)	200 (1.40)	400 (2.80)	600 (4.10)	800 (5.50)	1000 (6.90)
50	-	-	-	-	20	39	48	53
60	-	-	-	17	52	62	67	69
70	6	23	35	44	67	73	76	78
80	38	46	55	61	75	80	82	83
90	54	61	66	70	80	84	86	87
100	65	70	73	76	84	87	88	89
120	76	79	82	83	89	91	92	93
140	83	85	87	88	92	94	94	94
160	87	88	90	91	94	95	95	95
180	89	90	92	93	95	95	95	95
200	91	93	94	94	95	95	95	95
240	94	95	95	95	95	96	96	96
280	95	95	95	95	96	96	96	96
320	95	95	96	96	97	97	97	97

Fabreeka 5/8" (16 mm) Thick

Forcing Freq.	Load - P.S.I. (MPa)							
C.P.S. (Hz)	50 (0.35)	100 (0.69)	150 (1.04)	200 (1.40)	400 (2.80)	600 (4.10)	800 (5.50)	1000 (6.90)
40	-	-	-	-	-	-	13	25
50	-	-	-	-	33	53	54	58
60	-	-	17	28	58	67	70	73
70	20	34	45	53	71	76	78	80
80	45	54	60	66	78	82	83	85
90	59	66	70	74	83	86	87	88
100	69	73	76	79	86	88	89	91
120	79	81	83	85	91	92	93	94
140	84	86	88	89	93	94	94	95
160	88	89	91	92	94	95	95	95
180	91	92	93	94	95	95	95	95
200	93	94	94	94	95	95	95	96
240	94	95	95	95	96	96	96	96
280	95	95	95	95	96	96	96	97
320	95	95	96	96	97	97	97	98

Fabreeka 1" (25 mm) Thick

Forcing Freq.	Load - P.S.I. (MPa)							
C.P.S. (Hz)	50 (0.35)	100 (0.69)	150 (1.04)	200 (1.40)	400 (2.80)	600 (4.10)	800 (5.50)	1000 (6.90)
40	-	-	-	-	10	32	39	48
50	-	-	6	23	53	61	65	69
60	14	33	45	54	69	74	77	79
70	44	55	63	69	77	81	83	84
80	60	67	73	76	83	85	87	88
90	70	75	79	80	87	88	90	90
100	76	80	83	85	89	91	93	93
120	83	86	88	90	93	94	94	94
140	87	90	91	92	94	95	95	95
160	90	92	94	94	95	95	95	95
180	93	94	94	95	95	95	96	96
200	94	95	95	95	95	96	96	96
240	95	95	95	96	96	96	96	97
280	95	95	96	96	96	97	97	97
320	96	96	97	97	97	98	98	98

Fabreeka 2" (50 mm) Thick

Forcing Freq.	Load - P.S.I. (MPa)							
C.P.S. (Hz)	50 (0.35)	100 (0.69)	150 (1.04)	200 (1.40)	400 (2.80)	600 (4.10)	800 (5.50)	1000 (6.90)
30	-	-	-	-	-	25	35	45
40	-	-	24	38	57	63	68	70
50	24	46	58	64	72	78	80	81
60	52	64	72	75	83	85	88	89
70	67	74	79	84	88	90	92	93
80	74	81	85	88	92	93	94	94
90	80	86	90	92	94	94	95	95
100	85	90	92	94	95	95	96	96
110	88	92	94	94	96	96	96	96
120	91	93	94	95	96	96	96	96
130	93	94	95	96	97	97	97	97
140	94	95	96	97	97	97	97	97

Fabreeka 4" (100 mm) Thick

Forcing Freq.	Load - P.S.I. (MPa)							
C.P.S. (Hz)	50 (0.35)	100 (0.69)	150 (1.04)	200 (1.40)	400 (2.80)	600 (4.10)	800 (5.50)	1000 (6.90)
30	-	-	18	33	54	61	65	69
40	28	50	61	68	75	79	81	84
50	59	69	76	79	85	88	90	91
60	72	79	85	87	92	93	94	94
70	80	86	90	92	94	94	95	95
80	86	90	93	94	95	96	96	97
90	90	93	94	95	96	97	97	97
100	93	94	95	96	97	97	97	98
110	94	94	95	95	95	95	96	96
120	95	95	95	95	96	96	96	96
130	95	95	96	96	97	97	97	98

FABREEKA®
VIBRATION & SHOCK CONTROL

United States

PO Box 210
1023 Turnpike Street
Stoughton, MA 02072
Tel: (781) 341-3655
or: 1-800-322-7352
Fax: (781) 341-3983
info@fabreeka.com
www.fabreeka.com

Canada

Tel: 1-800-322-7352
Fax: (781) 341-3983
info@fabreeka.com
www.fabreeka.ca

United Kingdom

8 to 12 Jubilee Way
Thackley Old Road
Shipley, West Yorkshire
BD18 1QG
Tel: 44-1274-531333
Fax: 44-1274-531717
info@fabreeka-uk.com
www.fabreeka.co.uk

Germany

Hessenring 13
D-64572, Buttelborn
Tel: 49-6152-9597-0
Fax: 49-6152-9597-40
info@fabreeka.de
www.fabreeka.de

Taiwan

PO Box 1246
Tainan 70499
Taiwan
Tel: 886-935 273732
info@fabreeka.tw
www.fabreeka.com.cn

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