How to install bevel gears for peak performance

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You can't put bevel gears together in the same way as spur and helical types and get them to work well. They need to be assembled in a specific way to ensure smooth running and optimum load distribution between gears.

To optimize the performance of any speed reducer, the gears must be oriented to each other so that they run smoothly without binding or interference. They must also maintain the correct amount of tooth clearance (backlash) at all operating conditions. For spur and helical gears, the best orientation normally requires only that the center distance and shaft alignment be correct — no further adjustment is needed.

This is seldom the case with bevel gears, where mounting arrangements allow for wide variations in position. All types of bevel gears — straight, Zerol, spiral, and hypoid — have an optimum position for best performance. The manufacturer determines this optimum position by running tests of individual gearsets. But, the gearbox designer and assembly technician share the responsibility for incorporating this optimum positioning in the gearbox. The designer must provide for ease of measurement, shimming, and assembly. And the technician must properly assemble the gears in the gearbox.

Key assembly parameters

Several parameters contribute to proper assembly so that the gearbox operates smoothly and efficiently. The most important are:

- Mounting distance.
- Matched teeth.
- Backlash.

Bevel gears of AGMA quality 8 or better are normally manufactured and tested in sets. Then, the manufacture marks the preferred values for each of the three parameters on individual gears.

Frequently, the manufacturer also marks a gearset number on each of the two gears in a set. Gears manufactured in sets should *only* be assembled with their mates. Similarly, if one gear in a set fails, the entire set should be replaced.

Mounting distance. The distance from a locating surface on the back of one gear to the centerline of a mating gear is called the mounting distance, Figure 1. This is the most important parameter for ensuring proper operation. The manufacturer establishes the optimum value for this distance by running the gearset and adjusting its position to obtain a tooth contact pattern that is consistent with smooth running and optimum load distribution between mating gear teeth. Because of dimensional variations between parts, each gear in a set has a unique value for the mounting distance and, in most cases, the manufacturer permanently marks this value on each gear, Figure 2.

It is possible to manufacture all gears to the nominal mounting distance specified on the drawing. But, the additional cost to do so is usually not warranted.

In cases where mounting distances have not been marked on the gears, assembly technicians must resort to a costly trial and error method of marking teeth with gear compound and adjusting

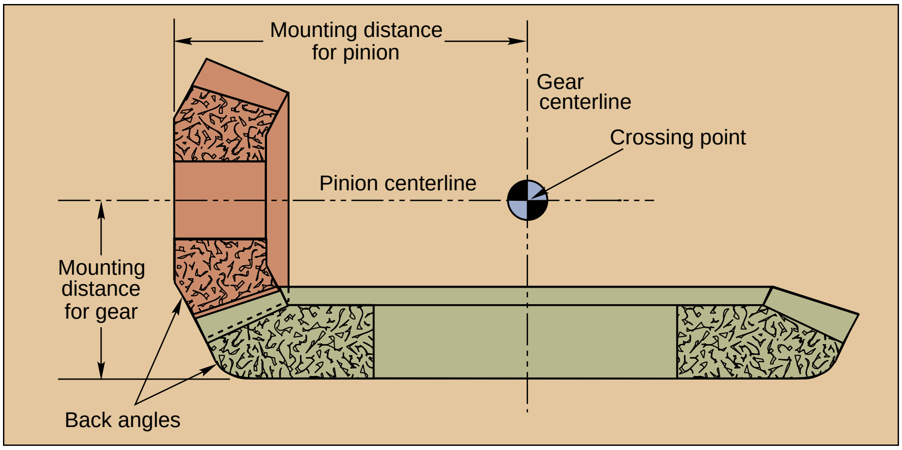

Figure 1 — Mounting distances used for assembling bevel gears.

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the gears to obtain a suitable tooth contact pattern. The lack of marked values may also indicate that the gearset was not manufactured for high capacity or consistency.

Matched teeth. After optimum tooth contact is obtained in the running tests, the manufacturer marks mating teeth in engagement for identification. These marks usually consist of x's or dots, Figure 2, on two adjacent teeth of one gear and the mating tooth of the other gear. When assembling the gearset, position the single marked tooth in the space between the two adjacent marked teeth.

Backlash. The third most important parameter for a bevel gearset is the space between mating gear teeth, called backlash. Unless otherwise specified, backlash is measured normal (perpendicular) to the tooth surface, Figure 3, and not in the plane of rotation. In most cases, the manufacturer marks the normal backlash value on the gear, Figure 2.

Measurements in the plane of rotation, called transverse backlash, are as much as 40% larger, and should not be used for assembly purposes.

Where mounting distances have been marked on one or both gears, adjust these distances first. Then, use the normal backlash value to verify proper assembly. *The backlash value should not be measured until after assembling at least one of the two gears, preferably the pinion, at its marked mounting distance.* The reason is simple. Because bevel gears are conical in shape, they can be assembled in an almost infinite number of positions (most of which cause poor performance) and still obtain the required backlash.

