when the sound is processed through a spectrum analyzer. Reducing the amount of backlash in the gear train and reducing the strength of the pulsing by improving the gear quality (runout, accumulated pitch error) are the approaches generally taken to alleviate this condition.

Standard recommended "normal" backlash for precision bevel gears is broken down in Table 1.

"Normal" here does not mean "regular." Normal is an engineering term meaning "at right angles to." In this case, it means at right angles to the spiral angle and the pressure angle at the heel end of the gear teeth at about mid-tooth depth. A dial indicator is used to measure the normal backlash. This is not always convenient when the gears are in the assembly. A convenient and accurate way to check the backlash in an assembly is to measure the backlash "in the plane of rotation." This can be accomplished by attaching a simple lever to the end of an accessible pinion or gear shaft. The dial indicator should be positioned so that the probe is contacting the lever at approximately the pitch radius of the teeth. The conversion from plane of rotation backlash (PRB) to normal backlash (NB) is:

NB = PRB x Cosine(Spiral Angle) x Cosine(Pressure Angle)

The actual backlash that we use for manufacturing is the backlash range specified on the customer's part drawings with the parts positioned in a rolling gear tester at the gauged print nominal mounting distance. The backlash specified on the part drawings must take into account the mounting distance variations that come from the assembly tolerance stackup if selective fit shims are not used. Sometimes backlash larger than the standard recommended backlash is required to accommodate the tolerance stackup. Equations 1 and 2 are formulas for calculating the change in backlash to be expected for a given mounting distance change, either for the pinion or the gear.

$$\Delta MD_P = \frac{\Delta B_P}{2\tan\phi\sin\gamma} \quad (1)$$

$$or\left[\Delta B_P = \Delta MD_P * 2\tan\phi\sin\gamma\right]$$

$$\Delta MD_G = \frac{\Delta B_G}{2\tan\phi\sin\Gamma} \quad (2)$$

$$or\left[\Delta B_G = \Delta MD_G * 2\tan\phi\sin\Gamma\right]$$

These formulas are useful for estimating shim thicknesses for a backlash adjustment. An example is given for a 3.545:1 ratio.

Example:
11 x 39 combination and 9.25 Diametral Pitch
Pressure angle ϕ =20°
Pinion pitch angle γ = 15.75°
Gear pitch angle Γ = 74.25°

How much does the backlash change if I move the pinion –0.005" (ΔMDP = –.005") or if I move the gear – 0.005" (ΔMDG = –.005")?

ΔBP = –.005 * 2 tan 20°sin15.75° = –.0010" reduction in backlash

ΔBG = –.005 * 2 tan 20°sin 74.25° = –.0035" reduction in backlash

Notice that the backlash change is three to four times as fast for a gear mounting distance change as for the same amount of pinion mounting distance change.

Special Considerations For Assembling Low Ratio Gear Sets

What if the ratio is not higher than 2.5:1 as discussed above?

The assembly has an extra step in it for ratios from 1:1 to approximately 2.5:1. As before, assemble the pinion and gear with backlash and check the tooth contact pattern. Shim the pinion in or out of mesh to put the pattern in the correct depthwise position on the teeth. Next, it is necessary to adjust for the correct backlash. This is where the assembly procedure changes. It is necessary now to move both the pinion and gear for the backlash adjustment in order to keep the contact pattern from moving out of position. Refer to Figure 16, a diagram similar to that of Figure 7, but now for a low ratio (1:1).

A small axial move of the pinion is represented again by a component in the depth direction and a component in the face direction. Now these components are equal. Also, the components for the gear are the same as those for the pinion for the 1:1 ratio.

The necessary pinion shim change will be related to the gear shim change by the ratio. So, if the ratio is 1:1 and the gear will be moved into mesh 0.005", then the pinion must be moved into mesh 0.005" to maintain the correct pattern. If the ratio is 2:1, a 0.005" gear shim change would be accompanied by a 0.0025" pinion shim change. You can use the calculations in Equations 1–2 to estimate the shim thickness changes. The relationship between the pinion and gear shim, mathematically, is:

Ratio = M = (number of gear teeth divided by number of pinion teeth)
Gear shim thickness change = (X.XXX)
Pinion shim thickness change = (X.XXX/M)

For low ratios, we can summarize as follows.

Low Ratio Rule:

The tooth contact is readily affected by changes in both pinion and gear axial position. Properly position the pinion first (or the gear if the backlash is close to 1:1) to be assured of a correct tooth contact and to eliminate misleading tooth taper thickness in the backlash check. The backlash is readily affected by changes in both gear and pinion axial position. Adjust second for backlash by moving the pinion and gear in proportion to the ratio.

Are You Hunting for Backlash?

When there is no common factor between the number of teeth in the pinion and gear, the ratio is said to be "hunting tooth." This kind of design could also be called "hunting backlash"! Ratios of this type require the greatest number of revolutions of pinion and gear before all pinion teeth have meshed at least once with each gear tooth.

Example: Ratio 2 x 3 (n x N combination)

As the pinion rotates with the gear, the pinion teeth match up with the gear teeth in a pattern that eventually repeats:

Pinion 1 2 1 2 1 2 1 (pinion teeth are numbered 1 and 2)
Gear 1 2 3 1 2 3 1 (gear teeth are numbered 1, 2 and 3)

The gear requires two (which is "n") rotations, the number of