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Shock loads

The most uncomfortable periods during a normal car ride occur during sudden accelerations, when passengers are thrown into the seat or belt. The same is true on machinery, where interrupted motion is generated by necessarily rapid sequences on automated, high-throughput packaging, printing, food processing, and assembly lines. This indexing motion isn't complicated and does not usually require sophisticated motion control; not too long ago it was generated exclusively by simple mechanical cams. But now for the sake of flexibility, some designs use servomotors to output rapid, interrupted motion.

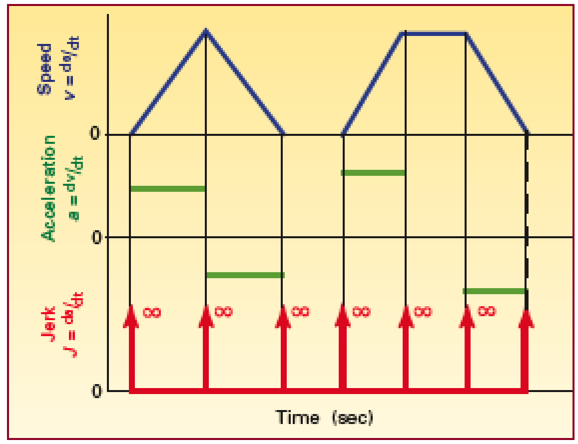
In the servo setup, the motion profiles used to generate start/stop and forward/reverse motion are often triangular or trapezoidal velocity profiles. As long as the derivative of acceleration (called *jerk*) at all points on these profiles is **finite**, there are no shock loads in the system and the servo solution gives good, smooth motion. If that's not possible because of a high-frequency motion sequence, additional service factors (depending on the expected magnitude of shock) must be used when the mechanical components are selected.

Q&A

Q: When can jerk become a problem in otherwise hearty systems?

A: Servomotors and drives for jerky applications are sized to peak (acceleration and deceleration) torque requirements, and to motor thermal-loading needs based on RMS torque; mechanical components in these systems are sized and selected based on inertial (dynamic) loads during acceleration, plus the torque required to overcome non-dynamic friction loads. Here's where problems arise: It is frequently assumed that there is no impacting or shock on servo-driven and controlled systems, excepting perhaps emergency stops. However, the two most common control profiles — triangular and trapezoidal velocity profiles — frequently become the inherent source for undefined shocks, especially if the system has low friction (for example, from very low damping) or mechanical backlash. These basic motion profiles feature constant acceleration value during the defined intervals. However, the derivative of the acceleration is not usually plotted or considered for systemcomponent layout — leaving multiple places where jerk value remains undefined and in effect, *unlimited*.

Undefined and detrimental



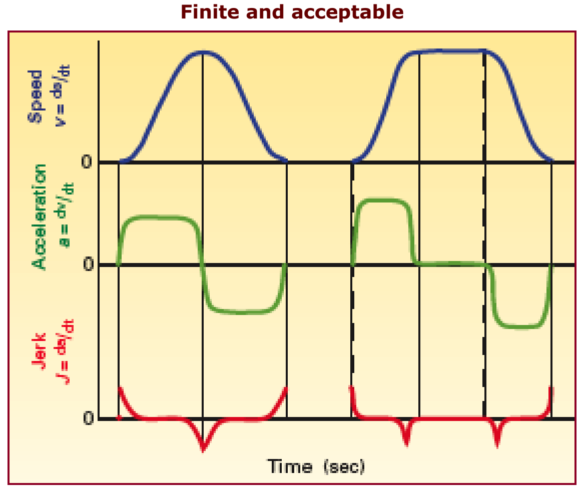
The derivative of the acceleration *j* = *da*/dt is called *jerk* or jolt. Sudden changes in acceleration (in the form of undefined jerks) should be avoided when designing a motion profile because they can damage systems.

Q: What kind of effect does jerk have on a system?

A: Undefined jerk in mechanical systems has practically the same effect as a sudden jam, crash, or emergency stop. This can cause significant shock loads, which can result in failure of the mechanical components — whether instantaneous or fatiguing over time. It's easy to predict and calculate dynamic loads during periods of constant acceleration, but it is extremely difficult to predict shock-load magnitude resulting from undefined jerk without thorough analysis of inertia, backlash, elasticity, and damping-characteristic interactions of involved system components. It's also difficult to measure peak stresses in mechanical components during shock loading.

One common misconception is that there is no high transient shock loading present in servo systems because the current draw of servomotors is limited. In fact, a current-limit setting on a servo system can only protect against overloads during a controlled acceleration — in short, if the value of jerk (j = *da*/dt) is defined. Cam designers have always known this, which is why a fundamental rule of cam-profile design is that jerk shall not become undefined at any point on the profile. To have a consistently finite jerk value, the transition between different acceleration levels must be a steady function.

Finite and acceptable



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Q: How can controllers protect against jerk?

A: Many motion controllers allow for programming of an *S* function instead of the "sharp and pointy" triangular profile. If the motion sequence is repeated in high frequency with multiple cycles per second, there isn't much time left for a smooth transition. The originally smooth profile becomes more pointy as the frequency increases and the jerk again becomes undefined. If the cycle rate (or frequency) of the motion profile is moderate and the system damping is significant or the clearances (backlash) in the system are negligible, impact and shock is dampened and doesn't damage the system. However, in highfrequency applications where jerk-induced shock is present, mechanical components should be sized with an additional safety margin to protect against the effects of hard-to-quantify shock.

This month's handy tips provided by Gerhard G. Antony, Ph.D., of Neugart USA LP. For more information, call (412) 835-4154 or visit **www.neugartusa.com**.