1 BACKGROUND INFORMATION (OBJECTIVE)

The effects of impact on design features, such as when an injection piston may bottom out on the injection housing, are currently verified using a transient analysis through FEA. This not only is time consuming but involves rather limited FEA resources. A simplified approach was desired that a mechanical designer could use in a first pass type of analysis.

2 BACKGROUND THEORY

2.1 SIMPLIFIED IMPACT

The force applied to a material during impact can be approximated if it is treated as a mass-spring system. According to Hooke's Law, a displacement x can be associated to a force F in a mass-spring system by the stiffness, or spring constant k: $F = kx$ (1). However, by applying the principle of conservation of energy, the impact velocity v can be related to the deflection:

$$kx^2/2 = mv^2/2$$

or rearranged:

$$x = \sqrt{mv^2/k} \tag{2}$$

Substituting back into (1):

$$F = k\sqrt{mv^2/k}$$

$$F = v\sqrt{km} \tag{3}$$

This equation is valid under the assumption that all of the kinetic energy is transformed into the strain energy of the deflected object, while neglecting energy lost to friction, damping, or plastic deformation. Furthermore, the mass is assumed to remain intact throughout the duration of the impact and there is perfect impact—no initial point or line contact—and so all of the kinetic energy is transformed into strain energy. The weakness of this method is that all the energy is assumed to be converted to strain energy thus yielding higher than actual impact forces. It would be beneficial to include the effects of material damping in this simplified approach in order to get a more realistic result.

Equation 3 can now be applied to the test components by treating each part as a mass-spring system and determining which masses and springs will contribute to the deflection of the impacting surface.

2.2 MASS-SPRING SYSTEM SETUP

The first step in the analysis is to determine which objects are moving and which remain stationary during the impact. Only the masses with a velocity will have their masses and stiffnesses represented in the mass-spring system. Stationary objects will be represented with only a spring.

The next step is to create the mass-spring system under examination. Any components that extend below the surface of impact are divided at the plane of impact. Figure 1 shows a simplified case of a stationary cylinder (cyl), and an impacting piston made of a flange (fl) and rod.

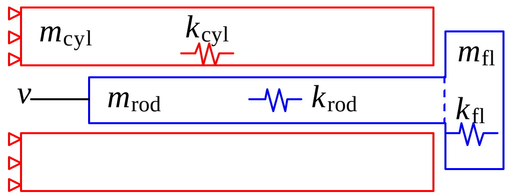


Figure 1: Impacting mass on stationary cylinder

The scenarios of imparted forces can be represented using two mass-spring systems as shown in Figure 2. Each system can further be broken down into a system of one equivalent spring and mass.

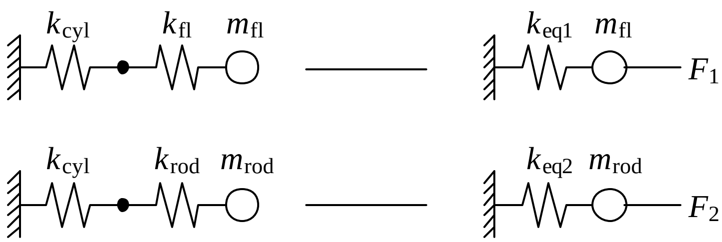


Figure 2: Mass-spring systems of imparted forces

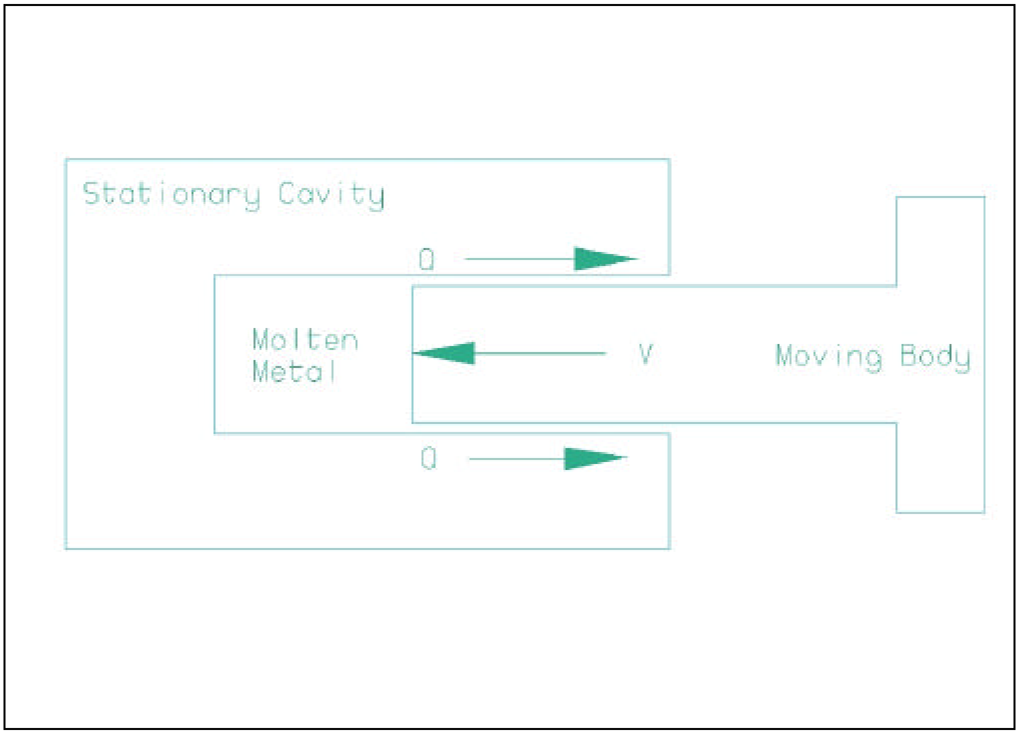
Because the springs are in series, they can be combined into an equivalent spring by taking the inverse of the sum of inverses of each spring constant. For example, the first spring constant equivalent would be:

$$k_{eq1} = (1/k_{cyl} + 1/k_{fl})^{-1} \tag{5}$$

It is this value of k_{eq1}, along with m_{fl} that is substituted into Equation 3 to obtain F_1. A module within our CAD software Unigraphics is called UG/Scenario which is a linear FEA code. This is used to determine the stiffnesses of the components and finally to determine the equivalent stiffness or spring constant of the system.

In reality, the two bodies have a thin film of hydraulic fluid between the two contacting surfaces. The removal of this thin film as the two surfaces approached, would also tend to remove energy from the system and provide additional damping. If time permits, determining the effect of this could be studied.

There is also the situation of our moving body impacting a molten metal in an enclosed volume. If time permits,we would like to determine impact forces and the effects of the molten metal's bulk modulus and damping on the impact forces. There is also a leakage past the impacting body (indicated by Q on the sketch) created by clearances between the two bodies. It would be beneficial to also determine the effect in general terms of the leakage flowrate on the impact force. A rough sketch is shown below.


Stationary Cavity
Q
Molten
Metal
V
Moving Body
Q