THE PRESSURE'S ON FOR DECREASED DISTORTION

By Gerald Lindell

Many manufacturers [1] have reported that low pressure vacuum carburizing (LPC) has resulted in less distortion on gears than atmosphere carburized gears when accurate comparison tests were done.

The LPC process has been applied to gears, cams, and other components for reduction in machining time (reduced stock allowance) and reduced heat treat distortion (scrap or rework). There are, however, some dimensional differences involved that should be addressed when switching from typical atmosphere carburizing processes to low pressure vacuum carburizing.

Atmosphere Carburizing and LPC Differences

In many cases during atmosphere carburizing by traditional methods, the part (gear) is heated to austenitizing temperature in a carburizing atmosphere where the thinner sections (top of the gear tooth) reach this temperature before the heavier sections (root), which can cause an uneven case depth (deeper at the tip than the root). In LPC the part is completely heated to austenitizing temperature in vacuum before the carbon is added, which produces a much more consistent and uniform case depth from tip to root. The case carbon in LPC can be much better controlled to a higher carbon content deeper into the case and results in a deeper depth of HRC 58 or greater, usually more than twice as deep as atmosphere carburized parts. Typical depth of HRC 58 for an atmosphere carburized part is approximately .015-.020 (inches), and typical depth of HRC 58 for a LPC part is .030-.040 (inches) [2].

Atmosphere carburized coupons yielded compressive surface stresses (x-ray diffraction) of 98 MPa (14.2 ksi) compared to compressive surface stresses of 135 MPa (19.6 ksi) for LPC [2].

Because of LPC's proven ability to better control the carbon content throughout the case, lower retained austenite values (<10 percent visual) have been found on LPC coupons than on atmosphere carburized coupons (20 percent visual). In addition, no inter-granular oxidation has been seen on the LPC coupons, compared to inter-granular oxidation to a depth of approximately .002 (inches) on the atmosphere carburized coupons [1].

Distortion

Distortion is "shape change" from original dimensions, such as out-of-roundness or warping which can result in areas of

THE GOAL IS TO DO IT WELL, AND DO IT ONCE, SO IT'S BOTH DISHEARTENING AND EXPENSIVE TO DISCOVER A FLAWED PRODUCT. THAT'S WHY YOU SHOULD KNOW ABOUT THE BENEFITS OF LPC.

FIGURE 1

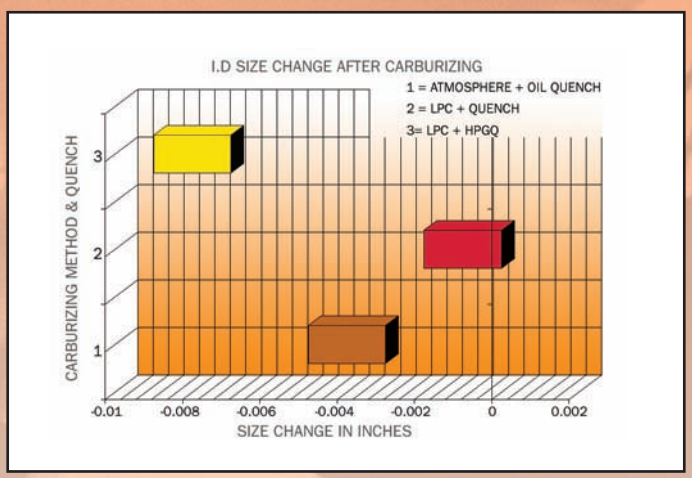
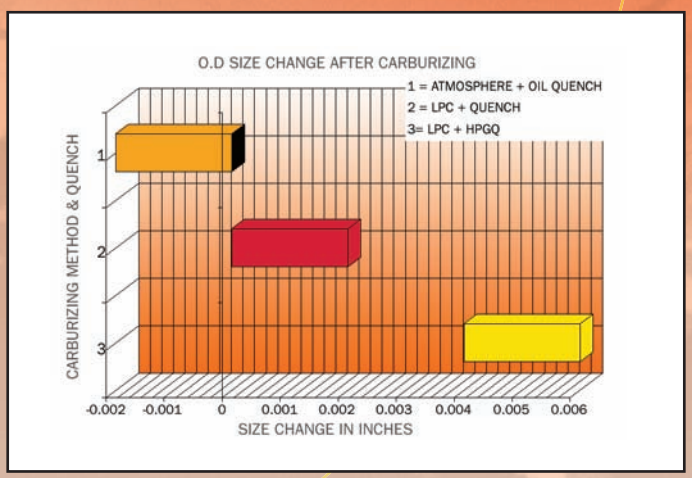


