MRM™ & VPS™ Shock Isolation Systems for Forging Hammers
Forging Hammer Isolation

Vibro/Dynamics began producing isolation systems for forging hammers in 2002 after receiving numerous requests for an improved mounting system from hammer builders and forging producers. Vibration and shock isolation of forging hammers is very difficult due to their large masses and extreme shock forces. Vibro/Dynamics first developed the FS Series Coil Spring Isolators with viscous fluid dampers and then followed with the development of MRM™ and VPS™ Elastomeric Isolation System. Both types have proven to be very effective in isolating hammer and shock forces.

Coil spring and viscous damper units provide the greatest isolation performance, but have higher initial cost, more expensive foundations, and potential maintenance issues. The viscous dampers in the spring isolators are difficult to protect if a pit should flood; a situation usually requiring the replacement of the damper fluid. Some competitive damper designs have leaked due to the cracks developing in the damper tube walls, which requires the removal and repair of the spring isolators.

As a result, the MRM and VPS Systems has become an accepted standard for vibration and shock isolation around the world. They offer superior isolation performance over timber and pad systems without the larger inertia mass, flooding issues, and higher maintenance cost associated with coil spring isolator systems. They are easy to install and maintain and have proven to be durable.

This document seeks to address the technical issues involved in the isolation of forging hammers. The technical understanding of the isolated hammer system can be best understood at three conditions:

1. When the ram is falling,
2. When the ram is performing work on the part,
3. When the ram rebounds.

When the ram is falling

Hammer capacity is generally rated by the amount of energy that can be delivered by the falling mass, which includes the ram and upper die. Most hammers are designed such that the falling weight starts with zero or near zero initial velocity and impacts the work piece at 6 to 7 m/s (18 to 23 ft/s). It is simple to calculate the hammer’s capacity by knowing the maximum falling weight by Equation 1.

The falling mass is calculated by taking the falling weight, w, and dividing by one gravity, \( g = 9.8 \text{ m/s}^2 \) or 32.2 ft/s\(^2\). The impact velocity, \( v_i \), should be in units of m/s or ft/s. The units of energy capacity, \( E \), are N·m = J for metric and ft·lb for imperial measure.

\[
E = \frac{1}{2} \cdot \frac{w}{g} \cdot v_i^2 \tag{1}
\]

In the case of drop hammers where the falling mass is accelerated by gravity alone, the energy capacity of the hammer may be determined by multiplying the falling weight by the height of the drop, \( h \), per Equation 2.

\[
E = w \cdot h \tag{2}
\]

Some hammers accelerate the falling weight by using a piston powered by steam or pneumatic pressure, or by hydraulic accumulators. These hammers typically hit with higher blow rates. It is important that the isolation system be applied with sufficient damping such that there is no movement when the next blow occurs. If the system is traveling downwards when the next blow arrives, the blow will increase the amplitude of the downward motion more than the prior hit, possibly overstressing the isolation system and building over several blows to an unstable situation. For soft mounting systems and when the falling weight is accelerated by the piston, the hammer’s recoil may unload the isolation system, possibly leading to instability. Usually, hammers have sufficient anvil weight so recoil is a minor issue compared to the shock caused by the ram doing work on the part.

When the ram is performing work on the part

The very short time in which the ram contacts the work piece and deforms the work piece is the most important time in the operation for the hammer user. There is a wide range of forging work that can be done in a hammer, so the magnitude of the blow force and the duration of the blow force can vary significantly. Hot open die forging work will impose a lower magnitude and longer duration force between the ram/part/anvil than a hot die forge blow. The finishing blows in die forging operations are the most severe. The analysis of the reaction of the anvil to the blow is actually simplified by the fact that the anvil is much more massive than the ram and the duration of the impact is very short. The ram travels downward until the anvil velocity is increased to equal the ram velocity, and then it rebounds.

Hammer builders understand that to develop maximum force on the part, the anvil must be much more massive than the ram. Figure 1 shows the theoretical hammer force relative to an extremely massive anvil that is 100 times as large as the ram. Note that once the anvil is more than about 10 times greater in mass, there is little change to the peak force attained.
The anvil’s inertia is used to generate the blow force. Softer isolation systems will slightly decrease the peak force of the blow. Both elastomer and spring type isolation systems reduce the available impact force to approximately 99.985% of the force compared with traditional timber support. Because only 0.015% is lost by employing a more efficient isolation system, the benefits to the hammer, foundation, personnel, and nearby equipment easily justify using an economical and reliable isolation system.

