# Electrical and Mechanical Torque Limiting

## THE QUESTION

My company manufactures high-speed metal forming machinery. We have one application on a feed axis where we are encountering problems with the coupling. Every time the drive axis encounters a blockage due to operator error, the coupling is destroyed. This does not make much sense to me because I have the servo current limited to never exceed the coupling's torque rating. The coupling manufacturer has recommended trying a larger size, but we simply do not have the space for it. Since it is a high-performance application on a servo gearbox, I need zero backlash and my options are somewhat limited. What alternatives might be out there?

## Response provided by Niilo Nykanen, application engineer and quality coordinator, R + W.

Electronic current limiting is not always a 100-percent-effective way to prevent torque overloads in a mechanical system. On a servo motor it is relatively easy to set torque limits in the parameter programming of the machine. When doing so, one must remember that the electronic torque limit is at the motor only. This means that the motor's electronics do not account for the masses of gears, couplings, shafts, etc., further along down the driveline. Oftentimes a manufacturing process is many mechanical power transmission components away from the motor. Additionally, the servo drive and/or PLC monitoring the torque of the motor may not pick up an over-torque condition quickly enough to prevent damage from occurring. In the case of rotating equipment, there are often gearboxes and shafts which have a lot of rotating inertia not accounted for by electronic means. Additionally, linear applications impart their inertia into the rotating components, driving them when they stop or crash.

When we examine what happens in a machine crash, it is often useful to look at an impact force equation:

$$F = (.5m^*v\text{^}2)/s$$

*where:*

$F$ = force in Newtons
$M$ = mass in kilograms
$v$ = velocity in meters-per-second
$s$ = stopping distance in meters

Examining this equation tells us that the force imparted by an impact is directly proportional to the mass and/or velocity, while being inversely proportional to the stopping distance. That being said, the more massive any component is—and the faster it's moving—the more impact force exhorted during a crash. For many mechanical designers this is pretty obvious, although many electronic programmers do

not account for this principle while limiting currents and/or torque values. Because the stopping distance is in inverse proportion to the impact force, the smaller it gets, the more force is imparted by the crash. This can be very difficult to predict and plan for by system designers. It can be fairly straightforward to find the mass of mechanical power transmission components and know how fast they will be moving. What is difficult to gauge is how the machine will likely crash and what will cause this to happen.

Further examining the force equation above from a mechanical design side, one can see that the effects of a machine crash can be mitigated by keeping the mass of the moving parts to a minimum. One way to do this would be to use lighter materials, such as aluminum vs. steel, if possible. There are companies that produce hollow carbon fiber and aluminum line shafts for this reason. Slowing down the speed of moving parts also cuts down on the forces associated with a machine system crash. While decreasing speeds are not often a good option in the world of manufacturing machine building, designers can be creative. For example, in

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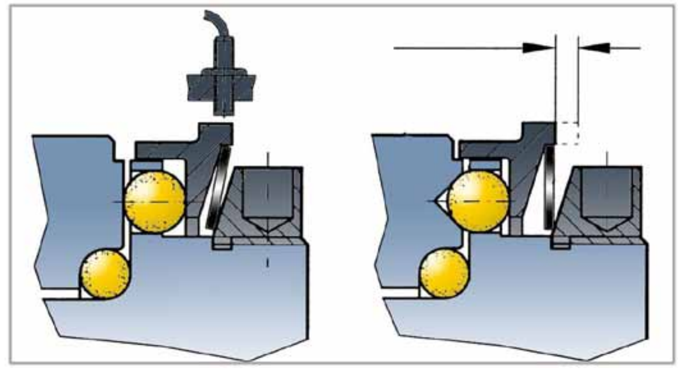
certain metal forming operations, making multiple parts in a slower fashion can be preferable to making single parts very quickly.

Because mass and velocity are directly proportional to inertia, decreasing either obviously cuts down on impact forces in a machine crash. Preventing a crash and/or cutting down the distance at which it occurs is difficult. One obvious method of protecting operators and preventing externally initiated jams would be to ensure proper guarding is always in place. This is an OSHA requirement around many processes and prevents operators from dropping tools, clothing—even themselves—into moving parts. Limit switches at the ends of actuation paths in conjunction with soft bumper stops can also be very helpful. A linear motion application, such as moving a machine center's cutting table with ball screws can benefit from this. One example would be a table moving past its limit switch with enough inertia from the workpiece that it shuts down the process by moving past the limit switch, but still hits the soft bumper at the mechanical stop. This is a case where the stopping distance would be significantly increased, which would decrease the impact force of the crash.

Because many people from different backgrounds are often involved in machine design, aspects of how the machine will operate holistically can be ignored by folks concentrating on their area alone. Mechanical drive guys may concentrate on the process and drive components without thinking about the full capabilities of the motor and electronics. Conversely, electrical programmers and designers do not always consider how the total mechanical inertia of drive systems can impact their overload settings.

Electrical designers are generally trained to implement multiple levels of overload protection into circuits. Most industrial control boxes normally have main breakers and or fuses and protection on each branch circuit. Many individual devices also have their own overload protection. This concept has not taken as deep of a root in the mechanical design side of machine building. Oftentimes drive components such as belts, chains, and couplings are designed to be mechanical fuses. Many systems are built with a series of shear pins to protect the drive line. A newer technology on the market is mechanical



torque limiters. These can be used to limit torque as well as linear chain or belt pull. A torque limiter is essentially a mechanical circuit breaker. Rather than having a component that breaks and needs to be replaced, a torque limiter can trip and be reset many times during its life.

An advantage of using mechanical torque limiters over shear pins and/or relying on a belt or coupling to break apart in an over-torque condition is that they are available in maintenance-free designs. The best advantage of using them in conjunction with electronic torque limiting is that they can usually be installed very close to the device where a crash could occur, as well as at multiple points in the system. Mechanical torque limiters are designed to instantaneously detect an over-torque condition and disengage very quickly. On occasion mechanical torque limiters are capable of disengaging an over-torque drive line before an electronic device, such as servo motor, even begins to pick up the condition.

In the newly developing study and career field of mechatronics, a mechanical torque limiter allows for an integration of mechanical and electrical design. An electronic proximity switch can be positioned near an actuation mechanism which moves in the event of an overload. This system works well because the overload is detected and disengaged, followed by an electronic signal to a PLC or process controller to shut down the part of the system with the over-torque condition. Because torque limiters can be placed in multiple parts of a machine, the source of the jam can be detected very quickly using proximity sensors.

To summarize the answer to the question, the peak process torque value must be known. This value must be calculated through the driveline back to the servomotor and be programmed into the servo drive parameters. Bear in mind that this will only truly protect the motor from the over-torque condition. The best backlash-free option to limit torque at the process is to install a mechanical torque limiter as close to the area that jams as is practical (both for maintenance of the process and possibly resetting the limiter). Essentially, machine builders should be aware of not putting all of their eggs in one basket when mitigating machine crashes. Circuit breakers, fuses and electronic limiting should be used at multiple levels on the electrical design. Torque limiters, guarding and bumpers should be employed on the mechanical design. As always, consult the manufacturers of each component if there are any questions or concerns. **PTE**