The Importance of Feet on Machine Applications

Compliance in the Wrong area can be worse than no compliance

Various Feet

Differences

- Depending on different applications, the selection of the feet of a machine is often overlooked.
- This is a very important part of the machine as it supplies the path of energy that a machine would have to ground.

Compromises

- Leveling style of feet have rubber or other polymer isolation on the bottom. Depending on the durometer (Polymer Hardness rating) of the material, the feet will have a compliance at some distinct frequency. This is what is important, frequency
- The threaded rods of feet also have an effect if they are either jacked up quite high or they are excessively thin compared to the energy implied upon them. A standing wave along the axis of adjustment could be sustained.

Why is Frequency Important

- Frequency is directly related to the amount of motion that an object is moving. Let's consider a sine wave since this will rock back and forth. Assume a single frequency of rocking back and forth at some amplitude value. "$A*\sin(\omega)$"
- So if we needed to find the position of this, we can look at it as an acceleration. You must integrate the information for position.

The Distance related to Frequency

- Given A*sin (ω)” as an acceleration, then the velocity and position would be
- $\iint$ A*sin (ω) dt= -A/ ω $\int$ cos(ω)dt + c
- The instantaneous position would be
- -A/ ω $\int$ cos(ω)dt + c = -A/ ω^2 sin(ω) + c
- Ignoring constants, the denominator is the dominant factor and increasing the frequency reduces the amount of distance, hence movement. Stiffening a system increases frequency!

Why is Frequency Important

- In a control system, the ability to impart and change within a period of time, is frequency.
- Mechanical control systems are analyzed by their frequency and ability to reject disturbances below the bandwidth capability of the system. Most machines have position bandwidth requirements of less than 30 Hz.
- The compliance of many of the leveling feet happen in this area too.

Raising the Frequency of Resonance

There are a few things that you can do to raise the resonant frequency of something.

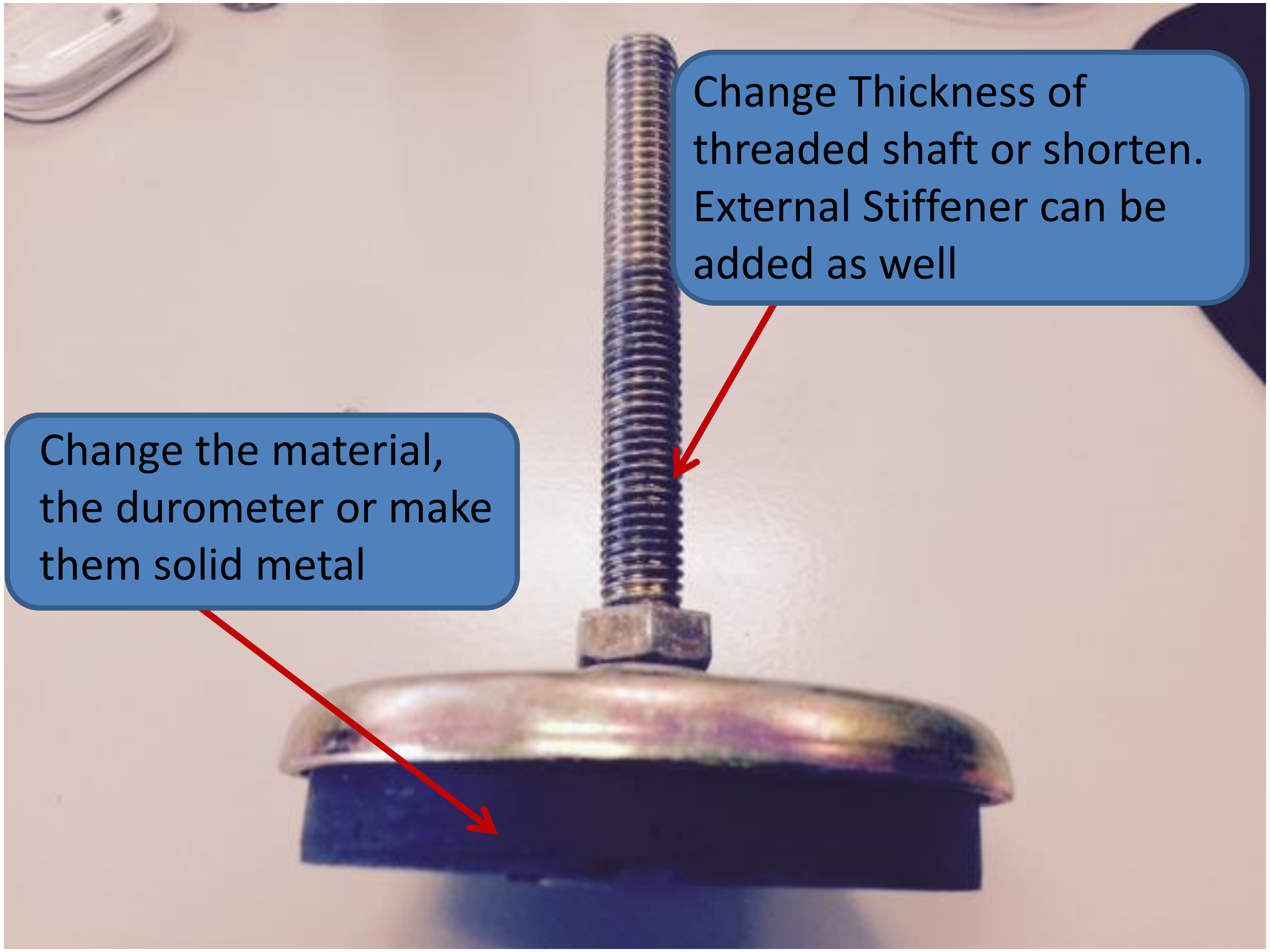
1. Stiffen the system
2. Lighten the system
3. Shorten the moment or wave area