All hammer blows occur over a very short time compared to the oscillations of the anvil after the blow is struck. See Figure 2. The time for one oscillation of the anvil is the natural period of the hammer system. Traditional hammer support systems using oak timbers may be used as a benchmark for the performance for other isolation systems. Even with timber support, the natural period of the hammer system is much greater than the shock impulse duration of the ram striking the work. The difference results in a significant reduction in the force transferred from the anvil to the foundation. However, because the blow forces are extremely large, even small levels of vibration transmitted to the surroundings may be very disruptive and damaging. In general, the softer the support system, the greater the natural period and isolation effectiveness. The transmitted shock of the hammer will be reduced if the system natural period is at least six times greater that the shock force duration. Soft systems transmit less vibration to the surroundings than stiff systems.

The collision between the ram and workpiece transfers the momentum of the ram into downward motion of the anvil and the upward rebound of the ram. Once the ram and anvil reach the same velocity the ability of the ram to do work is finished, and the maximum force on the workpiece is achieved. After this point in time, the ram rebounds upwards and the anvil continues to travel downwards.

**When the ram rebounds**

Once the work has been done on the workpiece and the ram is rebounding, the impact shock from the ram is transferred to the anvil and the isolation system controls the motion and transmitted forces. Because the shock impulse is of very short duration, the hammer system can be accurately modeled by using the conservation of momentum principle. Because some energy is lost in the impact of the ram upon the workpiece, the collision is termed inelastic, but the conservation of momentum laws still apply.

\[
m_1 \cdot v_i + m_2 \cdot v_{2i} = m_1 \cdot v_f + m_2 \cdot v_{2f}
\]

Where:

- \( m_1 \) = ram mass
- \( m_2 \) = anvil mass
- \( v_i \) = ram velocity immediately before impact
- \( v_{2i} \) = anvil velocity immediately before impact
- \( v_f \) = ram velocity immediately after impact
- \( v_{2f} \) = anvil velocity immediately after impact

The ram will not rebound at the same velocity; this change can be captured in the Coefficient of Restitution, \( C_R \), defined by Equation 4.

Open die forging operations that cause very large deformations in a hot work piece will have very low \( C_R \) values of 0.1-0.2. As the work piece cools with very little deformation taking place, as in the case of finishing blows in a closed die forging, \( C_R \) values may be as high as 0.5-0.6.

The hammer system can be modeled very effectively as a single degree of freedom system where the supporting isolation material is a simple spring and dashpot as shown in Figure 3. The dynamic stiffness, \( K \), of the isolation system determines the amount of motion and the amount of force transferred to the foundation.

The damping component, \( \xi \), of the system dissipates energy as heat as the system is brought back to the static state of equilibrium. The damping has little effect on the first downward peak displacement of the anvil, but over several cycles the anvil slows to the at rest state.

After the ram has struck the work piece and the momentum of the ram is transferred to the anvil, the anvil will oscillate about the equilibrium position upon the isolation system at a frequency, called the damped natural frequency of the system, given by Equation 5.

\[
\Omega_d = \sqrt{\frac{K}{m_2} \cdot (1 - \xi^2)}
\]
From this simple model, the equation describing the vertical motion of the anvil mass, \( m_2 \), can be solved as Equation 6.

\[
x(t) = \frac{(1 + C_R) \cdot \nu_i \cdot \left( \frac{m_1}{m_1 + m_2} \right) \cdot \Omega_d \cdot e^{-\xi \cdot \sqrt{\frac{k}{m_2}} \cdot t}}{\xi}
\]

Reviewing the variables within Equation 6:
- The motion of the hammer system is reduced when the anvil weight, \( m_2 \), is increased and,
- The motion is increased with a softer, lower natural frequency system, \( \Omega_d \).

If a generally accepted limit of 7mm peak motion is applied, then it is clear that for coil spring and elastomeric systems there may be a need for the anvil to weigh more in order to maintain the natural frequency and isolation performance, as shown in Figure 4. Because of the cost to add a concrete or steel inertia mass, the MRM and VPS elastomer systems are more economical at the expense of a very small reduction in isolation effectiveness. A steel inertia mass is more economic since a steel plate is more dense and requires less space, thereby reducing the area and size of the foundation, see Figure 5. Field installations have proven the steel inertia masses to be more durable.

