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Implementing technological advances in a vintage mechanical drive design will result in a more efficient, durable system that can meet increased production demands.

The quality of mechanical drive system components has evolved and improved over the years. Advances in drive system design, manufacturing capabilities, and materials technology allow existing components to be replaced with more durable and efficient equipment with significantly higher power densities.

Technological improvements

Some of the greatest advancements in drive system components have occurred with the girth gear set, consisting of a gear and pinion. Material technology, manufacturing techniques, and rating standards have changed, and now provide uprating and upgrading opportunities to facilities with vintage mechanical drive system designs.

First, material technology for steel castings has been refined, resulting in techniques that have drastically improved quality, integrity, and component hardness. In the 1950s, state-of-the-art in material technology could produce gear blanks with a hardness of only 180 HB (typical) or 225 HB (maximum) and pinions with a hardness of 265 or 285 HB. Now, with the availability of high hardness girth gears and through-hardened or carburized pinions, durability and strength rating increases can be realized with the installation of such components. When installed as a replacement for an older drive system, these latest technology gears and pinions can achieve durability rating increases exceeding 100 percent and strength rating increases exceeding 50 percent.

Second, manufacturing methods have improved component quality. Tooth accuracy of pinions and gears is significantly greater because of modern machinery used in the manufacturing process. The gear tooth quality that 1950s or earlier vintage gear cutting equipment could produce is in the range of AGMA 6 for gears and 8 for pinions, compared with today's available quality levels of AGMA 10 for gears and 12 for pinions.

Third, the equipment rating standards developed by the American Gear Manufacturers Association (AGMA) have changed. In an attempt to quantify difficulties that arose in the manufacture of such large gears, rating methods differed for open girth gears and enclosed gears. Originally, the AGMA reduced the rating of large gearing, such as girth gears. Now, because of improved materials and manufacturing methods, rating standards more accurately model the actual performance of all gears.

Options

Depending on the required increase in production and the budget, there are different uprating and upgrading approaches to achieve the necessary output level: replace pinions, recut girth gears, replace girth gears, uprate the gear drive and couplings, or a combination of these options.

Replace pinion in girth gear set.

Taking into consideration improvements in materials, manufacturing, and rating standards, a higher hardness pinion can be installed to increase the power density and production level of a vintage girth gear set.

AGMA rating practices allow a rating increase by increasing only the hardness of the pinion. The replacement pinion can be either through-hardened or carburized, depending on the rating increase desired.

It is important to note that the rating increase from replacing the pinion assumes the girth gear is in like-new, as-manufactured condition. This is typically not the case and, therefore, the full rating increase may not be realized. An exact value for adjusting the rating of the girth gear set due to gear wear or damage cannot be assessed without a thorough inspection of the gear.

When replacing a girth gear set's pinion, tooth modifications can be performed. Grinding the new pinion's teeth to specific modifications will increase load carrying capacity and operating contact, and extend service life.

For a typical application such as a grinding mill, a significant production increase may be possible by increasing the number of pinion teeth. This results in a lower total gear ratio, which increases the mill's speed and, in turn, production ability. The exact speed increase depends on the original number of pinion teeth. For example, increasing the number of pinion teeth from 19 to 20 will increase the mill's speed by 5.3 percent. A 4.5 to 6.25 percent increase in speed is possible when adding one additional pinion tooth. But an increase in speed will put the driven equipment closer to a system's critical speed. The original equipment manufacturer should be consulted when making this change.

Increasing the number of pinion teeth may require that the girth gear set's center distance also be increased. Allowance for this is usually available in the pillow block foundation bolt holes. If not, the bolt holes can be slotted to accommodate the increased center distance.

When implementing any system upgrade that will increase speed, remember that the motor must be capable of providing the extra power required to drive the system at the increased speed. This is typically not a problem, as most systems draw less than full motor power. If a facility is operating at motor nameplate power, adding additional cooling to the motor can usually increase the motor power. When faced with this situation, the motor manufacturer should be consulted for a proper recommendation.

