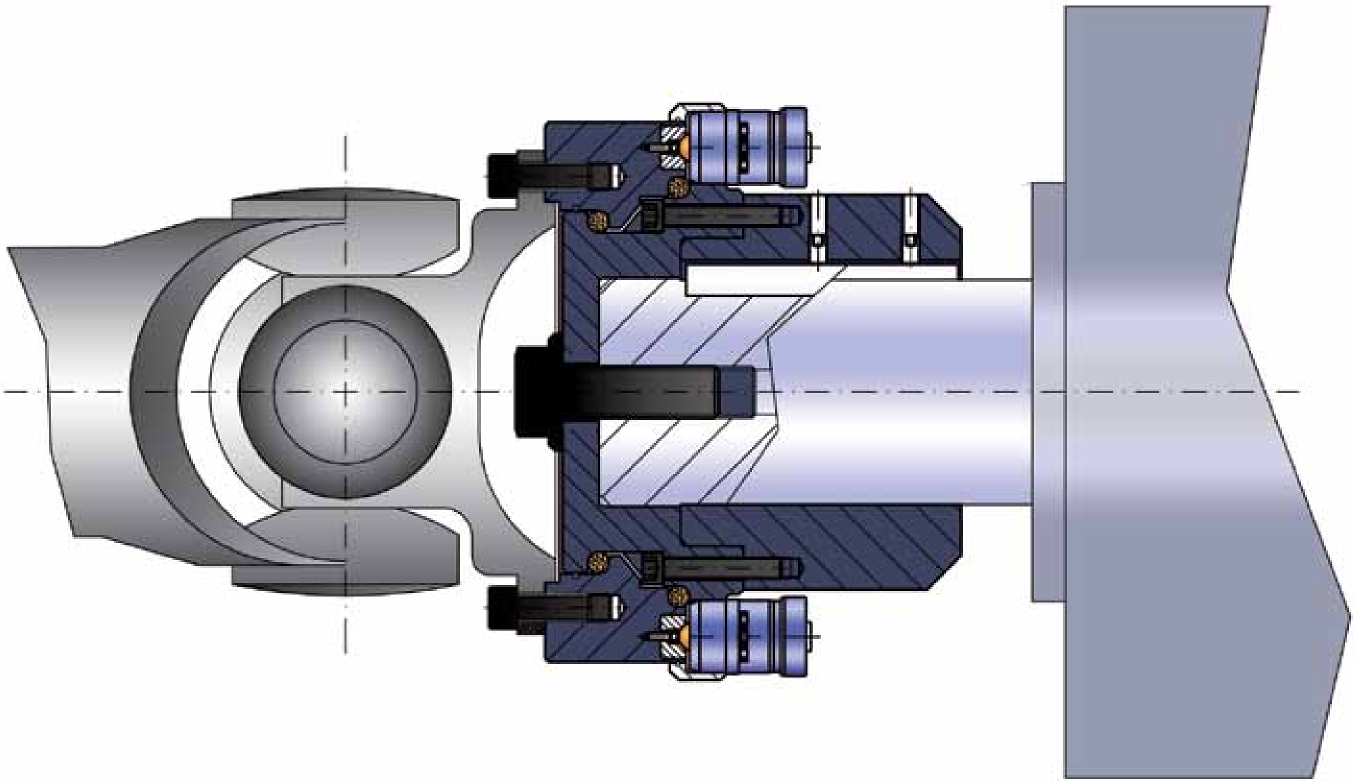


SAFETY ELEMENTS FOR

Mechanical Torque Limiters

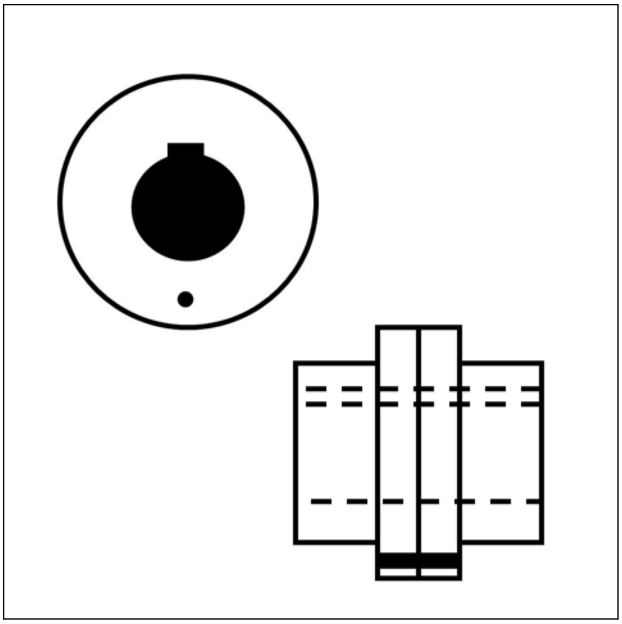
DESIGN CONSIDERATIONS FOR HEAVY EQUIPMENT

Andrew Lechner, R+W America

The world of high horsepower drives often calls for mechanical design to be approached from different perspectives. As motors, gearboxes and machines increase in size, power density can become disproportionate from one driveline component to the next, emphasizing the need for more rugged, robust and compact equipment. Precision mechanical components used in the packaging and light manufacturing automation industries, for example, can lack adequate scalability, becoming outsized quickly as drive requirements reach into the thousands of horsepower. This disparity is clearly evidenced when examining the design of modern torque overload release devices, the majority of which has focused on torque release values inappropriately low for use on large recycling equipment, gas turbines, windmill test stands, industrial crushers, and other heavy equipment requiring operation and disconnect at torque levels beyond 10 KNm. While market demand may be greater for smaller torque limiters, the availability of such devices becomes ever more critical as mass, inertia and destructive forces increase in high powered machinery.

One exception to the rule of disproportionate size increase is perhaps the oldest and most rudimentary form of torque overload release device; the shear pin coupling. In this case, two rotating bodies are linked by one or more pins with known yield strength, located at a pre-defined radius from the center of the rotational axis. At some torque level near the calculated maximum, the pin(s) will break, allowing for a complete separation of the driving and driven shafts, and a failure to transmit the excessive torque.

