Christoph Weidemann
INTEC GmbH

SIMPACK Tips & Tricks Understanding Damping

The meaning and importance of damping is not so obvious as it is for masses, stiffness or friction coefficients. However, model behaviour and even integration stability may be severely influenced by damping. This article explains the basics for the most common application cases.

WHY IS DAMPING SO IMPORTANT?

SIMPACK Force Elements usually require a "damping constant", *d*, in the unit Ns/m or Nms/rad, or a corresponding damping-velocity characteristic given by an Input Function. These can easily be determined if a viscous damper, etc. is to be simulated. However, in situations where this value is not given, it will not suffice to simply ignore the damping. Usually, a missing or too low damping causes far too long integration times whilst a too large damping hides important oscillations or yields huge forces or torques. It is important to note that SIMPACK's SODASRT integrators do not superimpose a noticeable "artificial" numerical damping. Systems without explicit damping will actually appear undamped in the simulation.

WHAT IF THE DAMPING IS UNKNOWN?

There is a simple but effective method to *estimate* an appropriate damping coefficient. Just consider the system as a one-mass oscillator (see Fig. 1). If mass and stiffness are not explicitly given or not constant, then characteristic "effective" values must be used instead.

The estimation formulas are given in Fig. 2. With stiffness *c* and mass *m* known, the damping constant *d* can be derived from the natural damping *D*, which is usually given in percent. Typical values for *D* are 2% if the elastic material is steel, or 2–5% in case of elastomer. So, for example, a helical steel spring that suspends an effective mass of 10 000 kg with a stiffness of 10^6 N/m would require a damping constant of about 4 000 Ns/m. However, if there is sufficient additional damping from a separate viscous damper, then the material damping can often be neglected.

Most systems are more complicated than a simple one-mass oscillator but, the — rough — estimation often applies even in these cases. The masses connected by the spring must be combined by adding their inverted values: $1/m_{eff} = 1/m_1 + 1/m_2$ (Fig. 1). However, the easiest method for larger models with many masses is to check and adjust the different natural dampings with the help of an eigenvalue analysis.

DAMPING IN CONTACT SITUATIONS

The aforementioned method is also valid for contacts like in bumpstops or gearwheel teeth (Fig. 3) but, three special points must be considered here:

1) The damping must be applied only when the two bodies are in contact — this is ensured by, e.g., Force Element (FE) 018 or FE 005 with clearance functionality, but not when a simple bumpstop spring characteristic is used in FE 005.

2) When the contact is being released, the damping force must not exceed the remaining elastic force, in order to avoid "sticking". FE 018 has the option to switch the damping off during the expansion (parameter 7), the gear pair FE 225 allows a smaller damping constant to be used for the expansion phase — about 50–75% of the "standard" compression damping is recommended.

3) When contact Force Elements are used without Root Functions then the sudden switching of the damping force at the moment of contact may cause integrator convergence problems that lead to long calculation times and "peaks" in the results. The damping transition feature of element FE 018 and others removes this drawback by slowly increasing the damping along with the interpenetration. A recommended transition depth is about 1/10 of the typical interpenetration values.

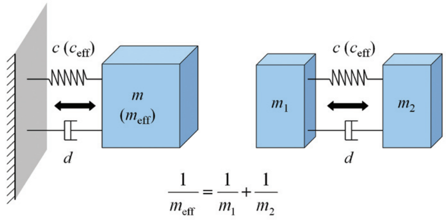

Fig 1: One- and two-mass oscillators

$$\leftrightarrow \quad d = D \cdot 2\sqrt{cm}$$

$$\circlearrowleft \quad d_{rot} = D \cdot 2\sqrt{c_{rot} I}$$

$$d(f) = \frac{c \cdot \tan\delta}{2\pi f}$$

Fig. 2: Relations between damping constant d and natural damping D (translation and rotation). If the loss angle δ is given the damping depends on the frequency f

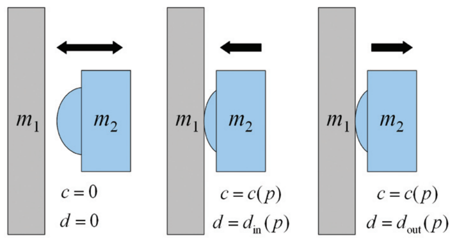

Fig. 3: Bumpstop contact with interpenetration p and different dampings for compression and expansion