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Crowning: A cheap fix for gear noise and misalignment problems

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Noisy gear trains have been common problem for design engineers for a long time. With today's demands for smaller gearboxes transmitting more power at higher speeds - and, of course, greater efficiency - the situation isn't getting any easier. Here's a look at how crowning can reduce vibration and limit noise without increasing costs.

Standard methods

Some popular solutions to the noisy gear problem include enlarging the pinion to reduce undercut; using Phenolic, Delrin or other noise-absorbing products, where possible; or changing to a helical gear train.

Other methods include tightening specifications to ensure greater gear quality or redesigning the acoustical absorption characteristics of the gearbox. Occasionally, experimentation with gear ratios can limit harmonic frequency amplification, which otherwise can cause a gearbox to amplify noise like a finely tuned stereo system. Engineers can also study material and hardness requirements, so that modifications may be made to minimize heat-treatment distortion or possibly eliminate the need for heat treatment entirely.

Particular attention must also be paid to gear geometry to ensure maximum contact.

Crowning

Another approach to the gear noise problem that yields good results is crowning or barreling of

the teeth. This technique involves changing the chordal thickness of the tooth along its axis. This modification eliminates end bearing by offering a contact bearing in the center of the gear.

A second benefit of the crowning approach to gear cutting is the minimization of misalignment problems, caused by inaccurate machining of the casting, housing, shafting, gearboxes, or bearing journals. Crowning can also reduce lead problems in the gears themselves, which causes the gears to wear unevenly and bind because of eccentricities and position errors. Obviously, a gear with a center contact is less affected by discrepant manufacturing or design; furthermore, one can reduce the backlash requirements and allow the gears to wear in rather than wear out.

Shaving is a secondary gear-finishing operation done after rough hobbing or shaping to create the desired crown. Crown shaving has long been a popular method, especially in manufacturing coarse-pitch gears. The recent evolution of gear equipment capable of crowning while cutting eliminates the need for shaving just to achieve a crown.

Manufacturing options

Two variations of the crown-shaving method will produce a gear to compensate for off-lead or misalignment conditions. One approach produces a crown by rocking the table during the reciprocation of work piece and cutter. The degree of crown is readily changed by this method. The other approach is plunge feeding, which requires dressing the shaving cutter to the desired crown. Generally, it is faster to plunge feed, but the technique can subject the cutter to greater wear. Of course, it is more difficult to change the crown, provided one starts with good quality gears. Shaving improves the quality of profile and reduces error in the gear tooth, through the cutting and burnishing action of the cutters.

The crown form can be produced on gear teeth in several other ways. One method is to shape the gear with a crown cam in the shaper back-off mechanism. The proper radius of the gear is calculated using the amount of crown on the flank and the pressure angle of the gear. Unfortunately, the blocks, while not complex, tend to be expensive.

The latest generation of gear equipment has made two methods of crowning while hobbing popular. Both methods produce crowns by increasing and decreasing the center distance of cutter to work piece. The first method uses physical copying of a template by a hydrocopying or mechanical following device. This allows taper hobbing or can even create sinusoidal wave forms, if desired. More recently, the second method, CNC hobbing, has become commonplace. Depending on software limitations, CNC allows cutting gears in almost any desired form. A disadvantage to this approach is the high cost of the equipment, though the payback has decreased considerably, in recent years.

New CNC shapers can cut a crown gear or spline without the need to buy a special crowning cam. On our Gleason Pfauter P 300 ES, for example, we can crown by cutting a slight right and left hand helix angle along the face width of the part. This leaves the root diameter straight. We also have a Bourn & Koch Fellows MS 450 with a U-axis for controlling the back-off. It can be programmed to move the cutter spindle in and out during the stroking cycle to crown the tooth by cutting deeper at the ends of the face width and more shallow at the high point of the crown.

Potential users

Users of heavily loaded gears have been using crowning for quite some time. Another area ripe for crowning is in the manufacturing of hydraulic wobble motors. Here, the application is strictly for misalignment problems rather than for noise reduction. An allied area involves heavily loaded pinions used in actuators for aircraft control surfaces. Generally speaking, it is more

advantageous to crown the pinion because it makes more revolutions per minute and may generate more noise. In this case, it is of paramount importance to compensate for load deflection.

Unfortunately, few companies in the United States have been applying this technology to commercial fine-pitch gearing. However, the few manufacturers who have tried it are pleased with the results. Some users have reported a 5 to 10× reduction in noise, accompanied by less vibration, wear, and power draw.
Prime candidates for use of crowning techniques are the small fractional horsepower motor manufacturers or anyone dealing with spur or helical pinions that are susceptible to noise or misalignment. Because crowning on foreign gear-hobbing equipment has been available for a longer time, this method has been developed to a greater extent in Europe.

American manufacturers would be wise to take advantage of this technology. Exploration of crowning as a solution to noise and misalignment problems can produce a real competitive advantage for gear manufacturers and users alike.

Links:
[1] mailto:ken.korane@penton.com
[2] http://forestcitygear.com
[3] http://machinedesign.com/content/image-february-12-2010-336pm-0212