While shear pins have been protecting rotating equipment for centuries, they have become outdated to a large extent, as they lack accuracy and can require a great deal of time to repair after overload. In the interest of maximizing plant uptime and improving the accuracy of release torque, a variety of torque overload release devices has been developed with integral bearings and simplified mechanical reset features, of which a limited number have been reconfigured for high horsepower.



Two rotating bodies are linked by one or more pins with known yield strength, located at a pre-defined radius from the center of the rotational axis (courtesy of R+W).

The first widely used modern overload release devices came about in the 1930s, for use in the steel industry, where downtime can be severely expensive, and replacement of shear pins time consuming and dangerous. Utilizing the same fundamental principle of a set release force located at a specific center distance, it was for these cases that the spring tensioned, form fit torque limiter was developed. In spring tensioned torque limiters, ball or roller bearings are precisely loaded into detents machined into an output flange, which is made to break away quickly and accurately at a predefined torque level. This type of torque limiter can be designed to either ratchet or free wheel during and after overload, depending on size considerations and the rotational speed of the axis.

In general this design of overload release device is desirable since it normally allows for simple torque adjustment through the turning of a single screw or spanner nut. Available ratcheting features also represent a very fast and convenient means of recovery from overload since all they require is either low-speed operation or manual back driving of the axis after the blockage has been cleared. Since their initial development, many hundreds of designs of "ball-detent" and "pawl-detent" mechanical torque limiters have been introduced, with a variety of adaptations made for high speed, high accuracy, light weight and backlash-free operation.