By Hooke's Law, the force transmitted to the foundation is the product of the isolation system dynamic stiffness, \( K \), and the anvil motion \( x(t) \):

\[
F(t) = K \cdot x(t)
\]

The forces generated in the die space are enormous. The exact magnitude and time duration are generally not known because measuring the force is not possible. However, experienced hammer operators can easily notice a significant reduction in body and arm fatigue of an isolated hammer compared to a traditionally supported hammer on timbers or thin pad material. The correct application of a well designed isolation system will result in a significant reduction of the ram's enormous impact shock. The MRM and VPS Systems transform the impact shock from a series of short duration, high magnitude impulses, as shown in Figure 2, to a series of longer duration, smaller magnitude impulses, as shown in Figure 6. Isolation of these impact shocks will decrease health problems, decrease building maintenance, decrease neighbor complaints, and decrease foundation costs.

**Summary**

The MRM™ and VPS™ Elastomeric Isolation Systems have proven to be a very effective for forging hammers. When compared to traditional forge hammer installation methods, like timbers and rubber pads, the isolation performance of MRM and VPS Systems are clearly superior, yet they’re faster and easier to install due to their unitized construction. MRM system isolation performance approaches that of coil spring systems, while VPS systems are slightly stiffer. Both are economical and extremely durable. See Vibro/Dynamics Technical Bulletin M/L 710 for vibration isolation comparisons.

Since Vibro/Dynamics Corporation has the technology and know how to design and build both MRM and VPS Elastomer and FS Spring Mount Isolation Systems, we are in the best position to recommend an isolation system that best fits your needs.
MRM™ and VPS™ Isolation Element Construction

MRM™ and VPS™ Systems are specially designed for die forgers and drop hammers. These revolutionary new products have the simplicity of a layered elastomer system, with shock isolation effectiveness similar to viscous spring isolators.

MRM Systems feature thicker, softer, elastomer modules for greater vibration and shock control. Vertical dynamic natural frequencies as low as 8 Hz are achievable. Typical isolation efficiency is 60-80% reduction compared to traditional oak-timber systems.

VPS Systems use stiffer, higher load capacity, elastomer modules for very effective vibration control in a more economical package.

MRM and VPS Systems feature unitized construction. Each Element is constructed using alternating layers of custom elastomer modules and galvanized steel sheets that are securely fastened together. The elastomer modules are molded from proprietary compounds for superior shock isolation, durability, and creep resistance. Each Element is encased in a protective foam barrier for further protection against pit debris.

All MRM and VPS Elements are designed to be simply lowered into the foundation as complete units. No difficult and time-consuming layout and “in the pit” stacking of pads and plates is required!

The unique design features of the MRM Isolation System result in superior shock isolation, trouble-free installations and long lasting performance.

Application Engineering

Vibro/Dynamics Engineers carefully analyze every application using proprietary computer modeling software. Motion and force transmission charts are provided to assist the customer in their hammer installation and foundation design.

Foundation guidelines are also provided to help the forger design and maintain the hammer installation. If an inertia mass is required for reduced motion, Vibro/Dynamics will assist in determining its weight and size.

Typical Foundation Layout Drawing

MRM4x9-12 shown with protective foam to seal against contamination from solid debris.
Installation Photographs

50,000 lb. Erie Steam Hammer on (6) MRM8x10-1-15711-G.

Erie 33,000 Steam Hammer on (6) MRM6x8-2-15703.
16 Ton Die Forger on 14) MRM8x8-16366-G

3 Ton and 8 Ton Open Die Hammers

10 Ton Die Forger Foundation
CUSTOMER LIST

COMPANY PROFILE

Since 1964, Vibro/Dynamics Corporation has been the leader and pioneer in the design and manufacture of vibration isolation and machinery installation systems for the metal forming, metal cutting, forging, can making, die casting, plastics, and woodworking industries. Our Products and Services are designed to effectively reduce transmitted shock and vibration and to provide a way to precisely level, align, and properly support industrial machinery.

No other isolator manufacturer offers a broader product line and the most solutions. Whether it’s a heavy blanker or forging hammer disturbing the neighbors, or an injection molder or die caster that likes to walk, Vibro/Dynamics has the best solution for you!

OUR COMMITMENT

Vibro/Dynamics provides high-quality products, responsive service, and technologically innovative solutions for our customers.

The commitment, desire, and ability of our personnel to design, engineer, manufacture, and supply valuable solutions to meet our customer needs is the foundation of our success, growth, and long-lasting customer satisfaction.

ISO 9001 CERTIFIED

Since 1997, Vibro/Dynamics Corporation has been unconditionally approved for ISO9001-2000 certification by ABS Quality Evaluations, Inc., Houston, Texas. We are very proud of our people and their effort in achieving this goal and maintaining this certification. We believe that this demonstrates our Company’s commitment to quality and service.

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