



HOTSEAT

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Powder metal gears can be carburized and quenched, with the alloy and size dictating the quenching process.

Powder metallurgy has been around for hundreds of years, but has only been used for commercialized applications within the last 50 years. And like any new technology or process, PM was billed as the greatest innovation since sliced bread for manufacturers—especially gear makers. Today, its promoters have joined the “Green Revolution” bandwagon, primarily because of its near-net shape attributes and reduced waste of raw materials—the same advantages associated with 3D printing.

For those new to the technology, powder metallurgy is the process of compacting alloy metal powder with a binder in a hydraulic press to form a complete part. Minimal machining is required to produce a working gear. Once compressed, the part must have the configuration that will allow it to be pushed out of the die/mold used to form it. This is where helical and bevel gears lose the battle of economics, due to very complex die/mold assemblies, compared to machined wrought gears, and where 3D printing might win the war if production issues can be overcome. There is an entire industry dedicated to PM technology, including powder development, binders, die/mold makers, and heat treating—debinding, sintering, and carburizing.

As compacted, the powder metal gear has no significant strength, and must be sintered to diffuse the powder particles together and increase density. That isn't sufficient for many applications. As compacted, the highest practical density will be about 7.0 g/cm³ (0.25 Lb/in³ or 436 Lb/ft³) with <0.75% (Zn) zinc-stearate binder. For comparison, wrought steel has a density of 7.85 g/cm³ (0.28 Lb/in³ or 490 Lb/ft³). Sintering increases the maximum practical density to about 95% of pour-free wrought steel or about 7.45 g/cm³ (0.27 Lb/in³ or 466 Lb/ft³).


Before a PM compact can be strengthened, the binder used to lubricate the powder and hold the particles together must be removed. For zinc stearate, a common binder, compacts are heated in nitrogen or dry, rich exo gas to approximately 427°C [800°F] to boil off, collect, and condense the binder. This process requires specialized equipment that can uniformly heat the parts and keep the binder material in vapor form, then with purge gas collect the material in a condenser or trap. After debinding, the compacts, although slightly stronger, can be sintered. Here, more furnace options are available, depending on the part and production, batch or continuous.

Continuous sintering furnaces are almost always mesh belt types that can handle part loading of about 5 to 10 Lb/ft² (24 to 49 Kg/M²) and capable of 1204°C to 1232°C (2150°F to 2250°F). A protective atmosphere is essential to prevent oxidation and carburization therefore dissociated ammonia (75% H₂, 25% N₂) is the gas of choice. The batch sintering option is generally vacuum furnaces. They provide

a neutral atmosphere with the cooling function. Sintering is the process of making the powder particles stick to each other by solid-state diffusion. In effect, the particles form a “no seam” bond with small pores equally distributed throughout the part including at the surface.

As-sintered parts, depending on their alloy content, will have strength properties roughly 75% to 90% of their wrought counterparts. These may include parts that don't require sliding wear properties or high strength. If additional strength is required, through- or case-hardening (carburizing) will be required. Here again there are process choices: atmosphere or vacuum. In some cases, forging is employed to increase strength; internal engine connecting rods are a classic example.

PM gears can be carburized and quenched with the alloy and size dictating the quenching process, oil, or in rare cases high-pressure gas quenching (HPGQ). Having said that, because PM gears have less strength, adding alloy content doesn't increase the strength that much. Therefore, many PM gears are made from lower-grade steel and carburized, making HPGQ not applicable. The one caveat, however, is carburizing time. Even after sintering, the porosity remaining will allow a more rapid penetration of the carburizing atmosphere into the PM part. Generally speaking, depending on the final maximum sintered density, carburizing time is always faster for PM parts compared to wrought material. Very generalized, the timesavings can be ½ to ⅔ of the time for the same case depth in wrought steel. LPC (low-pressure carburizing) would seem to be a desirable process but due to the porosity variation and rapid carbon diffusion, LPC can be very difficult to control surface carbon with the pulse/boost/diffuse recipes used for wrought steels. For this reason, endo gas carburizing sees as much or more application for PM parts, due primarily to the equilibrium surface carbon reaction with the steel. In endo carburizing, however, load size or surface area can pose a challenge for initial CP control because of the very large volume of air and/or water vapor adsorbed to the infinite surface area, comprising a large load.

For drivetrain applications, PM gears have limited application due to their lower surface density—none are used in automotive transmissions. Timing gears however, are a more common application. A qualified exception to that rule has been the development for a densification process where the gear's teeth are rolled or otherwise manipulated to create a near wrought density surface greatly improving its wear properties when carburized. But that, too, due to excessive manufacturing costs, cannot displace the advantages of traditional carburized wrought alloy steel gears. 

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