Frequently, a casual user assembles bevel gears to obtain a specific amount of backlash without regard to the mounting distance. This is especially true for low quality or lightly-loaded bevel gears. Although this method occasionally works, it is a risky approach where gears are loaded to maximum capacity. It usually causes shorter life and poor performance. Only at the proper mounting distance will a gearset run correctly and still have the right amount of backlash.

Gear assembly

In most bevel gearsets, particularly those with ratios above 2:1, the pinion position (mounting distance) effects tooth contact (the most important parameter for good performance) to a larger extent than the gear position. Conversely, the gear position has a larger effect on backlash. For this reason, the manufacturer may have marked the mounting distance only on the pinion. In such cases, be sure to accurately position the pinion according to its marked mounting distance before adjusting backlash. This can be accomplished either by gaging or by direct measurement. Gages are used mostly for large gear production runs, and are based on the direct measurement method. For this reason, only the measurement method is described here.

Note that when mating gears are adjusted to their optimum position, their back angles, Figure 1, will probably not be flush with each other. *Do not attempt to position bevel gears by making the back angles flush.*

Measurement method. A typical gearbox, Figure 4, contains both an overhung and a straddle-mounted gear. The procedure for assembling the bevel gears in this gearbox by the measurement method is simple:

- On the housing, measure the distance from locating surface to bore centerline in both horizontal and vertical directions (HMD and VMD).
- Record the gear and pinion mounting distances (MD_G and MD_P).
- Measure the gear and pinion thicknesses (W_G and W_P).
- Assemble the gears into their subassemblies.
- Measure the length that controls gear position in each subassembly (MA_G and MA_P).
- Calculate the distance from shim mounting surface to crossing point for each subassembly (MDV and MDH).
- Calculate the required shim thicknesses and assemble the gearbox with shims in place.

To aid the assembly technician, mark the housing measurements on the housing after it is machined and inspected.

Measurements involving the pinion and gear are taken on the subassemblies, which consist of gear, shaft, bearing, and gear mounting components. This minimizes any variations due to fits between these components and greatly reduces the number of measurements required. In this example, only the gear thickness is measured before putting together the subassembly. Subtracting this distance from the mounting distance lets the technician measure from the front of the assembled gear.

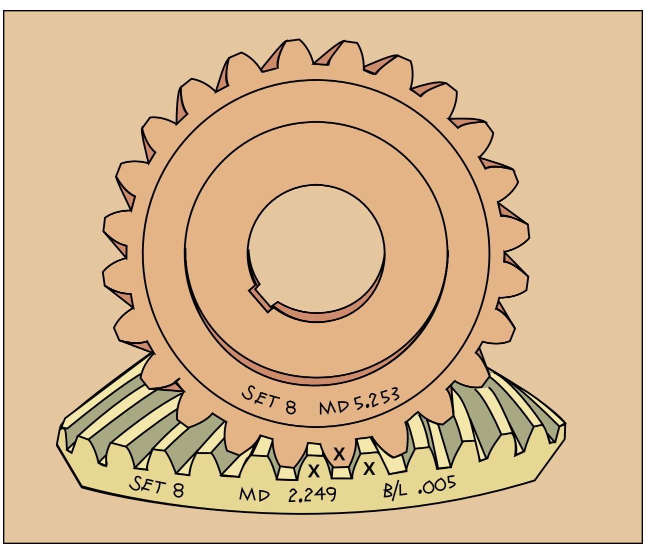

Figure 2 — Typical markings on bevel gears include (left to right) the gearset number, mounting distance (MD) in inches for each gear, x's on mating teeth, and the backlash dimension (B/L) in inches.

