With this issue *Gear Technology* introduces what will be a continuing feature accepting and addressing reader questions on all things gearing, i.e.—*Ask the Expert*.

Here's how it works: Have a standards question? Design query? How about a backlash or tooth profile problem that needs fixing? Or maybe you need a material recommendation or are wrestling with a tricky noise issue. And just which lubricant is best for those open gearing applications?

Well, you need look no further. That's because *Gear Technology* will call upon its deep reserve of industry experts from around the world to help solve your dilemma and get you back on track—whether on the drawing board or shop floor. Any question—if it's about gears—is fair game.

Got a Gear Question?
Ask the Expert!

Our extensive roster of licensed engineers, engineering school professors, respected consultants and others are here for you.

And did we mention there is no fee for receiving this expert knowledge acquired by these individuals over many years of hands-on experience?

Simply e-mail your question—along with your name, job title and company name (If you wish to remain anonymous, no problem)—to:

Jack McGuinn, Senior Editor
jmcguinn@geartechnology.com

The Question

I am currently writing a design procedure for the correct method for setting up bevel gears in a gearbox for optimum performance. I have read your excellent guides, but the answer I seek is not written in your guides or I have not found it. I have written about shimming so that the correct mounting distance is achieved and the correct backlash is maintained. However, when it comes to the bearing, we have a choice of pre-load or end-float.

What is the best way to maintain the correct mounting distance, and, hence, contact tooth pattern?

If a pre-load is used on the bearing, then this would push the bevels together. If end-float is used, the gears would be allowed to move apart in the axial direction, possibly shifting the contact tooth pattern over to the edges of the teeth.

Is there any literature on this subject or is it possible for you to recommend a suitable method? I believe the bearings should be pre-loaded to take out the axial play so that the teeth are always in contact. I believe (this) is an issue that not many design engineers think about. Thank you.

Stephen Marsh, design engineer
Goodrich Actuator Systems U.S.

Answer Number One

Dear Steve,

It is necessary to point out that—should spiral bevel and hypoid gears be assembled in their housing—the axial, radial and vertical positions—as well as the shaft angle—must be correct within a certain tolerance. The vertical position (offset) and the shaft angle are given by the machining operation of the housing. Bevel gear sets with a module of 4 mm already show a severe contact pattern change with a misalignment of three angular minutes if the profile crowning is small. An offset error of ± 50 microns leads to a contact pattern change of about the

continued

same magnitude; the gearbox housing accuracy and stiffness must be assured accordingly.

Assembly of a gearbox affords one the opportunity to realize and understand the optimal axial location of pinion and gear, independent of the housing accuracy. At the outset there already exists a 50-micron deviation of the axial pinion location from the correct position, leading in turn to more severe changes than mentioned in connection with the offset. The axial ring gear position is vital due the fact that it controls the backlash. A 50-micron error in the gear axial position might change the backlash by 35 microns.

Axial pinion and gear positions depend not only on the geometrically correct assembly, but also on the correct preload on the pinion shaft and gear carrier bearings. The pinion shaft should be supported with tapered roller bearings in an "O" or "X" arrangement. The pinion bearing preload can be achieved with pre-machined bushings or with a collapsible bushing; the latter is preferred for modern, low-friction bearings. The axial position of the bearing pre-assembly must be achieved independent of the bearing preload arrangement with shims, as shown in Figure 1, Items 1–2.

After the pinion is in position, the tapered roller bearings of the gear assembly are pre-loaded; at the same time the gear assembly is placed axially in the housing and the threaded rings shown in Figure 1 are torqued (Items 3–4). However, during torquing the deflection of the bearing preload influences the axial ring gear position. In turn, the gear preload influences the gear position due to asymmetric housing deflections. The backlash must be measured and threaded ring corrected. In order to keep the preload constant (before and after a ring gear axial position change) the one ring must be rotated clockwise and the opposite side ring counter-clockwise by the same ring rotational angles. Shims or snap rings of various thicknesses can also used to position the gear sideways to the correct backlash.

