WILLIAM P. NEBIOLO
PRODUCT MANAGER •
• REM SURFACE ENGINEERING

Mechanical paste polishing vs. CAVF finishing of gears

Choosing the best gear finishing method often comes down to production volume, processing cycle times, and gear profiles.

A recent Materials Matter article compared generic deburring versus CAVF (chemically accelerated vibratory finishing.) Both techniques are conducted in a vibratory unit. The main advantage of CAVF processing is its ability to use HDNA, high-density non-abrasive media, to generate an isotropic superfinish, a surface with a non-directional texture and roughness values of ≤ 4 μin (0.1μm). In the gearing world, many applications where an isotropic superfinish is required are vehicular or aerospace related. In such applications, the predominant base gear alloys are SAE 8620, SAE 9310, Pyrowear® 53 (AMS 6308), and for many new applications, Ferrium® C64 (AMS 6509). Parts are typically heat-treated to HRC 58-65 and post heat-treat ground to remove quench distortion and/or apply tooth crown. This is especially true of the higher AGMA class number gears.

CAVF chemistries are available to support the isotropic superfinishing of typical carbon steels (as referenced above), bearing steels, 300/400 series stainless alloys, precipitation hardened stainless alloys such as 17-4PH and 18-8PH, titanium alloys, nickel-chrome superalloys, as well as copper/copper alloys. Mechanical paste polishing is also capable of refining the surface of these materials and can be considered as an alternative to CAVF for surface finish improvement of hardened gear applications. This article will compare the two processes in a quick overview.

A QUICK REVIEW OF CAVF PROCESSING

In CAVF, an HDNA media fills the vibratory unit. The high-density, non-abrasive media is commonly 100 percent aluminum oxide in composition but has been kiln-fired at such a high temperature, the aluminum oxide is vitrified and loses all mechanical cutting characteristics. The CAVF chemistry reacts with and forms a mono-molecular layer of a soft conversion coating on the tooth flank. HDNA media is used as a wiping tool during CAVF refinement. The media's density, typically 125 lbs/ft^3, generates superior downward force as parts roll in the mass and efficiently wipes off the soft conversion coating. On a microscopic scale, the coating reforms and is again wiped away, as the part continues to move in the vibratory unit. Each coating formation and wiping cycle reduces the height of gear tooth grinding asperities. As a function of time, depending on the starting Ra value of the gear, asperities are gently planarized, achieving the improved surface quality.

Being high-temperature kiln vitrified, HDNA media has a negligible attrition rate of 0.008 percent. An attrition rate of 0.35 percent is typical for a 20-bond, abrasive-ceramic media. There is an approximate 44-to-1 attrition rate difference between the two. Looking at this in another way, HDNA media must run 44 hours to achieve the same amount of attrition and media swarf generation that a 20-bond media will generate in one hour of run time. Without mechanical-abrasive cutting characteristics, there is a lower propensity to over-radius critical dimensions when HDNA media is used. Additionally, the reduced mechanical force required to affect surface material removal created by the conversion coating further allows for the maintenance of existing gear tooth profile and avoids differential material removal rates between the addendum and dedendum of a gear tooth. Finally, HDNA maintains size and shape for a longer period of time, thereby extending the functional life of the media before attrition shrinks the media such that it becomes a lodging concern.

MECHANICAL PASTE POLISHING

Mechanical paste polishing has been seen as an alternative to CAVF technologies. However, the technology for hardened carbon steel applications may not be a preferred option. Mechanical paste polishing is also conducted in a vibratory unit and can use HDNA media, porcelain media, or other media compositions. However, instead of using a CAVF chemistry to form a soft conversion coating, a mechanical paste is added to the machine.

Even with a metal removal rate of just 0.00001" per hour, edge locations and the addendum of the gear flanks are preferentially contacted in the vibratory unit leading to biasing of gear profiles. Conversely, little to no material removal may occur in the dedendum of the gear teeth. CAVF processing cycles, if properly applied, do not suffer from this issue.

After a water rinse and draining of the vibratory unit, the gear and media mass are left water-wet. The paste is added to the machine in the form of a dry powder (delivery as a gel is an alternative option). The amount of powder added varies depending upon the starting Ra value of the gears and the final Ra value desired. Addition rates in the 0.5 lb-1.0 lbs/ft^3 are typical. The powder is a blend of a gumming-agent and a finely-divided abrasive grit; 1,200 grit is a typical starting condition. The gumming agent reacts with the water to form a sticky, mucilaginous coating on the parts and media. The mucilaginous coating holds the fine abrasive on the surface to the gear tooth. As the parts roll in the media mass, the media forcefully presses the abrasive against the gear tooth. This abrasive rubbing scours the tooth flank to improve surface quality but at a slow refinement rate and only in areas where adequate force can be achieved.

Over time, the abrasive breaks down to form 2,000 grit, which eventually becomes a 4,000 grit, then an 8,000 grit, etc. Since the grit is exceptionally fine, the metal removal depth per hour is minuscule. In CAVF applications, metal refinement typically proceeds at a rate of 0.0001" per hour in well-contacted locations (although this speed can be increased if desired).

With mechanical abrasive paste polishing, the metal refinement rate is reduced to 0.00001" per hour in a well-contacted location. As a result, mechanical paste polishing is not an appropriate match for the high-volume production scenarios as seen in the vehicular transmission industry, for example. CAVF processing is favored where high volumes of parts are required on a daily basis and/or where single shift cycle times are required. For ultra-short cycle times, REM's Rapid ISF® Process combines CAVF processing principles with mechanically accelerated mass finishing equipment (such as a drag finisher) to generate isotropic superfinishes on matched, lapped spiral bevel gearsets in a matter of minutes.

A typical mechanical paste polishing processing run will require multiple shifts. The processing run may be started shortly after lunch and continue through the night, concluding the next morning when personnel return to the building. At that time, a soap cleaning step flushes the residual paste from the gears and generates the final clean part with the desired surface quality. The final processing cycle however is in the 20-hour realm.

Since long processing times and abrasive-only processes have a negative impact on sharp edge locations, such as the interface between a gear face and a tooth flank, such locations are likely to become overly radiused. Even with a metal removal rate of just 0.00001" per hour, edge locations and the addendum of the gear flanks are preferentially contacted in the vibratory unit leading to biasing of gear profiles. Conversely, little-to-no material removal may occur in the dedendum of the gear teeth. CAVF processing cycles, if properly applied, do not suffer from this issue.

ABOUT THE AUTHOR

William (Bill) P. Nebiolo received a B.A. from The University of Connecticut and an M.S. in environmental sciences from Long Island University. He has been with REM Surface Engineering since 1989 and currently serves as a sales engineer and as REM's product manager. Since 1978, Nebiolo has been an active member in the National Association for Surface Finishing (NASF) where he has represented the Connecticut chapter as an NASF national delegate and is the 2010, 2014, and 2015 recipient of the NASF National Award of Merit. From 1996 to 2000, he served as one of SME's Mass Finishing technical training program instructors. He has published and presented dozens of technical papers and is the author of the "SME Mass Finishing Training Book." Nebiolo can be reached at bnebiolo@remchem.com.