Gear Material Quality: How To Judge It... Pitting: How To Prevent It

Don McVittie

How do we know when the gear material we buy is metallurgically correct? How can we judge material quality when all gear material looks alike?

Don McVittie replies: Gear quality has two parts - materials and geometry. Most people find geometry easier to measure and understand, so they emphasize that and ignore material. The most accurate gear is a waste of money, though, if its material is weak or brittle. Only the best materials warrant the time and effort necessary to make an accurate gear.

What makes a gear material bad?

- Too soft for the job.
- Hard enough, but the wrong crystal structure (microstructure).
- Right structure, but too many nonmetallic inclusions.
- Cracks, holes, seams, and laps.

Fig. 1 shows the photomicrograph of the core material of a failed gear tooth. The light-colored areas are "blocky ferrite." They show that the gear was hardened in a separate reheat/quench/temper process after carburizing and cooling, and that it wasn't thoroughly reheated before quenching. Blocky ferrite is weaker than the

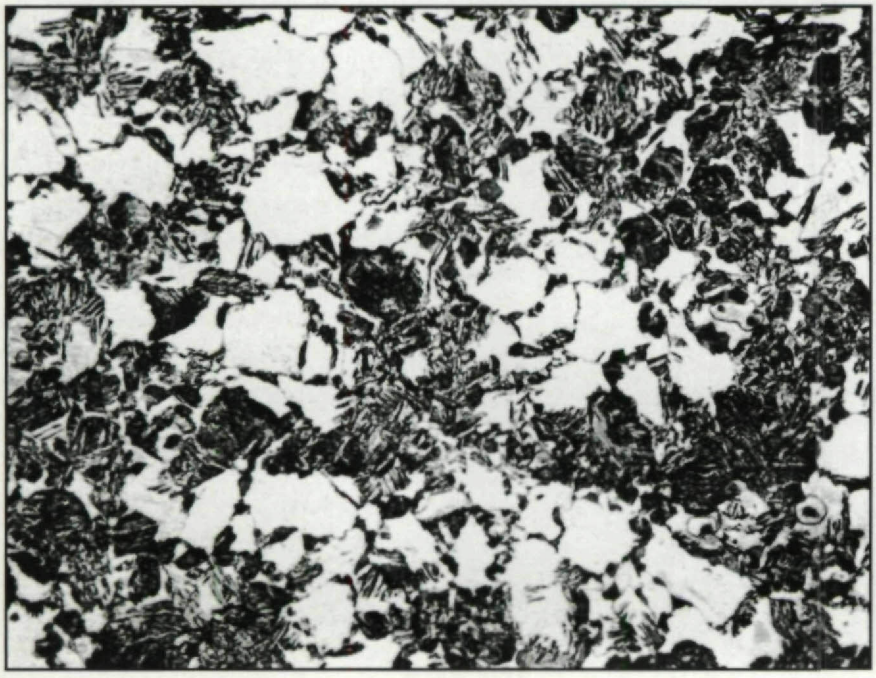
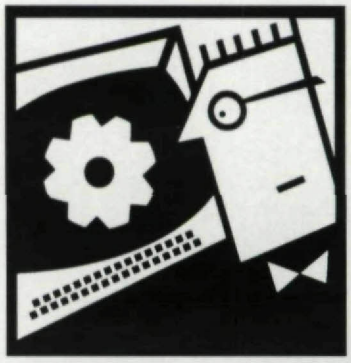


Fig. 1



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Address your gearing questions to our panel of experts. Write to them care of Shop Floor, Gear Technology, P. O. Box 1426, Elk Grove Village, IL 60009, or call our editorial staff at (708) 437-6604.

Don McVittie
is President of Gear Engineers, Inc., Seattle, WA. He is a past president of AGMA and Chairman of the U. S. Technical Advisory Group for International Gear Standards. He is a licensed professional engineer in the State of Washington.