FIGURE 2

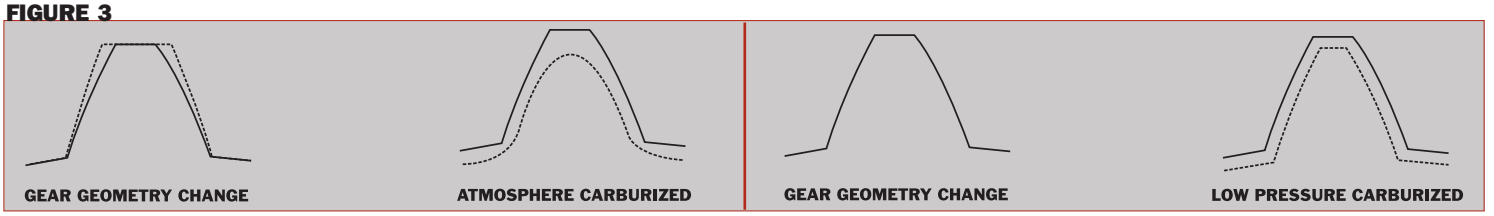


non-cleanup during finish machining. Since size change can be somewhat controlled, it should not be classified as distortion. LPC has been shown to markedly reduce distortion, especially if the parts can be high pressure gas quenched (HPGQ) [1].

HPGQ can be "adjusted" to a cooling rate that will produce the desired metallurgical properties while still minimizing the distortion. Oil quench "speed" is typically selected for the largest parts that will be run since it cannot be easily or economically "switched." This "speed" could be too fast for smaller parts, causing more distortion [1].

Numerous parts that previously had to be Gleason die quenched are now done using HPGQ, with sometimes even better dimensional results. Atmosphere carburizing with oil quenching (or marquenching) could not match the minimal distortion seen with LPC (oil quenching or HPGQ) in any of the comparisons we've done [1].

FIGURE 3



Size Change

Size change is growth or shrinkage from original machined dimensions and can be controlled if the material can be purchased to a close DI range (-.0 to +.3). The closer DI does not prevent it from changing size, but should make it very repeatable. An example would be holding a ± .001 (0.025 mm) tolerance after carburizing.

Unfortunately smaller companies find it harder to purchase steel to this kind of DI control. Some companies purchase steel to restricted hardenability and adjust stock for finish machining or grinding after carburizing when dealing with tolerances closer then ± .002.

Figures 1 and 2 show typical differences in sizes experienced between the processes on typical 8-10" diameter gears such as in figure 3. These OD and ID size changes are over wires on external gear teeth and between wires on internal spline teeth [1].

The information here is based on known part designs and materials and should not be used as exact values for all steels and designs. You must do your own testing and development. In the Midwest there are many new LPC commercial heat treat sources, and most will run some sample parts for you.

Other Considerations

When applying LPC it is absolutely necessary to present clean parts into the process. Most shops use water soluble cutting fluids which probably contain Boron. If the fluids are allowed to dry on, the Boron is very hard to remove later and can act as a stop-off. Washing the parts immediately after each operation helps prevent later problems. It is also imperative that the parts are effectively washed before carburizing, as oil films can also inhibit the carburizing process [1].

Because the process is done in vacuum, some water based stop-off paints can cause problems with LPC, preventing carburizing in non-painted areas [1].

Do not assume that the results from one LPC + HPGQ process will come out dimensionally the same as another since different furnace designs and gas quenching techniques could result in different sizes. LPC and oil quenching dimensional results should be very similar in different furnaces if the same speed oil is used.

You should closely monitor the tooth profiles on gears which are not finished after carburizing since there could be a difference

between atmosphere carburized tooth profiles and LPC tooth profiles. We had to modify shaper cutters which were developed for atmosphere carburizing [1].

Taper can be machined, hobbed, or shaped into diameters to compensate for taper changes due to the compressive stresses from the carburizing process. LPC + HPGQ yields very repeatable results and has helped allow machining in many part features which previously had to be done after carburizing.

Broaching internal splines might require changing the broach to a different (larger) size or not applying HPGQ to those parts. Shaping of these internal splines allows for easy compensation. Most OD gears or splines are hobbed or shaped so sizes can be easily adjusted [1].

Summary

Due to lower distortion and the ability to reduce stock removal after LPC, processing costs and distortion scrap costs should be lower. Samples need to be run before finalizing pre-carburizing dimensions. You might not be able to use the sizes you have previously developed for atmosphere carburizing.

References:

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ABOUT THE AUTHOR:

Gerald Lindell is corporate engineering metals specialist at Twin Disc, Inc. He can be reached at (262) 638-4000 or lindell.gerald@twindisc.com. Go online to [www.twindisc.com].