Replace pinion and recut girth gear.
Recutting the teeth of a girth gear restores the original tooth form and makes it possible to take full advantage of a new pinion (see Fig. 2). In addition, the gear structure is completely inspected during the recutting process and any defects are repaired. This provides the structural integrity required to transmit the increased torque. Defects in the gear structure are identified by nondestructive testing methods, such as magnetic particle and ultrasonic inspection, and weld repaired (see Fig. 3). If required, weld repairs are made before the girth gear is completely stress relieved and/or heat-treated to ensure proper integration of the repair with the base metal (see Fig. 4). All surfaces of the gear are machined to ensure dimensional accuracy and geometric tolerances that meet or exceed the original design.

A complete design review is undertaken to validate all aspects of the gear and pinion design and manufacture. This updates the design with current design methodologies and rating practices.

The new tooth surfaces also yield increased efficiency benefits. A recut gear operating with a new pinion restores the gearing to 99 percent or greater efficiency (see Fig. 5). This can translate into significant operating cost savings. For example, a 1 percent increase in efficiency for a 1000 kW (1341 hp) mill will result in savings of $3500 per year, using an electricity cost of $0.04 per kWh.

Fig.2 Representative tooth damage that can be repaired by recutting the teeth.

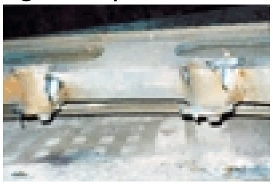

Fig. 3 After cleaning, nondestructive testing identifies defects in the gear blank structure that then are re

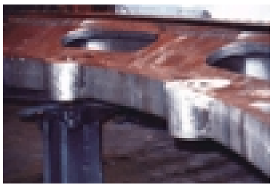

Fig. 4 The defects identified and removed in Fig. 3 have been finish weld repaired. The repaired areas a

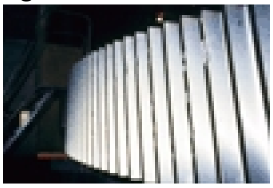

Fig. 5 Major tooth damage has been removed and the tooth-working surface has been restored to like-

The cost of refurbishing a girth gear will vary, depending on the amount of repair that is required. Typically, refurbishing an existing girth gear is 30 to 50 percent of the cost of a new gear. The exact final cost heavily depends on the amount of weld repair required.

Replace pinion and girth gear.
A third uprating option is replacing both the pinion and girth gear. This allows the use of the latest design methodologies and rating practices, and takes advantage of the improvements in manufacturing and materials technology.

Replace gear drives and couplings.
Uprating the girth gear and pinion is useless if the main gear drive and/or couplings cannot transmit the increased torque. In some situations, these components will need to be uprated or replaced with new counterparts.

The gear drive can be replaced with a higher hardness gearing. For a gearbox with through-hardened gearing, the typical uprate using only a carburized pinion is 15 percent. Replacing both the pinion and gear with carburized elements will result in an uprate of up to 50 percent.

At the same time the gearing is replaced, new bearings using latest material and manufacturing technology should be installed. Bearing manufacturers have released E-type spherical roller bearings that have significantly more load carrying capacity than similarly sized standard bearings. The typical uprate using E-type bearings in place of standard bearings is 15 percent.

Rating practices for bearings include adjustment factors for lubrication, cleanliness, and load zone. These factors can either increase or decrease the calculated life of a bearing. The result is a much better understanding of the actual operating life of the bearing. New seal design technology such as Taconite, Magnum or noncontact also can be installed during a gear drive upgrade to provide better leak protection, reduced operating temperatures, and longer seal life.

New seals with higher allowable operating temperatures, such as Viton seals, are additional technological improvements that can upgrade and uprate a vintage drive system.

Shaft couplings have experienced a similar uprate over the past 30 years. New materials and manufacturing processes have increased shaft coupling power density 70 percent for grid-type couplings. The rating of gear-type couplings has increased at least 55 percent, size for size. In essence, a dimensionally interchangeable coupling with a much higher rating can be used or a smaller coupling with the same rating can be installed to significantly reduce costs.

There are many ways to increase the power density of existing mechanical drive systems in order to meet increased production demands. Improvement of materials, manufacturing techniques, design methodologies, and rating practices over the past 40 years has resulted in mechanical drive systems that are no longer a limiting factor in achieving higher production goals. **MT**

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