Fig. 2

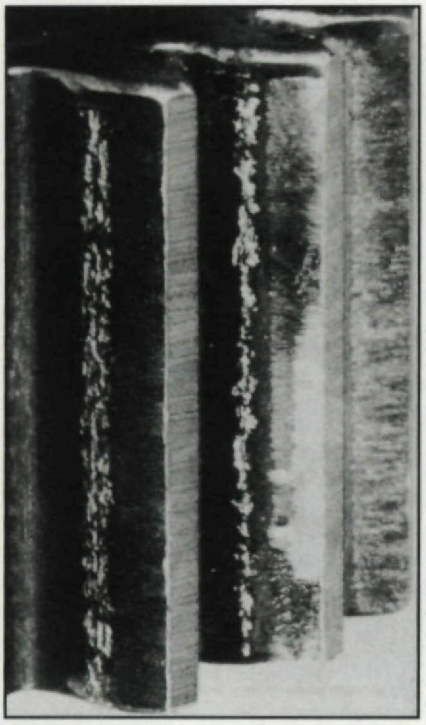

Fig. 3

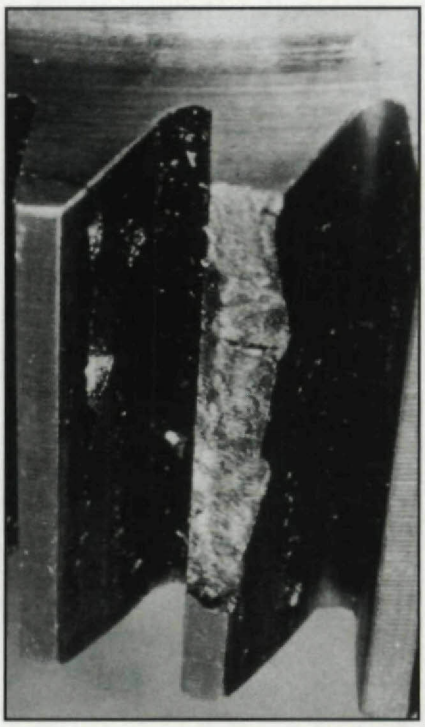

Fig. 4

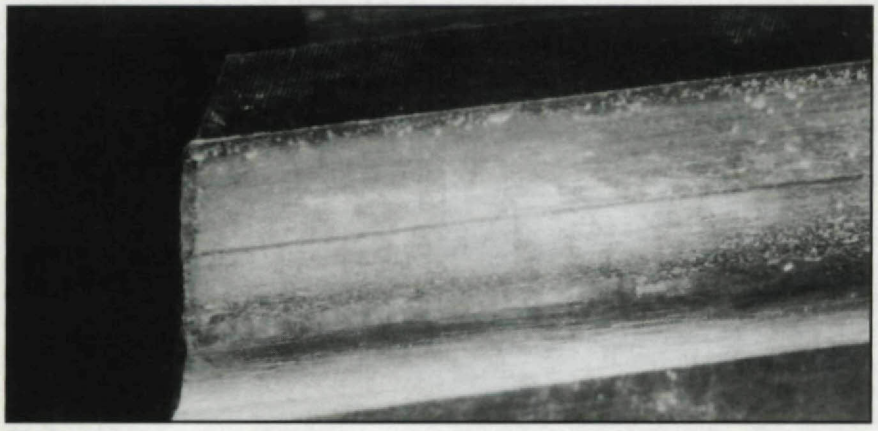

Fig. 5

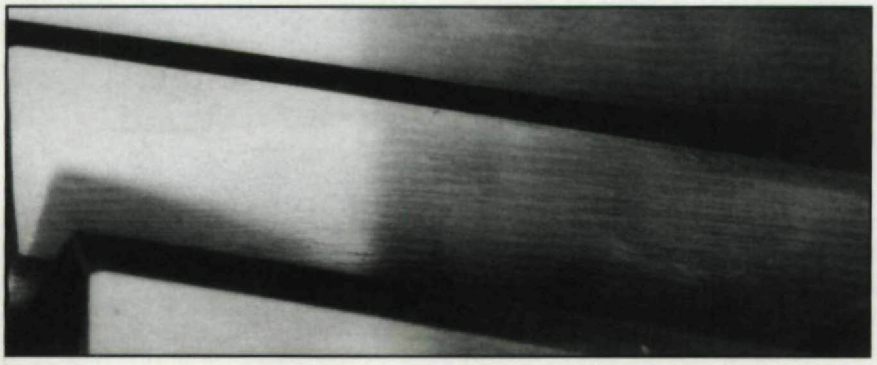

Fig. 6

desired "tempered martensite" structure and is not permitted in highly loaded carburized gears.