Reducing the Motion

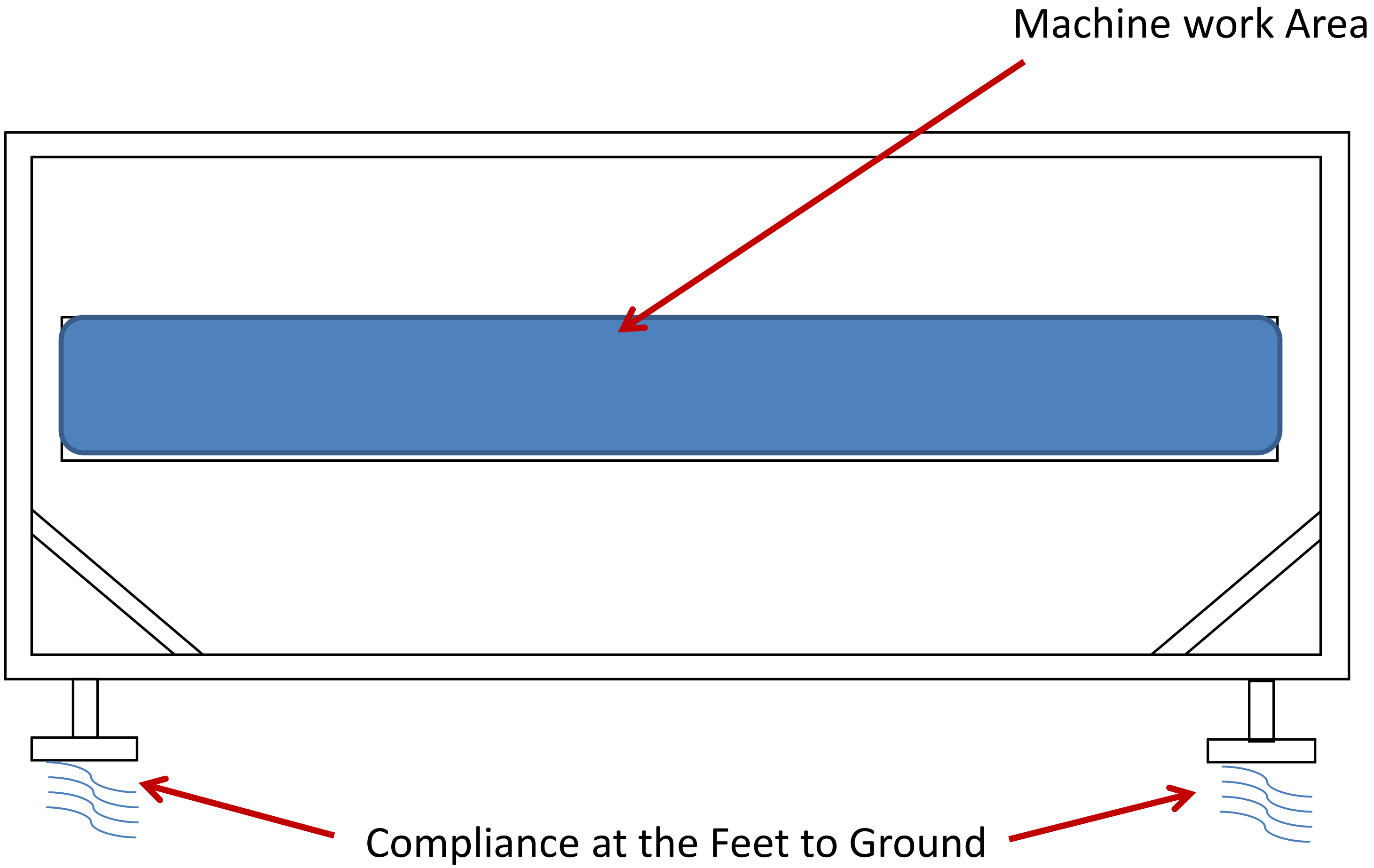
There are a few things that you can do to reduce the amplitude or amount of motion.