If a gear set is built in the correct position, using the recommended preload, a tooth contact pattern (for very light torque) then matches with the theoretical tooth contact analysis results. The size of the contact pattern increases if increased torque is applied in the operation of a bevel gear transmission; subsequently the housing, shafts and bearings deflect from their initial position. The so-called "V-H-deflection characteristic" of a bevel gear set can be matched to the typi-

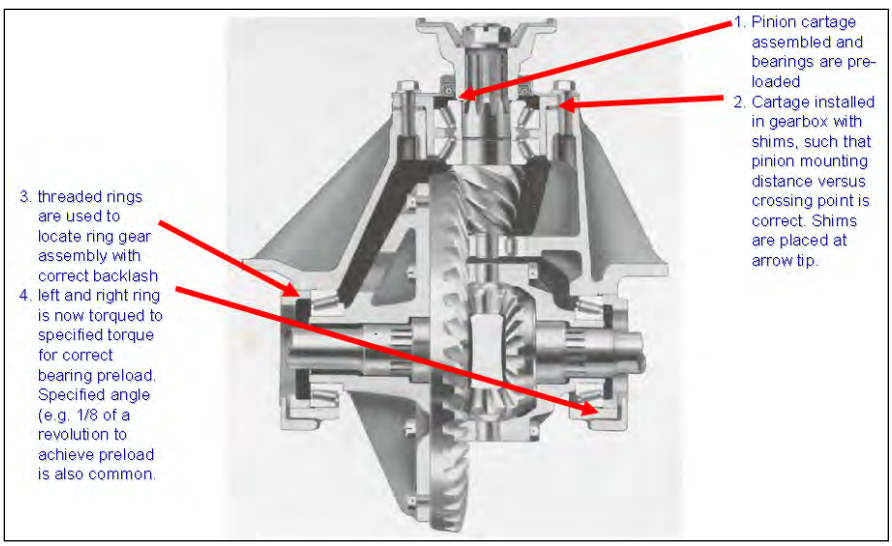

Figure 1—In Items 1 and 2 the axial position of the bearing pre-assembly must be achieved independently of the bearing preload arrangement with shims. After the pinion is in position the tapered roller bearings of the gear assembly are pre-loaded; at the same time the gear assembly is placed axially in the housing and the threaded rings (Items 3 and 4) are torqued.

cal deflections under load. As a result, increasing load will move the center of the contact pattern towards the larger gear diameter, while the size of the contact area increases. The contact area should cover the entire flank surface (without edge contact concentration) if the nominal load rating is reached.

If the preload is too low, pinion and gear then move away from their build position as soon as load is applied and edge contact occurs. If the preload is too high the efficiency of the unit drops and the operating temperature increases.

Best regards,

Dr. Hermann J. Stadtfeld,
Vice President
Bevel Gear Technology/ R&D, Gleason Corporation

Answer Number Two

Mr. Marsh,

You have touched on the "fly in the ointment" in setting position; the bearings play a significant part in setting proper position. The real issue is not so much where you *set* it, but more in where it *runs*. If you assemble bearings with preload, you usually do not have much variation in measurement; you are essentially working with some elasticity in the components, and the dimensional changes are small. There is always some variation in measurement and shim sizes in the nature of one or two thousandths of an inch, and bevels are not normally that sensitive where it is a problem.

End-play, however, can cause quite a problem. The traditional response would be to set the gears in the position they will run. That is, if the gears will move in a particular direction under load, force them that way at assembly, taking out endplay in that direction. If the gears run in both directions—or the operating conditions greatly affect endplay or position—the technique is not so simple.

Bearings typically like to run at a preload. If operating conditions are stable and the housing and shafts do not move or grow, the preload can be built-in at assembly. Ideally, that is the case.

However, if there is growth or movement, you want the bearings to go to light preload so all the rotating elements share the load. If you have done an advanced analysis of the system to predict the growth and movement, use the results to compensate for position at assembly. I might also add that those results should be considered in the bevel design to manufacture the teeth with the proper loaded tooth contact pattern. Most customers cannot predict how the components will be affected in service and, unfortunately, there is only one solution—testing. Build with your best estimate and then run the gearbox at operating conditions; then check to see what happened. Tear down and re-shim to compensate. What you are *really* looking for is, what is the *loaded* contact pattern? Regardless of how it looked at assembly, it is how it runs that is important.

Besides the papers and videos on our website, there is a national standard on bevel gear assembly: ANSI/AGMA 2008-D11—Assembling Bevel Gears. This document was just updated to include information on how to conduct a contact pattern test. There is some duplication with the material on our website, but it is still a useful document with additional material.

Hope this helps.

Robert F. Wasilewski,
Design Engineering Manager,
Arrow Gear Company