Misalignment No Beauty in Gearsets

Don McVittie

When we have problems with gearset failure, a common diagnosis is misalignment." What exactly is that and how do we prevent it?

The second most common "killer" of good gear sets is misalignment (dirt, or abrasive wear, is first). Gear teeth simply won't carry the load if they don't touch, and the portion that does touch has to carry an overload to make up for the missing contact area.

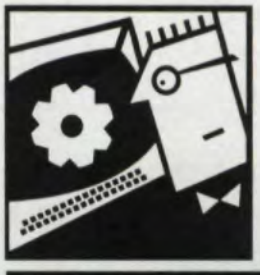
Fig. 1 shows the effect of one kind of misalignment - deflection of an overhung pinion. This example could be from any drive where both pinion bearings are on the same side of the gear. When power is applied, the pinion shaft bends and its bearings deflect, so the pinion teeth aren't parallel to the gear teeth. (See Fig. 2.) The deflected pinion is heavily loaded at the unsupported end. The load may not even cover the whole pinion face.

The heavily loaded end usually can't take the abuse, so it wears, pits, scuffs, cold-flows, or breaks. By the time it wears enough to allow the other end to carry some load, the gear is badly damaged. Wear progresses until teeth break, because there's no self-healing effect.

Some things that will help are:

- Tightening up the pinion bearings if they're adjustable.
- Reinforcing the pinion bearing support structure by adding extra bracing.
- Re-aligning the pinion to tip the free end toward the gear, so it's misaligned under light loads and bends into full-face contact as the load is applied. This works best if the load is always applied in one direction.
- Checking backlash at all positions of

Fig. 1 - Uneven wear on an overhung pinion. The stub of the broken shaft is still in the bore.



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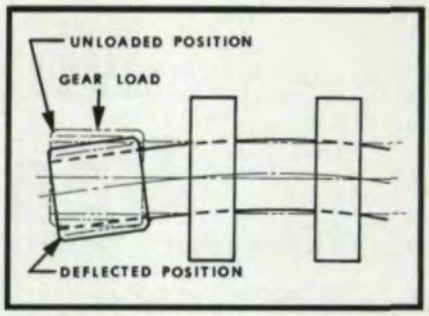

Fig. 2 - Deflection caused by gear misalignment.

the bull gear. Sometimes the bull gear runs out enough to bottom out with the backlash. This causes severe overload and aggravates the misalignment problem; it can even break the pinion shaft.

•Re-working the drive to mount the pinion on a loose spline, so it can find its own alignment even when the shaft bends.

•Making a tapered pinion, carefully calculated to match the slope of the deflected shaft under load. It should probably be crowned too, because it can only be a perfect match at one load level.

Misalignment of an overhung pinion is easy to understand, but sometimes we see signs of misalignment even though the gear and the pinion are both supported between bearings. Fig. 4 shows a pitting failure extending only half way across the tooth face - a sure sign of misalignment under load. What caused

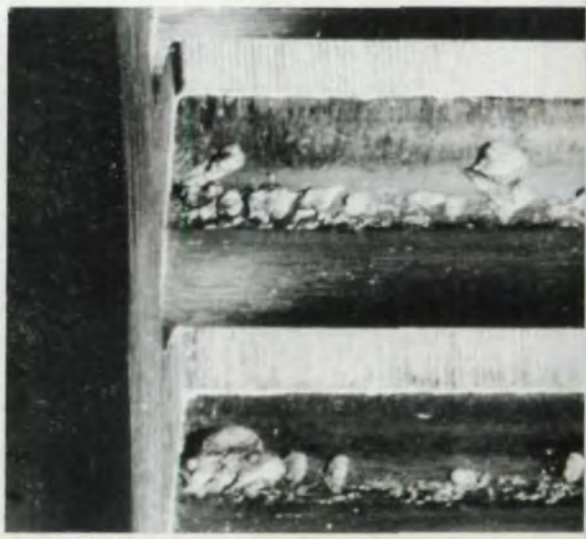

Fig. 4 - Pitting failure caused by misalignment under load.

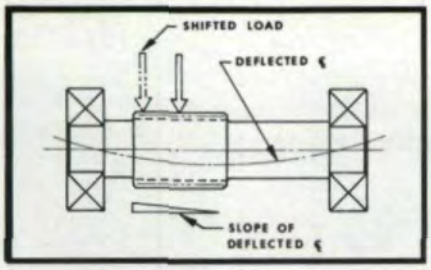

Fig. 3 - Bending deflection of the pinion shaft.

the misalignment? The key lies in the words "under load."