1. Dampen – this implies some compliance
2. Reshape resonating members (honeycombs are often used to prevent standing waves)
3. Reduce the excitation

What Can We Apply

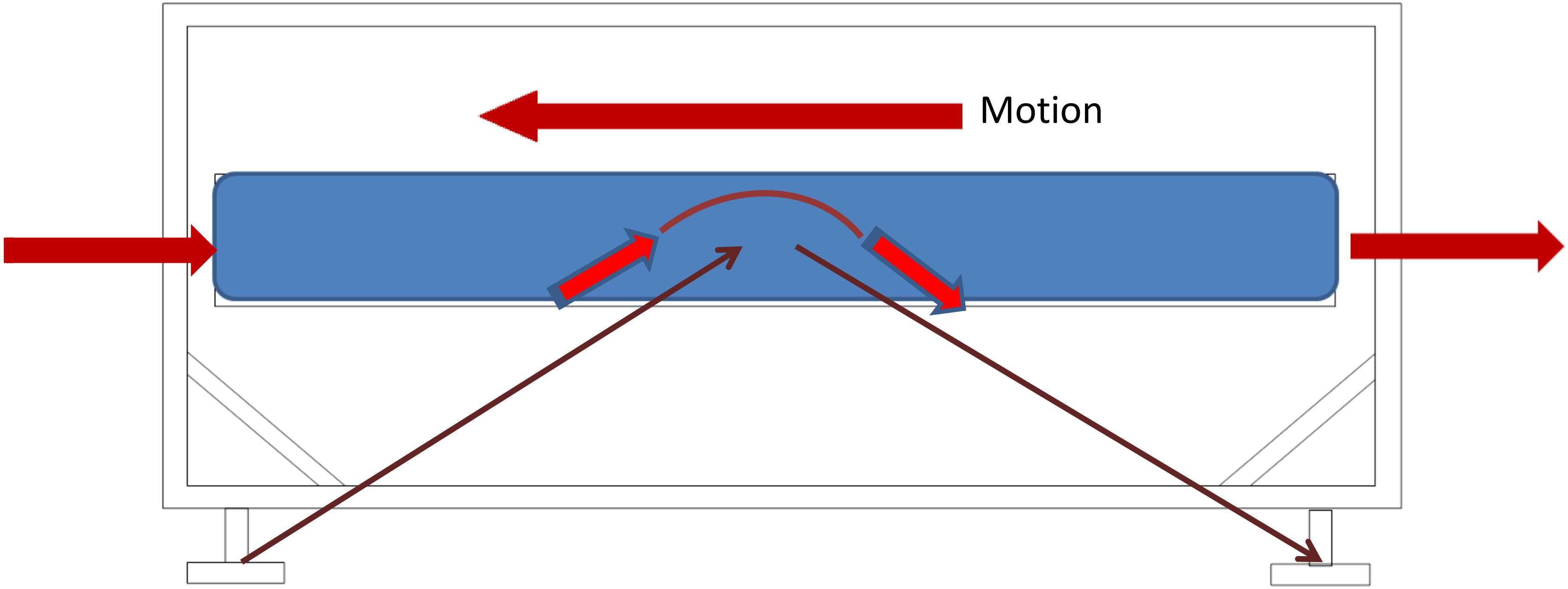


What Happens with Compliance at the Leveling Pads

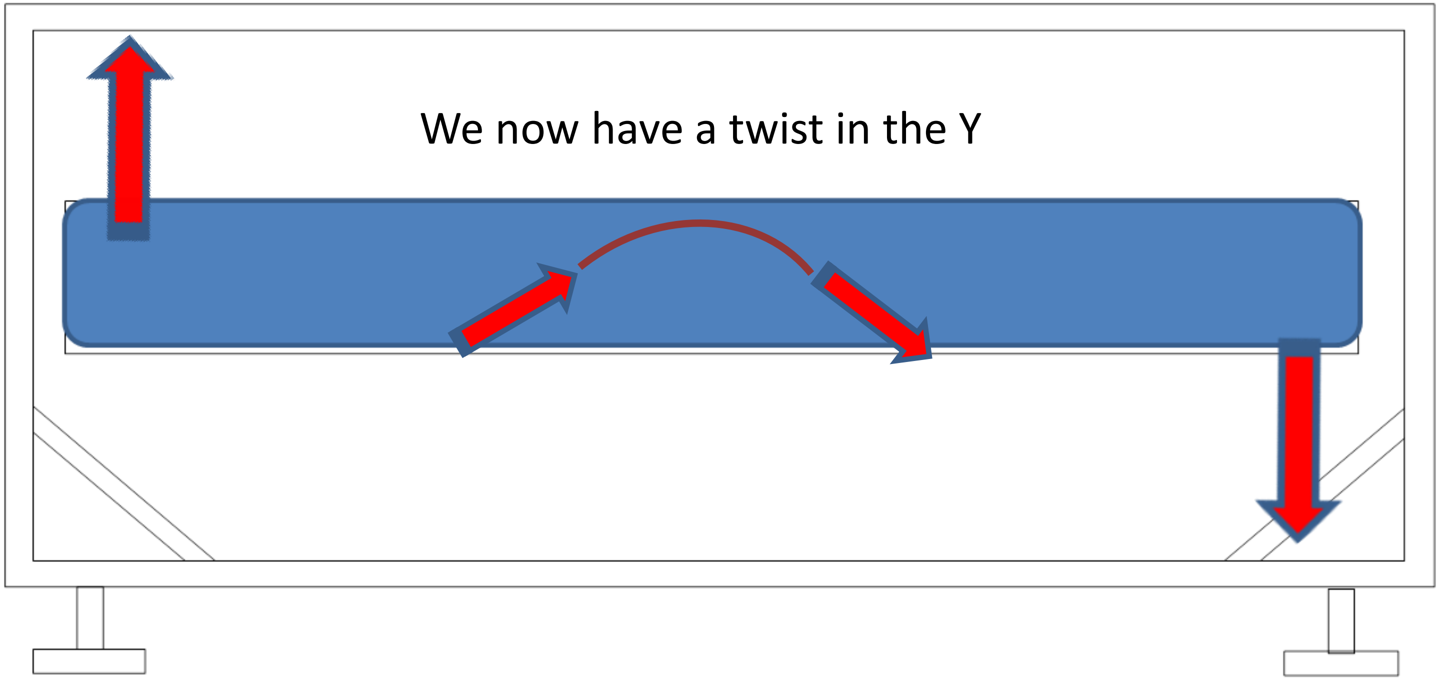


Vector Forces

The work area is the source of Vector X and Vector Y forces. Here is an + X – force caused by the motion in the –X direction.



Z Force from X or Y motion



Z Force Quantities

- Assume that the X Y motion is 981 N. This could be achieved by a 100 kg mass at 1 g acceleration or a 50 kg mass at 2 g's, etc.
- A common position for the force is that the work area would be 1 m from the base of the frame.
- Assume that the work area is infinitely stiff for the purpose of simplification.

