4.0 Analysis

4.1 Vibration Analysis (Spring Dampening System)

The function of a vibration isolator is to reduce the magnitude of force transmitted from a vibratory foundation to a machine. To isolate the adequate frequency range, the mount will be constructed to act as a hanging spring mass damper system. As a result, this will eliminate almost all movement in the Z direction. Because vibrations occur over a wide range of frequencies and the source which in this case is the firing of the MK-19 inside the VCCT will not be firing constantly throughout the entire simulation, it is hard to dampen these impulses. The solution to this is to design a system for the frequency of vibration that occurs most often during a 2 second interval of use. The most common frequency taken from the given data was 11Hz which was derived from the equation $1/\tau$. This number will be loosely used throughout this report, but you must note that this is not the only frequency that the projector is vibrating at.

When designing the system, if the for some strange reason the VCCT only vibrated at one frequency a simple spring would be placed under compression that is designed for that exact resonance. If not calibrated correctly the set system would have a reverse affect and vibrate more, with the intention to dampen the vibration in the ceiling. To accommodate for the large margin of error, instead of using a stabilizing device that hangs in compression from 4 parallel springs, the mount will be built with a series of interchangeable silicone filled springs that act as a spring and a damper. This will alter the springs resonate frequency allowing the system to dampen a wider range of vibrations.

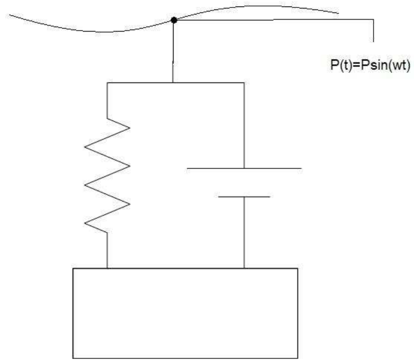

Figure 9: Model of Mechanical System

Knowing the resonance frequency of the spring is very important because if for some reason the projector begins to vibrate at the exact same frequency, the projector will begin to almost vibrate uncontrollably. This is why when picking the correct components the frequency of vibration must be well above the first resonance frequency. A good example of this phenomenon is the collapse of the Broughton Bridge, which was caused by a large number of solders marching across at the same resonance frequency as the bridge. The bridge locks onto the frequency, and with every step causes larger and larger bridge oscillations. The projector can act in the same way if not careful. If the weapon happens to be firing at the same resonance frequency as the manufactured spring, the vibrations will be magnified with every blast of the rifle.

For this system, a soft silicon gel mount that is placed inside a spring in compression will be used and purchased from Gel-Mec. The resonance frequency of this particular component is at 8Hz, which is near our estimated vibration point but is still outside of the range taken from the given vibration data taken from the projector during a previous run of the VCCT program.

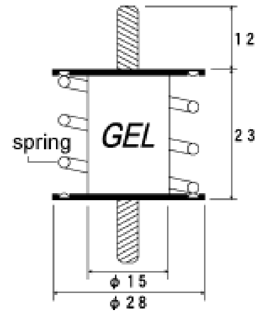

Figure 10: Compression Spring/Silicon Gel Mount

This is not why this particular component was chosen for our design; first we had to make sure that it would decrease the vibration of our target value of 11Hz. The projector in this system in Figure 1, I connected through a spring in parallel with a viscous damper to a movable support. The support is given a harmonic motion of the form P(t)=Psin(wt). The displacement of the projector is governed by the systems equation of motion

$$\ddot{x} + b(\dot{x} - \dot{p}) + k(x - p) = 0 \quad .$$

The Laplace transform of this equation assuming zero initial conditions is,

$$(ms^2 + bs + k)X(s) = (bs + k)P(s)$$

the transfer function between the displacement X(s) and the input force P(s) is

$$\frac{X(s)}{P(s)} = \frac{bs+k}{ms^2+bs+k}$$

Because the input to this system is P(t)=Psin(wt) it is a sinusoidal function and the sinusoidal transfer function becomes

$$\frac{X(jw)}{P(jw)} = \frac{\sqrt{b^2+w^2+k^2}}{\sqrt{(k-mw^2)^2+b^2w^2}} \; .$$

This can be called motion excitation, because the source of vibration is the foundation. The transmissibility of motion excitation is the ratio of the vibration amplitude of the projector to the vibration amplitude of the foundation.

$$TR = \frac{X(jw)}{P(jw)} = \frac{\sqrt{b^2+w^2+k^2}}{\sqrt{(k-mw^2)^2+b^2w^2}}$$

In this case transmissibility needs to be in terms of the damping ratio ζ and the undamped natural frequency ω_n, where $\beta=\omega/\omega_n$.

$$TR = \frac{\sqrt{1 + (2\zeta\beta)^2}}{\sqrt{(1-\beta^2)^2 + (2\zeta\beta)^2}}$$

The transmissibility of a motion excitation system should be relatively small because it represents the final percent of motion of the output of the system, or in this case the projector itself. The selection process for components first consisted of creating a program in mathcad and rearranging the spring and proportionality constants do decide what type of rubber and springs to use. This method was flawed and not very practical so it was quickly halted. The team then began to search for components and testing them one by one with the same mathcad program that is displayed in the appendix. This allowed the values to be realistic and not just random values pulled out of the sky that could not be reproduced by manufacturing a custom spring. We slowly stumbled across a company called Gel-Mec who constructs a silicone filled spring that acts as a spring and a dampening device. Once tested and proved that it will work with our design quickly became our top choice of isolation components. Not only does the BG-7 from Gel-Mec work under the conditions that is needed, but because this device sandwiches both components together it does not take up as much room and allows the projector to cool through natural convection, which in turn saves money by keeping the bulb cooler allowing it to last longer. The final theoretical displacement of the projector with respect to the base turned out to be 0.9 mm or .035 inches which is a fraction of the existing vibrations. This value was found by first finding the spring constant of the BG-7 to be 16600 N/m. This is a high value for a spring but it is not supposed to keep oscillating when the input stops, the spring must be able to be stiff enough also stop the movement of the projector as well.