Here are some possibilities:

•Bending of the pinion shaft. If the center of the pinion is not in the center of the bearing span, any bending deflection

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of the pinion shaft will cause a slope, forcing the load toward the end of the pinion closest to a bearing. Fig. 3 illustrates this.

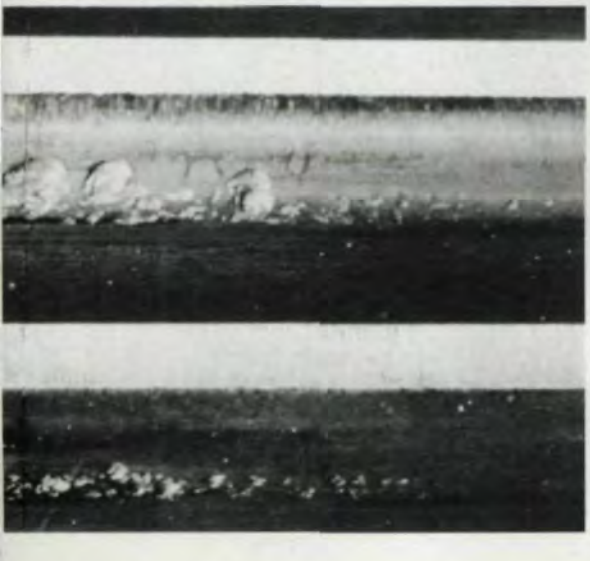
•Twisting of the pinion shaft. Heavily loaded, slender pinions "wind up" under load, forcing the load toward the end of the pinion closest to the input.

•Poor adjustment of tapered roller bearings.

•Bearing wear.

•Case deflection due to poor foundation or heavy load.

•Manufacturing error in the case or gears.



OOPS! In last issue's article, "Hard Finishing by Conventional Generating and Form Grinding," the name of Niles Grinders was eliminated from the list of formed-wheel gear grinding machines. These machines are most suitable for one off to medium batch production runs. They offer the capability of grinding gears with different pressure angles, addendum and modifications, tip and root relief as well as lead crowning without the requirement of additional equipment such as index plates, pitch blocks or special grinding wheels. The machines cover a working range with maximum outside diameters of 24" to 157" and maximum table loads of 880 lbs. to 88,000 lbs. Today, more than 5,000 Niles gear generating grinding machines have been installed throughout the world. We apologize for omitting Niles from the list.

***Fig. 5** - Bending failure caused by a misaligned gear set.*

In any case, the misalignment must be fixed. If it is allowed to persist, the teeth will fail. Fig. 5 shows a typical bending failure which resulted from failure to correct a misaligned gear set.

We should be aware that even parts supported between bearings can be misaligned under load. Fig. 6 shows a classic case. This new gear box developed problems during an overload test before going into service, but it could have happened at any time.

The diagram (Fig. 7) shows the bearing arrangement. Two tapered roller bearings, one at each side of the box, were expected to carry the radial load and the thrust load induced by the helical gear teeth.

***Fig. 6** - This new gear box failed because of misalignment even though it was supported between bearings.*

Unfortunately, a careless assembler didn't get the cone of one bearing seated all the way against its shoulder. A simple check with a feeder gauge between the back of the cone and the shoulder would have shown a gap, but the check was overlooked. The press fit held the cone in place for a while, but an overload moved it to the shoulder, creating a gap between cup and cone. A loose adjustment would have had the same effect.