However convenient, these torque limiter designs tend to fall off at torque levels greater than a few thousand Nm. The basic problem is that overload breakaway devices rely almost exclusively on torque as a measurable component of power. Practical implementation of high horsepower drive systems normally involves a slow, steady increase in the rotational speed of an axis, where the torque required for instantaneous acceleration would be overwhelming. Drive shafts and gearboxes therefore are not typically required to handle the severe peak torques associated with precipitous acceleration and deceleration of the load inertia, as might be found in lighter manufacturing systems. As a result they tend not to be as large as a proportionate size increase might require in terms of pure torque capacity. This poses a torque density problem for mechanical overload devices.

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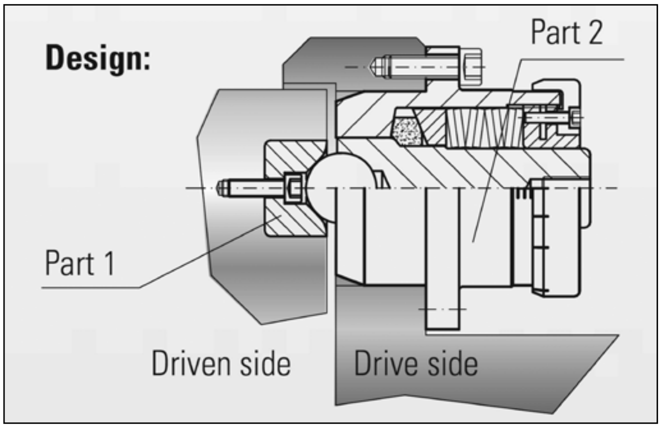
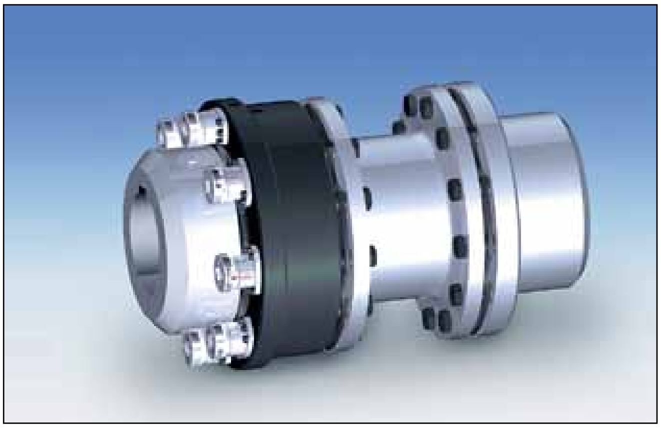


Part 1 is the engagement receptacle and Part 2 is the module with self contained, spring loaded plunger (courtesy of R+W).



Mechanical torque limiter design remains a dynamic field where safety and space considerations are always a factor (courtesy of R+W).

Beyond 10 KNm, common overload release designs become impractically large in outside diameter; the limiting factor being primarily the spring set used to load the components together. Since industrial gearboxes, motors and pumps tend to grow in diameter at a much slower rate than these types of torque limiters, as power increases there comes a certain point at which a traditional single-spring, form-fit torque limiter makes no sense at all, and it would tower over the equipment it was designed to protect. Clearly the lever arm component of the torque limiter design must be addressed, and the simple answer is to substantially increase the force by which the individual transmission elements are loaded into the output.

There are two widely accepted approaches to overload release devices for torque in excess of 10 KNm, both of which seek to increase force over a reduced lever arm distance. One is a compact, simple design involving hydraulic pressure applied between the two otherwise free-spinning surfaces. The other is based on a modified spring tensioned device similar to those previously addressed. Each has its advantages depending on the desired result.

Hydraulic torque limiters basically involve the application of hydraulic pressure between the two otherwise freely spinning surfaces. One or more chambers are inflated by hand to the desired pressure level, calculated as a function of release torque and based on charts provided in the manufacturer documentation. Special fluids are used to guarantee a constant coefficient of friction throughout various operating conditions. These chambers allow for a high level of force to be applied over a very small surface area. When the desired release torque is reached, the output will begin to slip against the input, causing the hydraulic valves to be sheared off, purging the fluid and fully releasing the input and output components of the torque limiter. An integral bearing allows for the load inertia to coast to a stop without further damage to the machine components or the torque limiter itself. Reconnection of the torque limiter involves replacing the valves, refilling the chambers and resetting the pressure.