How can buyers know what they're getting? After all, the gears look, weigh, and measure the same! The difference is invisible, like good character in an individual, but it's there and will become obvious with time.

If you could look inside a well-made carburized gear, the case microstructure would look like the photo shown in Fig. 2, with a uniform martensitic structure, free from defects.

Material quality is difficult to measure on a finished part because the critical areas are inaccessible. Quality is maintained by carefully controlling the manufacturing process and checking the results each step of the way, from the ingot to final heat treatment and inspection for hardness and surface defects.

Some purchasers have strict material specifications and internal quality control, allowing them to verify the

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quality of the parts they buy. Others don't have such in-house capabilities, so they buy from vendors who have internal quality controls. These "qualified vendors" utilize quality standards and inspection expertise to get the right materials and processes into the gears as they're made. The remaining buyers take their chances with the lowest bidder.

The American Gear Manufacturers' Association (AGMA) develops industry standards for gear quality, both in geometry and materials. The right quality level can be specified by reference to those standards, avoiding the need to write and maintain in-house documents.

We have a lot of problems with pitting in our shop. What causes pitting and what is the best way to prevent it?

Don McVittie replies: Pitting can be caused by things other than bad mate-

rial. Abrasive wear and misalignment will do it. So will overload. Fig. 3 shows a gear tooth that has a good contact pattern, but is covered with pits. The pits are caused by excess contact pressure; the material isn't strong enough to withstand the load being applied.

Material below the surface of the gear tooth flows away from the load, much like bread dough under a rolling pin or the top of a rail deforming under the pressure of train wheels. The failure is gradual, with particles of material flaking off into the oil; old pits close in due to the flow of surface material, and new pits form.

Eventually, the small pits join into larger pits, or spalls. The accuracy of the tooth form is destroyed, and the dynamic load on the teeth increases. As the teeth get thinner and rougher, breakage will occur through the stress risers caused by the pits, as shown in Fig. 4.

Theoretically, all gears will pit, even at light loads. In practice, we'd like them to outlast the machines they drive. In most gear drives, the pitting rate is slow enough that it can be tolerated with gear replacement every few years. Sometimes the increased vibration and noise caused by pitting require a more permanent cure.

Fig. 5 shows a form of pitting known as ledge wear, where the portion of the tooth below the pitch line (dedendum) is much more pitted than the portion near the tip (addendum). The tooth is no longer a true involute form. This is cause by a combination of poor lubrication conditions and mild overload. The mating pinion wore in a similar pattern. Such a gear can usually be saved by recutting it and making a new hardened and ground pinion (Fig. 6) that will promote a good lubrication film and hold its accurate profile form under high loads. The accurate pinion acts as a tool to maintain the gear tooth profile.

The real issue, of course, is to prevent pitting failures from occurring at all. Here are some preventative steps:

1. Thicker (more viscous) oil spreads the load over more tooth area and can

increase the capacity of a drive without much cost. It's worth a try with new gears, but can't be expected to cure already-pitted gears.

2. Extreme pressure (EP) additives in the oil also can help. Synthetic oils without additives seem to hurt pitting resistance. Frequent oil changes, particularly when the drive operates with oil temperatures above 160°F, also help.

3. Harder gear materials definitely make a difference. Changing from 180 to 321 Brinell hardness doubles pitting capacity and changing to carburized material doubles it again. The harder materials are more sensitive to misalignment (they can pit before they wear in), so the replacement parts must be made carefully and might require special geometry.

An economical way to repair a pitted through-hardened gear set is to recut the gear, exposing new surface material, and to replace the pinion with a new oversize carburized and ground pinion. The harder pinion will retain its accurate profile, work-hardening and protecting the gear from profile degradation, greatly increasing its life. ■

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