Once the bearings were loose, the

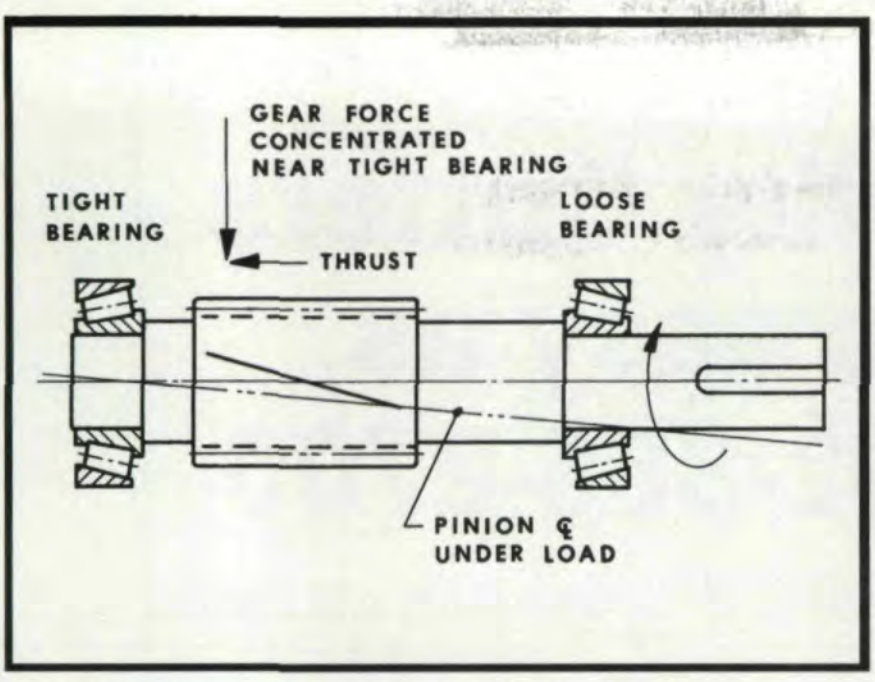


***Fig. 7** - The bearing arrangement of the gearbox in Fig. 6., showing the cause of the failure.*

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thrust from the helical teeth pushed the pinion tightly into one cup, as shown in Fig. 7. The other bearing was then loose, so its cone shifted laterally away from the load, leaving the pinion misaligned. The pinion teeth at the end with the tight bearing took all the load - until they began to pit.

Careful assembly will prevent this problem, if the gear case is stiff enough to support the bearings. Here are some easy tips to help you get it right:

•Be sure the cones are seated against the shoulders on the shaft; use a .001" feeler gauge between the back of the cone and the shoulder to check. When possible, press the bearing into place instead of heating it. It can't shrink back from the shoulder if it's pressed against it.

•Be sure cups are seated too. A stray burr can keep the cup from seating and leave room for movement when the load is applied.

•Be extra careful shimming gear box bearings. They really should run at no clearance, but that may be too tight to run cool. One to three thousandths is usually enough clearance.

•Check bearing temperatures and gear tooth contact patterns after a few hours under load to be sure everything is as you left it.

Sometimes there simply is no easy fix for a misalignment problem. Maybe the box is bored out of line, the gears weren't matched originally, or the parts are so slender that they bend under load. In any case, the load is so heavy at one end of the teeth that wear is unacceptable. Fig. 8 shows this kind of pitting pattern on a helical pinion.

***Fig. 8** - The pitting pattern on this helical pinion is the result of a heavy load at one end caused by misalignment.*

If it can be removed, the whole gear box should be sent to a good gear shop. There the cause of the bad contact can be found and the part(s) causing the misalignment reworked.

The gears will first be checked on true center distance in a test fixture as illustrated in Fig. 9. If the contact pattern in the fixture looks good, but the contact under load is bad, the box will be checked to make sure that the bores are parallel. The theoretical bending and twisting deflections are calculated to estimate the amount of deflection under load.

With this information, a correction can be made to the helix angle of the gear or pinion, creating an intentional mismatch at no load. When the gears wind up under load, they match and their capacity is increased. If they have to run at a variety of loads, the required tooth form can be curved or "crowned."

Sometimes the gear box can't be removed, so only the gears are available for checking. The repair is still possible, using the test fixture to simulate the gear box, but it's difficult to know if the fault lies in the gears, the box, the deflection,

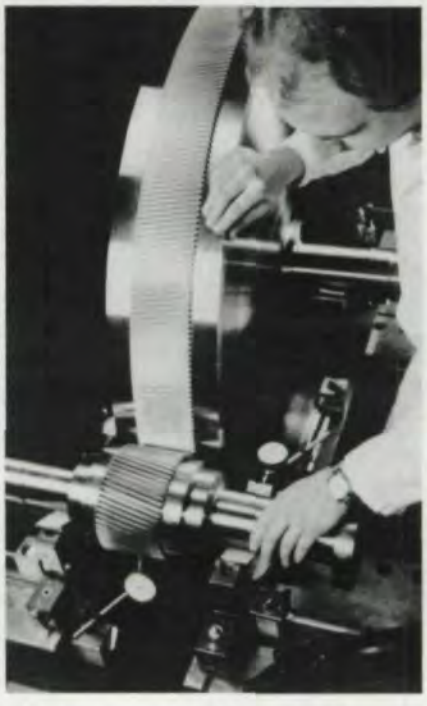

***Fig. 9** - A contact check in a test fixture is a crucial step in correcting misalignment.*

or all three. If only the gears are available for a modification, it may take more than one try to get it right.

This article originally appeared in consecutive issues of the "Tooth Tips" column of Pitch Lines, a newsletter of The Gear Works, Seattle, WA. Thanks to Mr. Roland Ramberg, president of Gear Works, for allowing us to reprint them.