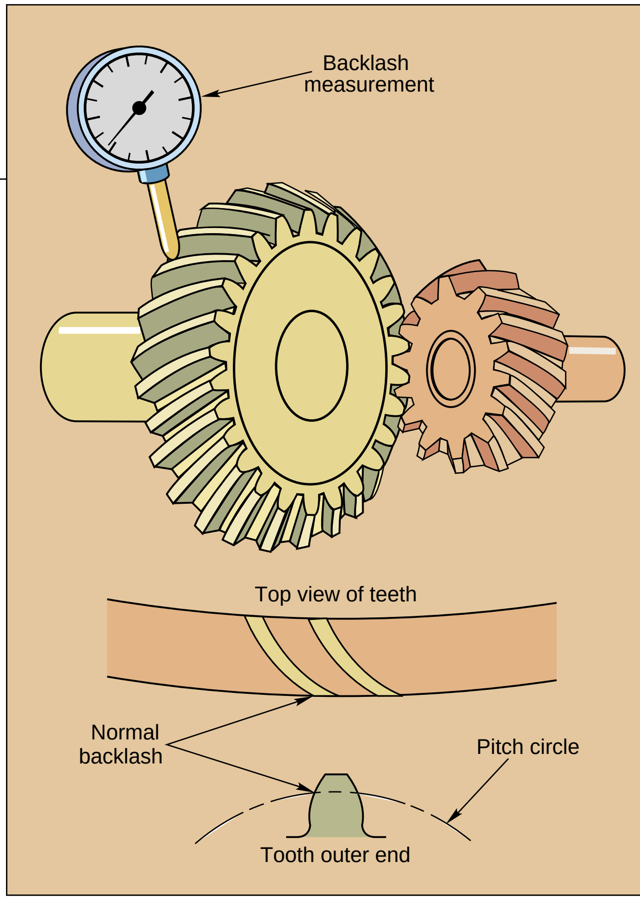

Figure 3 — Normal backlash in a set of spiral bevel gears is measured perpendicular to the tooth surface at the outer end (heel) of the tooth, using a dial gage.

Verifying proper assembly. Use the measurement method to assemble both gears, making sure that the matched teeth are properly engaged. Only after positioning both gears at their mounting distances should you measure backlash to verify proper assembly. In cases where only the pinion is marked with a mounting distance, position the pinion at its mounting distance first, then adjust the gear position for the required backlash.

To obtain further verification, you can perform an optional contact pattern check. This involves painting the tooth surfaces on one gear with a thin marking compound and rotating the assembled gears under light load. The compound transfers from one gear to the other and shows how the teeth contact. Numerous publications contain charts with typical contact patterns (ANSI/AGMA 2008-B90 and ANSI/AGMA 2005-B88). The patterns seldom look exactly like the published examples and frequently require some interpretation.

Technicians familiar with contact pattern checking may believe that this technique is the preferred method of assembly. However, the manufacturer has already performed this check as part of the testing (to determine mounting dimensions) and interpreted the contact patterns so you don't have to. ■

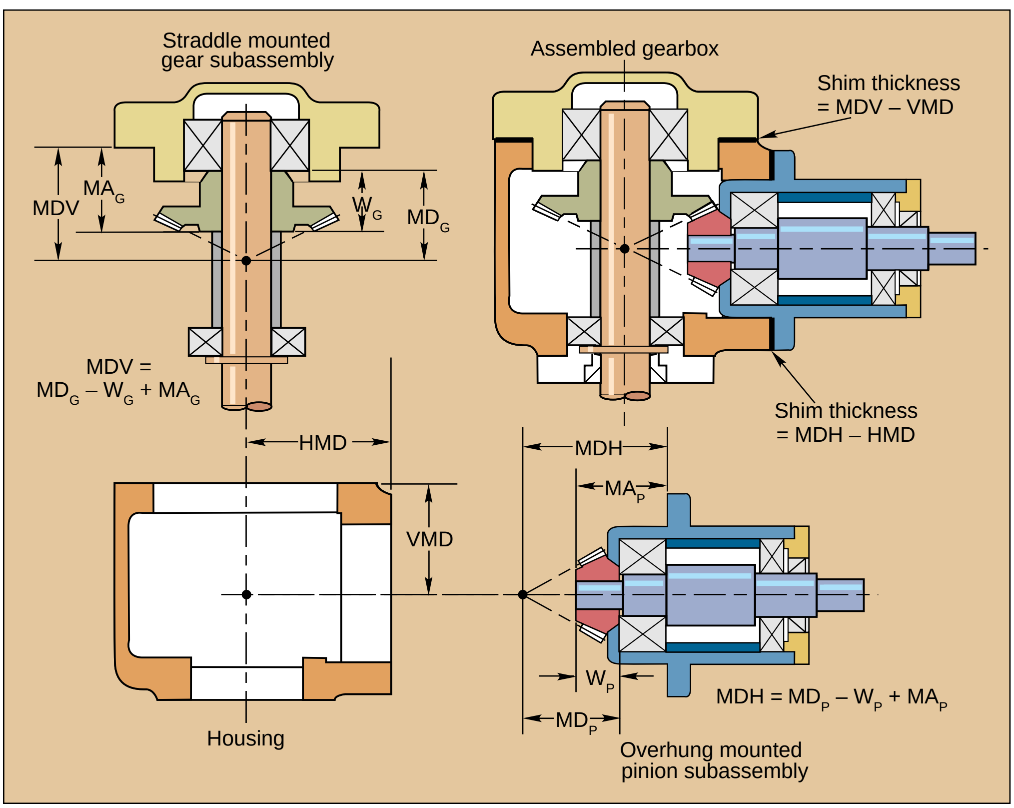

Figure 4 — Measurements required for mounting both overhung and straddle-mounted bevel gears in a typical gearbox.