Some manufacturers are increasingly providing these torque limiters as fully integrated flexible safety couplings, such as jaw, gear and disc pack types to name a few (courtesy of R+W).

Compared with shear pins, hydraulic torque limiters allow the user to maintain strict control over the disengagement torque setting, which can be unpredictable in the case of shear pins. They otherwise represent a compact solution for accurate torque overload release at tremendously high torque values, handling as much as 10,000 KNm. What they do not offer is a major reduction in the time required to recover from an overload event.

For maximization of plant uptime, a slightly more sophisticated form of the ball-detent design still offers the fastest means of re-engagement after overload release. Several decades ago, torque limiter manufacturers began to develop self-contained tangential force modules, based on a plunger design. The torque density problems associated with traditional ball-detent torque limiters are then addressed through the use of one or more of these individually spring-tensioned elements, across which very large tangential forces can be tolerated.

Since the individual torque transmission elements are required to provide their own back stop for the spring tension, these devices incorporate an array of small blocks, which are forced outward to clear the way for the plunger core to retract into the housing after sufficient tangential force has been applied to actuate the system. The result is a "snap action," which causes a prompt retraction of the plunger into the housing within a few milliseconds of overload. Once again, an integral bearing allows for the load inertia to coast to a stop without further damage to the machine components or the torque limiter itself.

The key advantage to this design is the quick reloading of the individual elements into the output flange with either a gentle blow from a mallet or light pressure from a pry bar. Once the driving and driven components of the torque limiter are rotated back into the necessary orientation, re-engagement of the torque limiter takes place quickly and easily. Depending on practical considerations, pneumatic actuation systems can occasionally be incorporated to facilitate automated re-engagement, though future designs are likely to incorporate a more widely applicable, self-contained and fully mechanical reset function.

As with traditional ball-detent torque limiters, spring tension can be adjusted through the rotation of a nut, only in this case the elements are individually adjusted to the desired tangential force value, and a torque calculation is made based on the number of elements and their distance from the center of the rotational axis. While the earlier designs of safety element torque limiters involved special datasheets to be used in conjunction with measurements taken from the spring height, increasingly, manufacturers indicate the correct nut location with a marked scale. Coarse adjustment is then accomplished through the addition or removal of safety elements, which is made increasingly more plausible by torque limiter designs with the maximum number of receptacles pre-machined into the base element, and with simple covers installed to guard them from contamination. This eliminates the need to ship the torque limiter back to the manufacturer for rebuilding in the case of gross miscalculation of the torque requirement.

Because of the modularity of the design, safety element type torque limiters can be used for virtually infinite torque release values, depending on the size and number of elements used, and limited by the maximum diameter allowed by adjacent equipment. For this reason, individual safety elements are normally made available for incorporation into existing machinery designs or completely customized coupling systems, including some used for linear force limitation.

For the most part, safety element torque limiters are supplied as a pre-set and self-contained package for integration into timing sprockets, sheaves and cardan shafts. Some manufacturers are increasingly providing them as fully integrated flexible safety couplings, such as jaw, gear and disc pack types to name a few. Increasing levels of customization are known to include special materials, integral brake discs, high temperature felt seals, and added bearing support. As is the case in any field of design, manufacturers are driven to improve reliability and ease of use, while simultaneously reducing weight and space requirements for installation.

While the basic principles are highly similar to those that have been known since some of the first machines were ever built, mechanical torque limiter design remains a dynamic field. Functionality, space restrictions, safety considerations and a continuously changing machinery design environment drive the need for even the most minor components to evolve. Mechanical torque limiters are no exception.

For more information:

R+W America, Inc.
1120 Tower Lane
Bensenville, IL 60106
Phone: (630) 521-9911
Fax: (630) 521-0366
www.rw-america.com

Andrew Lechner *has been product manager at R+W since 2001. He has written articles on thermoplastics in coupling design and proper selection of bellow couplings for previous issues of* PTE *magazine.*