WILLIAM P. NEBIOLO
PRODUCT MANAGER • REM SURFACE ENGINEERING

Vibratory media composition vs. attrition and density

Media content is based on the gear finish desired. High abrasive/low ceramic media leads to higher attrition rate; low abrasive/more ceramic causes less attrition, higher quality Ra surface value.

The third in our multi-part series on vibratory processing of gears is focused on understanding how media of different compositions have varying attrition rates and densities, and why these are important in vibratory finishing of gears.

VIBRATORY MEDIA COMPOSITION

Media, the tool in the vibratory bowl used to improve gear tooth Ra surface quality, is commonly a combination of abrasive grit and ceramic binder. The abrasive, typically aluminum oxide, can vary in grit size — such as choosing sandpaper at your local hardware store. The ceramic binder starts out as clay. Media manufacturers will blend abrasive and clay together in different ratios and use abrasives of different grit sizes to generate a myriad of compositions. The compositions vary according to the task at hand and are kiln-fired after extrusion to convert the clay portion of the composition into ceramic. (Remember taking clay in second-grade art class, shaping it into a pot for Father's Day, and having it fired in a kiln by the art teacher? It is the same principle.)

Since the ceramic is the portion of the media that acts as a binder, as its percentage of the composition decreases vs. the abrasive content, there is less binding capacity in the composition, resulting in a media having a higher attrition rate. The inverse is true as well. Less abrasive, more ceramic binder yields a lower attrition rate.

WHAT IS ATTRITION RATE?

Attrition rate is the rate at which media decomposes during the vibratory run. More abrasive media will have a higher attrition rate, but a higher rate of mechanical surface refinement. Abrasive media is good for rapid, gross metal removal but can easily over-radius sharp edges and thin-out tooth flank addendums. Likewise, it will generate substantial swarf (media sludge), which can be a nuisance to handle after part processing. If high abrasive rate media is chosen to generate a short processing cycle, beware that since it decomposes rapidly, if the size and shape chosen were concomitant with part morphology, the rapidly shrinking media can become a lodging issue. Increasing abrasive content typically generates a less dense media in the range of 80 lbs/ft^3.

Low abrasive content media have the opposite characteristics. Low abrasive content media typically has a lower concentration of finer-grained abrasives and produce a much higher quality Ra surface value while having a greatly reduced attrition rate. As such, low abrasive content media maintains its form for a longer period of time, reducing the onset of media lodging issues, and produce much less swarf.

Imagine, if you will, a one-inch cube (one inch in length, width, and height). Now, imagine a half-inch cube. Its linear measurements are exactly half those of the one-inch cube because it measures one half-inch in length, width, and height. However, volumetrically, eight half-inch cubes are contained within one one-inch cube. Let us think about this example from a different angle. If the one-inch cube is a piece of media, by the time it attrits to become a half-inch cube it is not one-half its original volume, it is one-eighth its original volume. In other words, attrition decreases media volume as a mathematical function of its cubed root.

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WHY IS THE DENSITY OF THE MEDIA IMPORTANT?

Remember vibratory media is the tool that is doing work for you in

the processing of gears. As the parts roll in the media mass, the most effective amount of force that can be applied to the part is when the tallest column of media possible is present. It is the weight of the media above the part that is allowing the media to bear across the surface of the part and, when abrasive media is being used, to allow the abrasive to polish the tooth-flank surface. The denser the media composition, the more downward force that can be applied.

The biggest crime that can be committed while vibratory processing is to run too shallow a depth of media. When run in this fashion, applied downward force from the weight of the media depth is reduced, as is the polishing efficiency. Regardless of the vibratory bowl being used, the height of the media at bowl mid-channel should be equivalent to the height of the OD rim. Such a set-up maximizes the positive advantage of force applied by the depth and density of the media.

As an illustrative example, consider a submarine running on the ocean's surface has little applied water pressure on its hull compared to a submarine running at a depth of 500 feet. Run your vibratory bowl as if the parts are that submarine at a depth of 500 feet. Do not skimp on media volume in the machine.

WHAT IS HIGH DENSITY NON-ABRASIVE MEDIA, AND WHY IS IT USED IN ISF?

The beauty of the ISF® Process, isotropic superfinishing, is that a completely non-abrasive media having a density of 125 lbs/ft^3 can be used. Such media will produce mirror-reflective, < 4µinch Ra surfaces on hardened carbon steels with an Rc hardness > 40. Since the media has no abrasive characteristics, it cannot improve surface quality in the traditional abrasive polishing fashion.

In the ISF Process, a chemical accelerator is added to the bowl. This chemistry is generally a mild acid that reacts with the steel to generate an incredibly soft conversion coating on the part's surface. The non-abrasive media improves surface quality by wiping, not mechanically abrading, the conversion coating. Since the coating is formed by reacting with the surface of the parts, the top surface of the part is removed simultaneously. On a microscopic level, the media is tens-of-thousands of times larger than part surface asperities. Therefore, the media cannot reach the soft conversion coating between asperities and the asperities are preferentially leveled. The conversion coating formation and wiping continue throughout the processing cycle to generate the final desired Ra value. A high-density media is favored in this process because, at 125 lbs/ft^3, it applies more downward force thereby making the wiping activity more efficient.

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.