Moments

Durometer to Spring Rate

- **K= (4/3)* Eo*3.142*Dm*(b/t)*(1+k (D-d/(4*t))^2**

where K= stiffness

Eo= Young's modulus based on hardness

Use Durometer to Young's modulus conversion charts

k= numerical factor based on hardness

Dm= mean diameter ie D+d/2

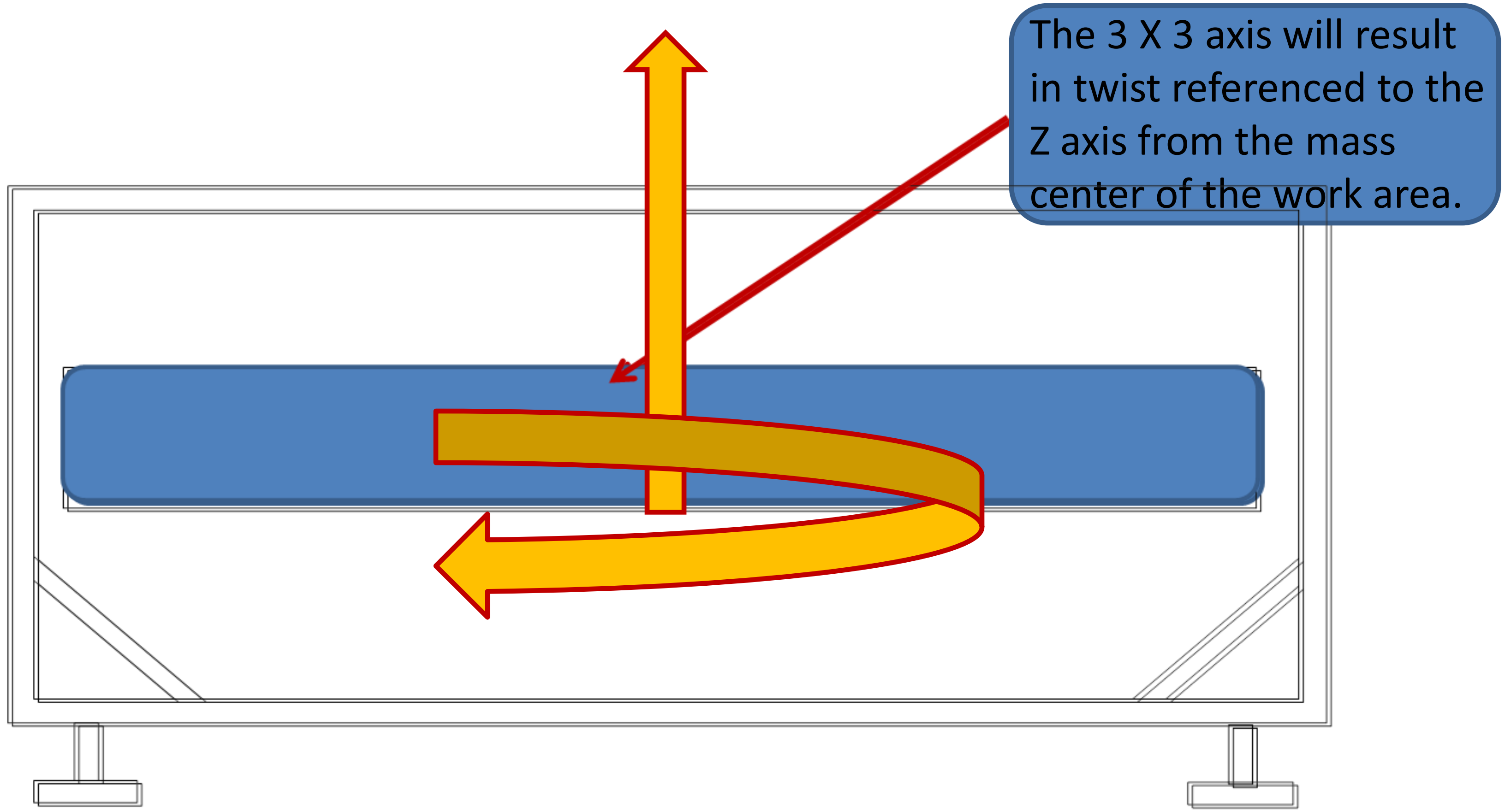
D= external diameter

d= internal diameter

b= radial width of section ie- D-d/2

t= thickness

3 X 3 Vector Results in another Twist with Simultaneous X and Y Motion



Complications

- We now have several forces that were unintended in Y and Z directions.
- We have no feedback to these directions so therefore, we cannot reject them.
- Sometimes, signal condition such as pre-filters will minimize.

Rigid Connection to Ground

- Assuming the rigid connection to ground, the Young's modulus of steel is used for the spring rate. An order of magnitude higher.
- The frame must be strong enough for the rejection of the forces. Using the Young's modulus, keep the frequency of resonance high (think small motion) and of small amplitudes.
- The frame must use as many gussets and stiffeners to minimize translational forces. Translational forces are usually minimized by reducing the number of right angles.